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Air pressure difference measurements in Finnish municipal service buildings

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Abstract

Current paper summarizes the preliminary results of air pressure difference measurements from five new and five retrofitted schools and kindergardens in Helsinki, Finland, as a part of field measurements in a research project COMBI. In general, it has been succeeded to keep slight underpressure levels as designed for the mechanical supply–exhaust ventilation systems in studied Finnish service buildings

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Keywords: Air pressure difference; field measurements, service buildings, schools, kindergardens, balanced mechanical ventilation.

1. Introduction

According to Energy Performance of Buildings Directive all new municipal buildings are required to be nearly zero-energy buildings in EU member states from 2019 onwards [1]. This have been creating challenges for the municipalities as the procurement process of each new municipal service building usually starts couple years earlier.

About two decades lasting effort for energy efficient construction in Finland has also raised some new challenges. The amount of building service systems (heating, cooling, ventilation and lighting) adjusting the indoor conditions for Finnish municipal service buildings is constantly increasing and becoming more complex. More airtight envelope structures put greater demands on the performance of service systems. These changes have created new issues where even smaller mistakes and deficiencies in installing, adjusting, application or service of building systems could

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aggravate indoor air conditions in buildings. Simultanous and smooth co-operation of different building service is becoming increasingly complex requiring good collaboration and constant attention of numerous high-qualified HVAC engineers adjusting the building service systems. The development of complex, more energy efficient building service systems with multy-operating schedules (e.g. energy saving periods outside working hours in weekends) which differ in different premises has led to a situation, where the users of service building are not allowed/able to do anything in order to solve the issue.

Increasing amount of indoor air-quality complaints have been reported also in existing service buildings resulting a long line of municipal buildings waiting for retrofits. Quite often issues have reported, where retrofitting exhaust ventilation systems into supply-exhaust ventilation have been affected the pressure differences across the building envelope.

Inadequately adjusted ventilation devices could create large pressure differences across the envelope structures, which could be harmful in both ways. Continuous large overpressures could cause the indoor air moisture flow to the building structures, which has a well-known detrimental effect to the durability of those structures. On the other hand, continuous large underpressures cause the flow of impurities (microbes, radon or sewage/flue smells) to the indoor air of a building. Indoor environmental quality has been extremely important issue to the Finnish society for many decades. According to the National Building Code of Finland [2], the buildings should be maintained under slightly negative pressure conditions (underpressure) related to outdoor in order to prevent moisture damage and microbe-caused health issues. Underpressure, in general, cannot be larger than 30 Pa [2].

According to a decree of the Ministry of Social Affairs and Health of Finland [3] if the ventilation system is causing overpressure conditions in a building, the system has to be re-balanced. Momentary overpressures due wind conditions or the geometry of a building are possible, and do not require corrective actions. The causes of underpressure of more than 15 Pa has to be found and to balance the ventilation system whenever possible [3]. Pressure-difference measurements were performed earlier in Finnish residential buildings with different types of ventilation system in two studies: 1) about one-month measurement in two multy-apartment buildings with mechanical exhaust system[4] and 2) moment measurements in 152 apartments of 26 multi-storey residential apartment buildings in INSULAtE project [5]. Currently, measured information on actual air pressure conditions of service buildings is urgently anticipated in Finnish society. Building physics research group at Tampere University of technolgy, Finland, has been leading and coordinating an on-going national research project COMBI: Comprehensive development of nearly Zero-Energy municipal service buildings (2015-2017). COMBI focuses on finding, which impacts and challenges relate to energy efficiency improvements of Finnish service buildings, and finding solutions on how to overcome these issues.

2. Case-study buildings and pressure difference measuring methods

2.1. Case-study buildings

12 new and 12 retrofitted service buildings (schools, kindergardens and nursing-homes) in the city of Tampere and its region as well as in Helsinki were chosen for COMBI field measurements. Supply-exhaust type of ventilation devices (balanced ventilation) were applied in all chosen case-study buildings. Altogether 120 supply-exhaust ventilation devices (and coverage areas) were counted in all 24 case buildings. Measurements were performed with a 5 min interval for at least one heating season per 60 ventilation coverage areas. Devices were placed to the upper and lower edge of a representative room belonging to each coverage area of ventilation device. This way the maximum and minimum pressure differences were simultaneously recorded taking into account the stack effect of pressure differences (due to temperature differences). Thus, half of the coverage areas per all case-building would be measured after first heating season and the other half after second heating season. The pressure difference tubes were lead straight to outdoor air through the drilled holes. Drillholes were tightened afterwards in order to avoid impairing the air-tightness of chosen service buildings. The outdoor hose endings were covered with protective cap in order to minimize the wind effect and to prevent the rainfall drops from entering the hose. Therefore, some amount of wind-generated pressures occur around the outdoor protective cap (as a small “obstacle”) on the external wall of a building, however minimizing the wind effects around the tube (inside the cap).

Current paper summarizes the preliminary results of pressure difference measurements from five new and five retrofitted schools/kindergartens in Helsinki. For better understanding, the two-week results are presented as figures and two-month results as tables, respectively.

2.2. Pressure difference measuring device

The case-buildings have determined the need for 120 pressure difference measuring devices. The huge amount of acquired data from all these devices would require the possibility for remote recording and repeated checking of data within reasonable time limits. Therefore, the differential air pressure transmitters (instead of loggers) were chosen for the study. The type (analog or digital), measurement range, accuracy and cost of commercially available pressure transmitters from 11 manufacturers were reviewed. The chosen type of pressure transmitters (I2C digital, no. 1 in Fig. 1) from four manufacturers enabled to reduce the amount of other electronic components (no need for signal transformer), and thus, their inherited errors. A mini-computer, Raspberry Pi 2 model B (no. 2 in Fig 1.), was found suitable due to its compatibility (digital output signal), reliability and affordable price for the data transfer from pressure transmitters. The other parts of device (power source, connectors, pressure tubes etc.) were chosen in order to conform to pressure transmitters. The mobile (GSM-) modem and cloud services were applied for the data online acquisition. One manufacturer offered similar measuring system with a possibility of online logging. However, the cost for their services on the same budget would have allowed the measurements only at very limited locations.

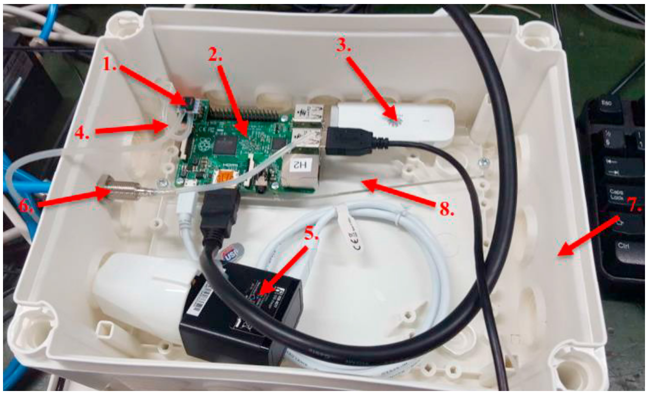

Fig. 1. Pressure difference measuring device. 1. Differential pressure transmitter (Honeywell TruStability). 2. A mini-computer for data transfer (Raspberry Pi 2 model B). 3. Mobile (GSM-) modem. 4. Flexible tube for differential pressure transmitter. 5. Power adapter for mini-computer. 6. A coupler for different diameter tubes. 7. Protective casing for the device. 8. Connection board (transparent plastic).

Six custom-made prototypes (two from each of the chosen three manufacturers) of pressure difference measuring devices were developed and comparatively tested in laboratory for determining possible offsets, static and dynamic changes of pressure difference etc. which could affect the results in field measurement. As two manufactures had very similarly better test results than third, transmitters of more affordable manufacturer (Honeywell) were chosen .

3. Results and discussion

Figures show measured pressure difference values from one ventilation coverage area (upper and lower edge) of new or retrofitted schools or kindergardens in Helsinki from the period 3.10.2016 0:00 – 14.10.2016 23:59 i.e. two working weeks and a weekend in between. The results in tables show respective pressure difference values from the period 1.10.16 0:00 – 29.11.16 12:00. The 95th and 5st percentile values are given in Tables 1-3 in order to indicate the possible existence of blunt peaks or plateaus of over- and underpressure, respectively.

Table 1. The statistical summary of pressure differences (n=51 445) from a group-room (one ventilation coverage area) at a retrofitted kindergarden (A) in Helsinki (1.10.201616 0:00 – 29.11.2016 12:00)

Statistical indicator	**Relative percentage of periods of under- and overpressure**
Max underpressure **-33.84** Pa	Period of underpressure **76.14 %**
Max overpressure **69.83** Pa	Period of overpressure **23.86 %**
95th percentile **3.23** Pa	
5th percentile **-7.09 Pa**	
Average **-2.31 Pa**	
Median **-2.72 Pa**	

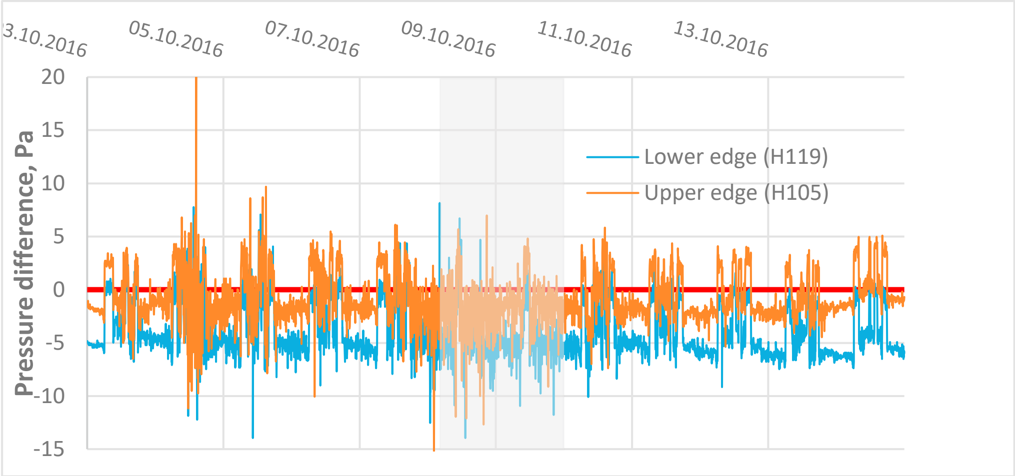

Fig. 2. The pressure differences from a group-room (one ventilation coverage area) at a retrofitted kindergarden (A) in Helsinki (3.10.2016 0:00 – 14.10.2016 23:59). The grey area shows weekend (Saturday and Sunday).

Table 1 and Fig. 2 demonstrate a good example of normal pressure conditions in a retrofitted kindergarden (A), where adjusting for small underpressure with supply-exhaust ventilation has been succeeded.

Table 2. The statistical summary of pressure differences (n=69 688) from a group-room (one ventilation coverage area) at new kindergarden (B) in Helsinki (1.10.2016 0:00 – 29.11.2016 12:00).

Statistical indicator	**Relative percentage of periods of under- and overpressure**
Max underpressure **-88.14** Pa	Period of underpressure **97.78 %**
Max overpressure **17.69** Pa	Period of overpressure **2.17 %**
95th percentile **-2.98** Pa	
5th percentile **-37.93** Pa	
Average **-20.45** Pa	
Median **-25.80** Pa	

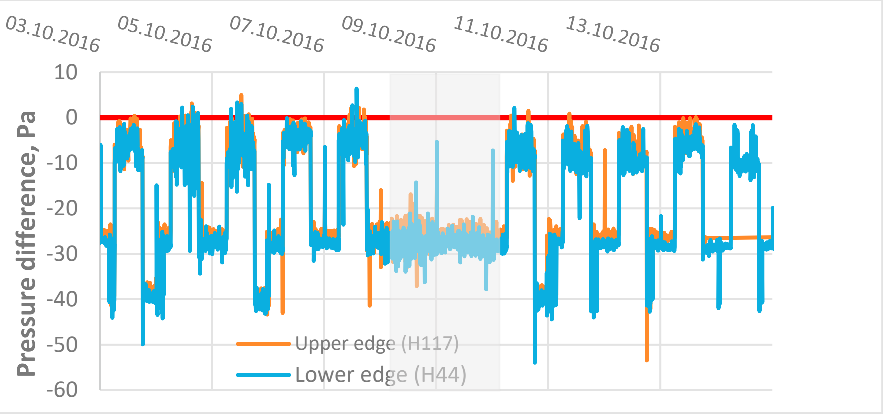

Fig. 3. The pressure differences from a group-room (one ventilation coverage area) at a new kindergarden (B) in Helsinki (3.10.2016 0:00 – 14.10.2016 23:59). The grey area shows weekend (Saturday and Sunday).

Table 2 and Fig. 3 on the other hand, demonstrate how the targeted slight underpressures during working days in a new kindergarden (B) are changing to large underpressures during the evenings/nights and weekends, indicated as a very low 5th percentile value in 2-months summary. As a result of this the measuresed ventilation coverage area in kindergarden B is staying for large underpressure conditions for too long time.

Table 3. The statistical summary of pressure differences (n=52 868) from a classroom (one ventilation coverage area) at a retrofitted high-school (C) in Helsinki (1.10.16 0:00 – 29.11.16 12:00)

Statistical indicator	**Relative percentage of periods of under- and overpressure**
Max underpressure **-56.58** Pa	Period of underpressure **92.90 %**
Max overpressure **41.41** Pa	Period of overpressure **7.10 %**
95th percentile **0.90** Pa	
5th percentile **-14.33** Pa	
Average **-7.15 Pa**	
Median **-7.36 Pa**	

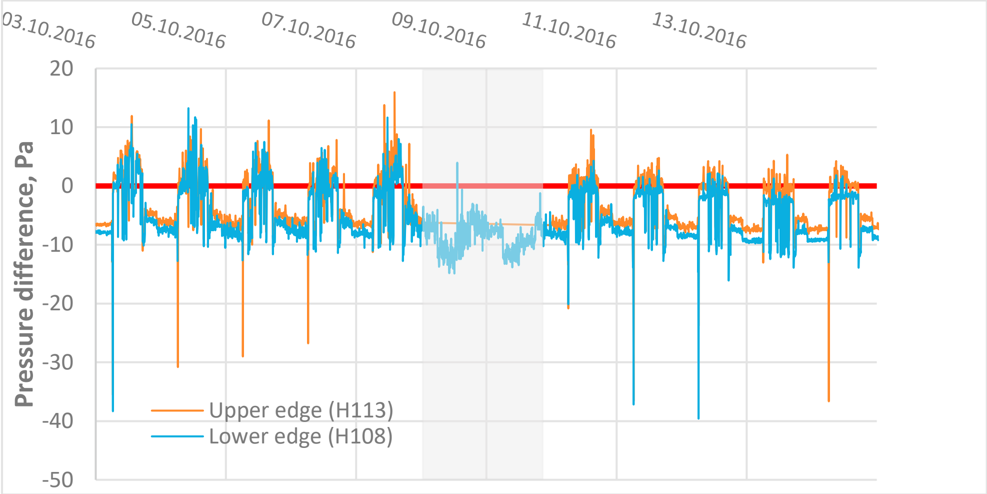

Fig. 4. The pressure differences from a classroom (one ventilation coverage area) at retrofitted high-school (C) in Helsinki (3.10.2016 0:00 – 14.10.2016 23:59). The grey area shows weekend (Saturday and Sunday).

In general, the majority of pressure differences values (other than peaks) in Fig. 4 are indicating small underpressure values as designed in Finland. Fig. 4 also shows sharp underpressure peaks occurring almost each working-day morning around 6:15. That indicates a change of air flows at the ventilation system for the start of a daily service time (working-day). No such changes are scheduled for weekends (Saturdays and Sundays).

The results from case-study buildings A, B and C are presented only as examples for demonstration and illustration purposes, which demonstrate the importance of adjustment of supply-exhaust ventilation systems in service buildings. The analysis of pressure differences at this stage cannot give fully factual information for the reasons of large over- or underpressures. The results are prestened as preliminary because only one ventilation coverage area and no other background conditions were analyzed in this paper. More complete results are expected later on from project COMBI.

The summary of of statistics of pressure difference measurements from five new and five retrofitted schools and kindergardens (10 case-study buildings) in Helsinki is presented as follows:

- The average pressure differences ranged from 0.48 to -20.45 Pa, and a median from -2.18 Pa to -25.80 Pa at different case-study buildings.
- The values of underpressure blunt peaks (5th percentile) ranged from -40.85 Pa to -8.28 Pa and overpressure blunt peaks (95th percentile) from 16.00 Pa to 0.08 Pa.
- The minimum single underpressure values ranged from -150.37 to -33.84 Pa and max overpressure values from 121.36 to 33.56 Pa, respectively.

4. Conclusions

In general, it has been succeeded to keep slight underpressure levels as designed for the mechanical supply –exhaust ventilation systems. Dominating overpressure conditions were found in one case building out of ten. According to the average pressure differences, one case building out of ten had too large underpressure conditions (< -15 Pa). According to the 5st percentile, five cases out of ten had underpressure blunt peaks (< -15 Pa). No such overpressure blunt peaks were found in case buildings. Large single under- and overpressure values were found from the case-buildings. It is important to find reasons for those values as more than 100 Pa under- and overpressures are harmful for releasing impurities, microbes and harmful gases from the structures and soil to the indoor air. Changes of amounts of supply and exhaust air should be checked between weekdays (normal service) and weekends (when buildings are much less used). However, the changes of pressure differences for the weekends found in this study were found to be not similar to each other and, therefore, no recommendation for the systematic adjustment of supply-exhaust ventilation devices could not be given.

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