Dependence of measured specific air leakage rate ($q_{E50}$) on envelope pressure differences and measurement position: a case study in an apartment building in winter conditions

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Abstract. Airtightness of the building envelope has become an important component in achieving ever stricter energy performance levels. However, airtightness measurements using blower door method are dependent on choices made by the specialist conducting the tests. One being the assessment of baseline pressure difference inside the building and position of the measurement equipment. Ideally, the test will be conducted without wind and stack effect which could disturb the envelope pressure measurements. Unfortunately, such conditions seldom exist, especially in colder climates. This increases the appeal of conducting apartment-wise measurements over whole-building measurements as it is far easier to comply with the ISO 9972. However, the apartment-wise method has a relatively random nature due to small share of actual building envelope. This paper investigates the effect of using different measurement positions and pressure levels on the airtightness measurement results. A 5-storey 15m tall residential building was used as a case study and measured as a whole and in select apartments. The results show that the variation caused by different choices of pressure levels, measurement positions etc caused relatively low variations and whole-building measurement should be preferred even if not all baseline and pressure level requirements are not met.

1. Introduction
Airtightness has become an important component in achieving ever stricter energy performance levels, which have had an impact on the airtightness of the buildings and on the number of airtightness tests performed to prove the compliance with the requirements [1,2]. However, airtightness measurements using blower door method are very much dependent on choices made by the specialist conducting the tests. One of them being the assessment of the nature of baseline pressure difference inside the building and suitable position of the measurement equipment.

Ideally, the test will be conducted without wind and stack effect which could disturb the envelope pressure measurements. Impact of the wind on building air leakage measurements has been assessed in [3]. Due to wind, uncertainties can be expected a combined expanded uncertainty of 6%–12% for wind speeds of 6–10 m/s, respectively [4]. Due to limitations in the existing pressurization test methods, in [5] an ‘average DP method’ was proposed in which the pressure difference values are measured at all floors and an average value is used. The stack effect related to temperature differences between the internal spaces of a building and the external environment in cold climate is presented in [6]. The actual infiltration distributions with stack-driven airflow is analyzed in [7]. To identify
unsuitable conditions, ISO 9972 recommends that the pressure difference is measured at the lowest floor level and specifies the baseline pressure limits to comply with the standard. Unfortunately, these conditions seldom exist, especially in colder climates. This would make most of the year unsuitable for whole building measurements, while the alternative of conducting apartment-based measurements would give random results due to large share of interior walls, ceilings etc. This paper investigates the effect of using different measurement positions on the airtightness measurement results.

2. Methods
A 5-storey 15m tall residential building on the coastline of the Baltic sea was used as a case study and measured as a whole (see Figure 1) – ventilation and sewage connections were sealed, windows closed, interior doors open; all apartments and the staircase were included in the measured volume. The measured volume was surrounded by outside air from all sides as the car park at the basement was open. Pressure differences (12 levels at ca 7 Pa steps between 10…100 Pa) during both pressurization and depressurization were simultaneously measured at different sides and heights of the building. Specific air leakage rates were then calculated (using same area of whole building envelope) from the whole pressure difference dataset and subsets of it to express different choices of pressure levels and measurement positions that the measurement specialist could make. For comparison, separate zone-based pressurization and depressurization tests were conducted in 3 apartments (see Figure 1 (b)) with a fan placed on the balcony door and the windows and doors opened in the surrounding zones.

3x Blowerdoor DG700 and 1x APT2 pressure gauges were used to measure the pressure differences, while a Blowerdoor fan model 4 were used for creating pressure differences. Inside and outside temperature during the test and throughout the building was measured using Onset Hobo UX100-011 loggers. Taps for measuring pressure differences over the envelope were in the same room as the feedthrough to the outside. Pressure transducers were located on the East wall of same floor as their respective measurement positions (1st floor, 3rd floor and 5th floor, see Figure 1 (c)).

Indoor temperature during the test was 18…23 °C, outside the temperature was ≈ -2 °C and mainly South-Eastly wind had an average velocity from 4 to 8 m/s with periodic gusts up to 12 m/s.

![Figure 1](image-url) (a) Building dimensions (b) Separately measured apartments (c) Pressure measurement positions

3. Results and discussion
Baseline pressure levels ranged from -9 Pa to +9 Pa (Basement: 2.1 Pa; 1. fl. East: -8.6 Pa; 1. fl. North: -7.8 Pa; 3. fl. East: -1.6 Pa; 3. fl. North: 1.3 Pa; 5. fl. East: 5.9 Pa; 5. fl. North: 8.5 Pa). According to ISO 9972 it exceeds the maximum allowable baseline pressure of 5 Pa, furthermore, the minimum exerted pressure difference level during the test should therefore be 45 Pa. Four different approaches were taken to calculate the specific leakage rates: 1) all pressure levels that conformed to the ISO 9972; 2) all pressure levels (regardless of ISO 9972 requirements); 3) minimum subset conforming to ISO 9972; 4) minimum subset starting from 10 Pa. Depending on the combination of used pressure measurement locations and pressure levels, the specific leakage rate q_{LE50} ranged from 0.78 to 0.82 m³/(h·m²). The lowest variation (0.784…0.809 m³/(h·m²)) was observed when widest dataset still conforming to ISO 9972 was used (“Ideal pressure levels”) with northerly facades generally resulting
in higher values – see Figure 2 (a). Nevertheless, these variations are an order of magnitude smaller than those measured in individual apartments ($q_{E50}$ measured there: 0.54; 0.59 and 0.83 m³/(h·m²)).

The random nature of apartment-wise measurement is further exemplified by Figure 2 (b), where the results from the currently studied building are accompanied by previous measurements from 4 other buildings. In Building B1 and B2 half of the apartments and in B3/1 & B3/2 all the apartments were measured separately in addition to the whole building air leakage test. Compared to the average of measured apartments, the whole building $q_{E50}$ was 19...46% higher in the studied building and in buildings B1, B3/1 & B3/2. On the other hand, building B2 exhibited 14% lower whole building $q_{E50}$ than that of the apartment-wise average.

**Figure 2.** (a) Specific leakage rates dependent on the number of pressure intervals (columns) and pos. of pressure monitoring device (lines). (b) Apartment-wise vs whole building measurements.

### 4. Conclusion

According to measurements described in this paper, the variation of measured $q_{E50}$ caused by deviations from EN-ISO 9972:2015 guidelines are an order of magnitude lower than those of the apartment-wise measurements (even if the latter adhere to the guidelines of the standard). Furthermore, the whole building $q_{E50}$ directly describes the quality of the exterior shell, which is used in energy efficiency calculations. Therefore, it does not make sense to prefer apartment-wise measurements only because it is easier to adhere to the pressure levels prescribed in standard EN-ISO 9972:2015 and whole building measurement should be conducted whenever possible.

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