VENTILATION AND COOLING

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(Title) AIRTIGHTNESS OF APARTMENTS BEFORE AND AFTER RENOVATION

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1. Synopsis

This study aimed to research the airtightness of the building envelope in apartments before and after renovation. Measurements were carried out in three apartment buildings. One to four apartments were examined in each building. Typical renovation measures included changing the windows and refurbishing the interior surfaces. In some cases the ventilation system was renovated as well. No special emphasis was placed on the sealing of the envelope. The airtightness of the apartments increased in most of the cases. There were, however, apartments that became leakier during the renovation. Poor workmanship was usually evident in these cases. The main leakage route in the measured apartments seemed to be the balcony door.

2. List of symbols

C	coefficient
n	coefficient
n_{50} is	air leakage rate at a 50 Pa pressure difference [1/h]
q is	air flow rate through the measured element [m^3/h]
q_m	air flow rate through the measuring device [m^3/h]
q_{50}	infiltration flow at a 50 Pa pressure difference [m^3/h]
T	temperature of air going through the measured element [K]
T_m	temperature of air going through the measuring device [K]
V	volume of the apartment [m^3]
Δp	pressure difference across the measured element [Pa]

3. Introduction

The airtightness of the building has a significant effect on the energy use and thermal comfort in apartments. The successful use of air-to-air heat recovery requires good airtightness to reduce the bypass of exhaust air due to exfiltration. On the other hand, sealing the envelope may lead to underventilation if the ventilation system is not renovated accordingly. This study aimed to research the airtightness of the building envelope in apartments before and after renovation. Measurements were carried out in three apartment buildings. The air change rate, pressure distribution and airtightness were measured in 8 apartments.

4. Methods

4.1 Buildings

Measurements were carried out in three apartment buildings that have a mechanical exhaust ventilation system. Building A is situated in the middle part of Finland. One apartment was examined in that building. Buildings B and C are situated in southern part of Finland. Four apartments were examined in building B and three apartments were examined in building C.

Building A, which is three storeys high, was built in the 1960s. The ventilation did not function properly before the renovation. The ductwork was leaky and the mechanical exhaust ventilation system was centrally controlled without external air intakes. After the renovation, each apartment had its own mechanical exhaust ventilation system with new ductwork. Furthermore, new air intakes were installed below the new windows. Measurements were carried out before the renovation in January 1996 and after the renovation in February 1996. In both cases the wind velocity was below 5 m/s.

Buildings B and C, which are both eight storeys high, were built in the 1970s. The ventilation was inadequate in both buildings before the renovation. The mechanical exhaust ventilation system was centrally controlled without air intakes. Some of the top floor apartments were found to be overpressurized. This caused humid indoor air to penetrate the wall structures and led to problems with dampness. Some occupants even got symptoms from fungi. Furthermore, some ground floor apartments had a positive air pressure compared to the hallway. Odours from these apartments penetrated into the hallway and from there into the top floor apartments, which were underpressurized as compared with the hallway. The ventilation was adequate in each apartment after the renovation. New air intakes were installed above the new windows. Each apartment now also has a sauna and balcony. Measurements were carried out before the renovation during January - February 1995 and after the renovation in October '96. In both cases the wind velocity was below 5 m/s.

4.2 Airtightness of the whole apartment

A fan-pressurization test was used to get information on the airtightness of the whole apartment envelope /1/. A fan was mounted in a duct that pierced the window panel, creating excess underpressure inside the apartment (Figure 1).

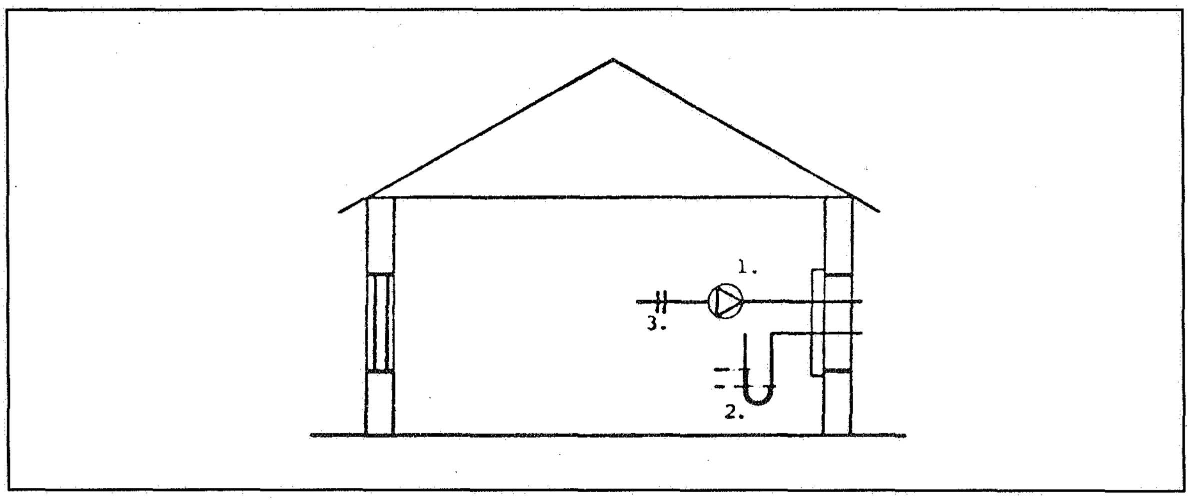

Figure 1. The principle of the fan-pressurization test. 1) adjustable fan 2) pressure difference meter 3) orifice plate for volume flow.

Both exhaust vents and external air intakes as well as the hallway door were sealed. The water seals of the floor drains and sinks were filled with water. All internal doors were left open. This caused air to enter the apartment via the cracks in the apartment envelope. The air flow rate of the incoming air was calculated from the air flow rate displaced by the fan and the density correction (equation 1).

$$q = q_m \frac{T}{T_m}. \tag{1}$$

The air leakage characteristics of the apartment envelope were determined by measuring the flow rate required to create a range of pressure differences (equation 2).

$$q = C\Delta p^n. \tag{2}$$

The coefficient C in equation 2 was corrected to standard conditions, that is 20 °C and 1 bar /1/. The final result of the airtightness is given by the air leakage rate at a 50 Pa pressure difference as

$$n_{50} = \frac{q_{50}}{V}. \tag{3}$$

The smaller the air leakage rate, the more airtight the apartment. In Finland there are currently no target values for the n_{50} in the whole apartment. However, a target value of $n_{50} = 1.0$ 1/h for apartment buildings is being planned. The target value for apartment buildings is 1.5 1/h in Canada, 2.2 1/h in the US and 4 1/h in Norway.

4.3 Airtightness of building components

Direct component testing was used in building A. The apartment was underpressurized as explained above. The individual building component was then sealed with a test chamber. The air that infiltrated through the component was conveyed to the orifice plates, whose pressure loss was compensated to zero by an auxiliary fan (Figure 2).

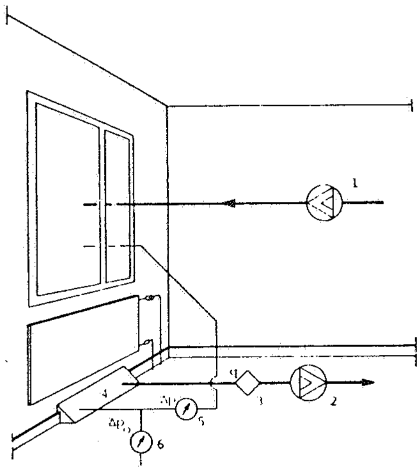

Figure 2. The principle of measuring airtightness of the building component (in this case the joint of the wall and floor). 1) adjustable fan 2) adjustable fan 3) orifice plate for volume flow 4) test chamber 5) pressure difference meter 6) pressure difference meter.

Indirect component testing through reductive sealing was used in buildings B and C. An airtightness test for the apartment was first carried out as explained in section 4.2. A component or group of components was then selected (e.g. windows) and sealed with adhesive tape and a polyethylene sheet. The airtightness test was then repeated. The difference between this and the first test was a measure of the airtightness attributable to the component or group of components which were sealed. Further components were then selected and the process continued.

4.4 Uncertainty of the measurements

The uncertainty factors in the airtightness measurements are the uncertainties of the air flow and pressure difference measurements and wind conditions. The measuring method (only an underpressurized situation has been examined) is also a source of uncertainty.

An orifice plate was used to measure air flows. The uncertainty of the air flow measurement with this method is estimated to be ±3 %. The wind velocity was below 5 m/s during the measurements, so its influence on the measured air flow can be estimated to be ±0.5 %. The influence of the measuring method on the measured air flow can be estimated to be ±1 %. Thus the expanded uncertainty of the measured air flow is ±3.2 %. An Alnor MP6KS micromanometer was used to measure the differences in pressure. The uncertainty of the pressure difference measurement is estimated to be ±0,6 Pa. The confidence level of the values given above is 95 %.

5. Results

5.1 Ventilation

The air change rate could be measured before and after the renovation only in buildings B and C. The results are presented in Figure 3: the ventilation unit operated at half capacity, which is the normal situation.

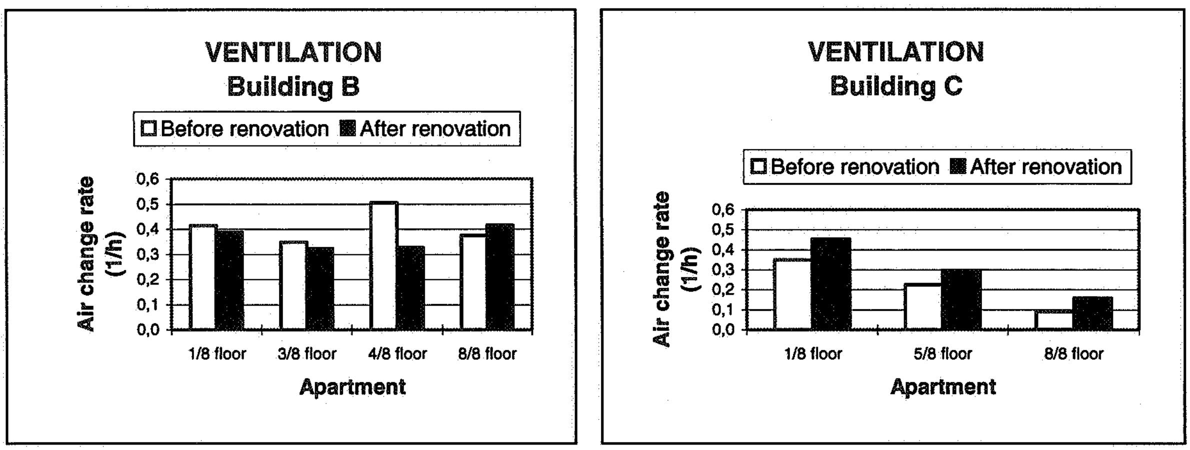

Figure 3. Air change rates in buildings B and C.

The air change rate in building B remained nearly the same after the renovation. In one apartment, the air change rate decreased remarkably. The ventilation improved in building C as a result of the renovation, but the air change rate in every apartment remained below the Finnish recommendation value of 0,5 1/h during normal ventilation conditions. The same situation existed in building B.

5.2 Pressure distribution

Pressure distribution could be measured before and after the renovation only in buildings B and C. The results are presented in Figures 4 and 5.

From Figure 4, one can see that the top apartments were underpressurized after the renovation.

The underpressure between the apartments and the hallway increased due to the renovation, but one apartment on the first floor of building C remained overpressurized (Figure 5).

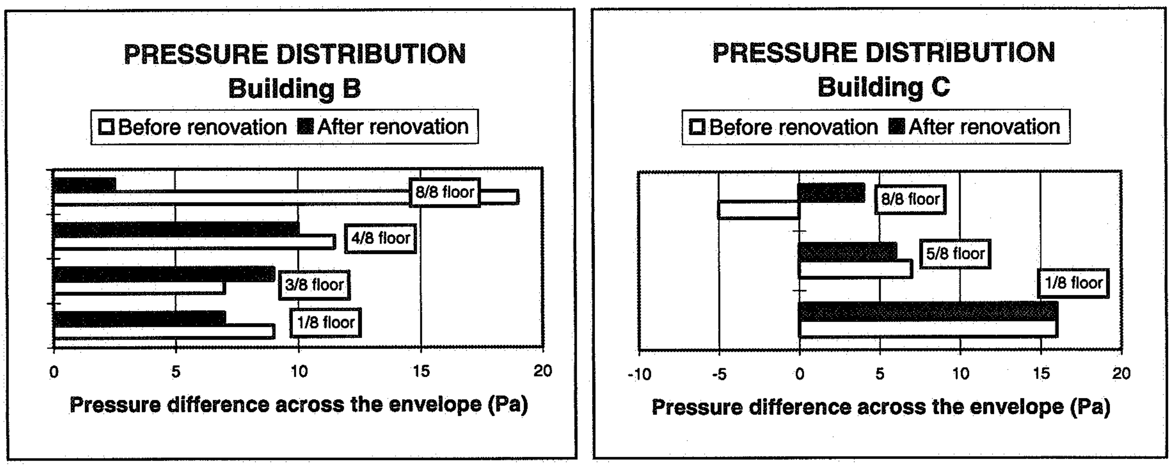

Figure 4. Pressure differences across the envelope in buildings B and C.

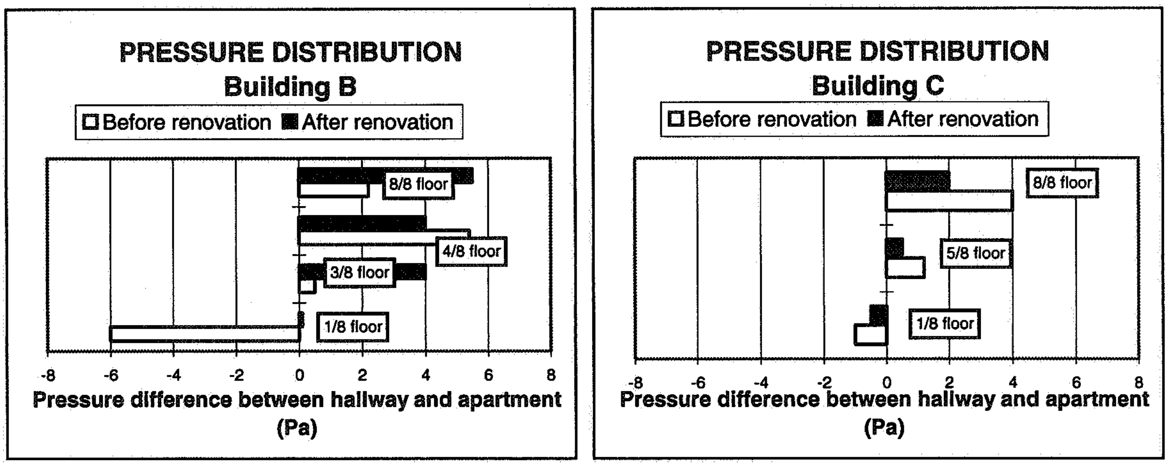

Figure 5. Pressure differences between hallway and apartment in buildings B and C.

5.3 Airtightness of the apartment

The airtightness of the whole apartment is presented in Figure 6. Airtightness is given by the air leakage rate at a 50 Pa pressure difference (n_{50}). The smaller the air leakage rate, the more airtight the apartment.

The airtightness of the apartment in building A improved as a result of the renovation (Figure 6). The air leakage rate value of 1.1 1/h after the renovation indicates a reasonably tight apartment.

In buildings B and C the airtightness of some apartments improved due to the renovation, but in a few other apartments it got worse (Figure 6). Poor workmanship was usually evident in these cases. A great difference in the airtightness of the apartments is apparent.

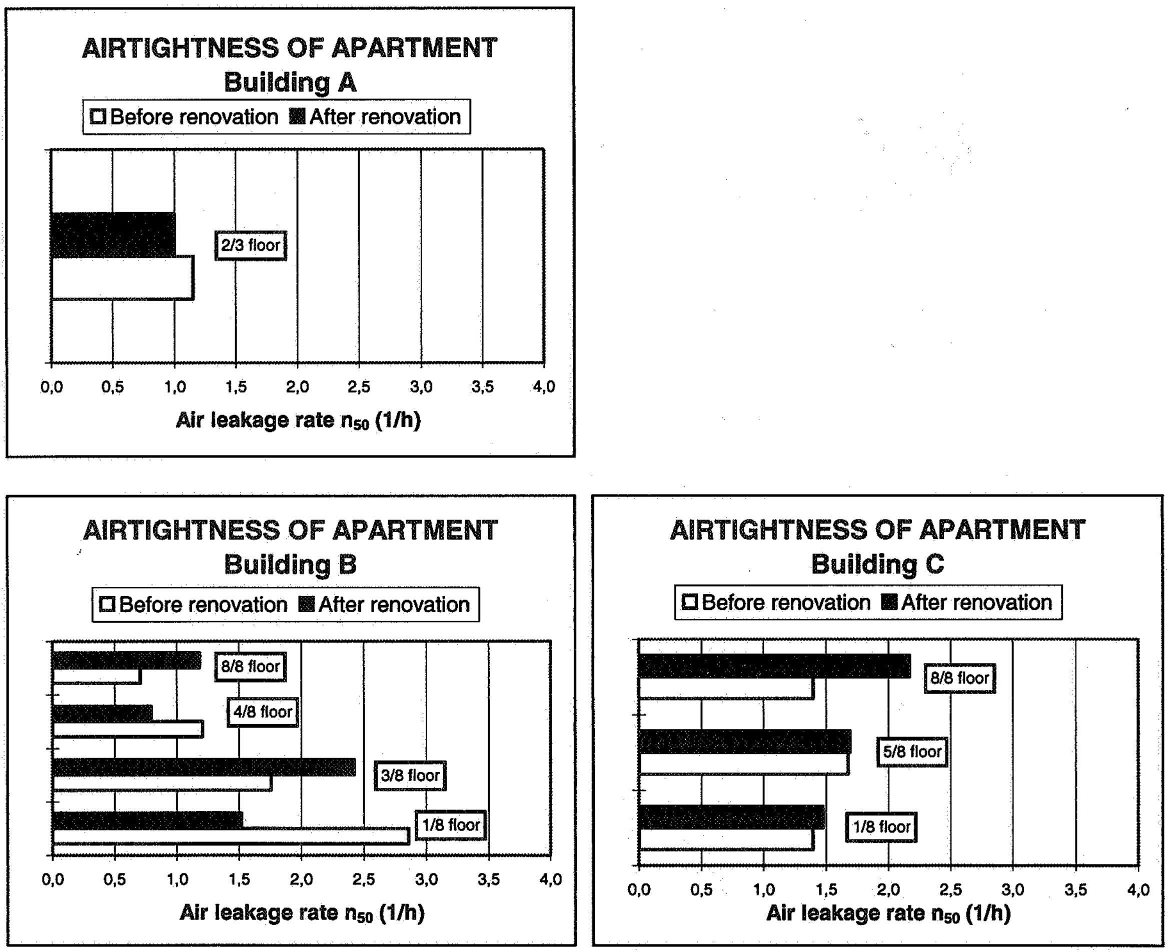

Figure 6. The air leakage rate n_{50} in three buildings.

5.4 Airtightness of building components

The airtightness of different walls was determined in building A (Figure 7). The direct component testing method was used, as explained in section 4.3. One can see from Figure 7 that the airtightness of every wall improved as a result of the renovation. One can also see that the balcony wall, including the door and window, was the leakiest one.

The airtightness of the windows, balcony wall and apartment door was determined in building B (Figure 8) by means of the indirect component testing method with reductive sealing, as explained in section 4.3. One can see from Figure 8 that the airtightness of the balcony wall worsened in many apartments as a result of the renovation. The airtightness of the windows and apartment doors improved in every apartment.

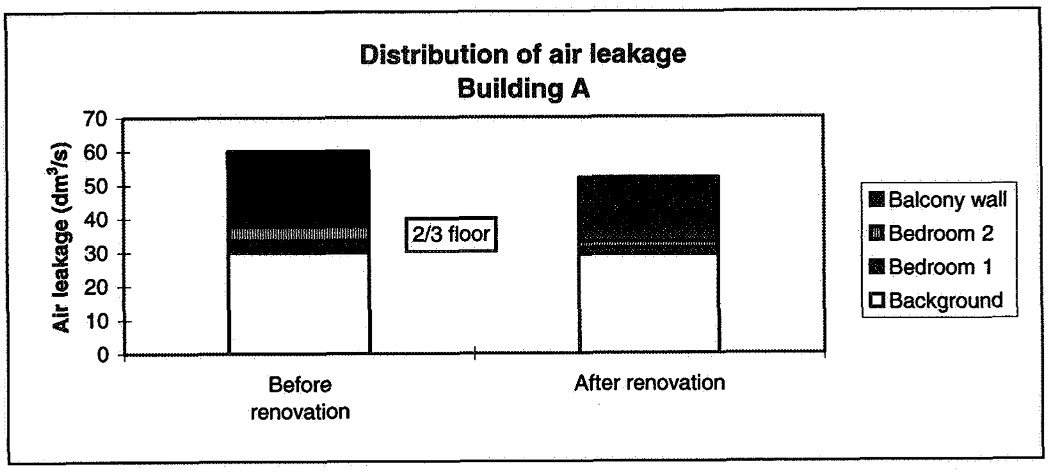

Figure 7. Airtightness of different walls in one apartment in building A.

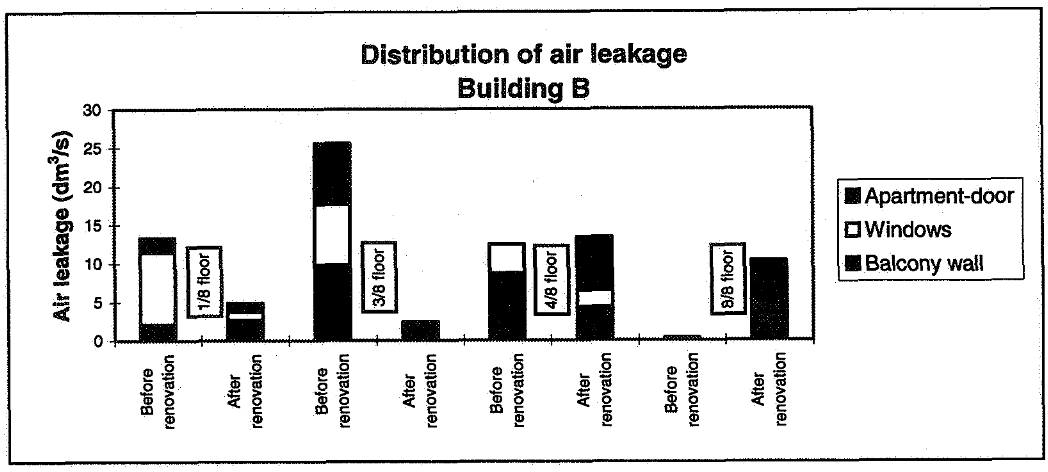

Figure 8. Airtightness of different building components in building B.

6. Conclusions

Eight apartments in three apartment buildings that have a mechanical exhaust ventilation system were examined before and after their renovation. The measurements that were made included examinations of the air change rate, pressure distribution and airtightness.

The apartments had no air intakes before the renovation and the ventilation was inadequate in every building. Some of the top floor apartments were overpressurized. In Finland's climatic conditions, this often leads to dampness and mould problems. Renovation measures included improving the ventilation system, changing the windows and refurbishing the interior surfaces. No special emphasis was placed on the sealing of the envelope.

After the renovation, every apartment had new air intakes below or above the new windows. The ventilation improved in many apartments as a result of the renovation. However, the air change rate in every single apartment was below the Finnish recommendation value of 0.5 1/h during normal ventilation conditions.

The underpressure between the apartments and the hallway increased due to the renovation, but one apartment on the first floor remained overpressurized. Every apartment was underpressurized after the renovation.

A great difference in the airtightness of the apartments was noticed. Airtightness ranged from 0.7 1/h to 3.1 1/h before the renovation and from 0.8 1/h to 2.9 1/h after the renovation. In most cases, the airtightness of the apartments increased due to the renovation. There were, however, apartments which became leakier. Poor workmanship was evident in these cases. The main leakage route seemed to be the balcony door. The airtightness of the windows and the apartment door improved in every single case.

Acknowledgements

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References

1. *ROULET Claude-Alain and VANDAELE Luk. "Airflow Patterns Within Buildings Measurement Techniques". Technical note AIVC 34. Air Infiltration and Ventilation Centre, 1991.*