SEASONAL VARIATION IN AIRTIGHTNESS

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ABSTRACT

Airtightness of buildings is necessary to obtain healthy, sustainable and energy efficient buildings. Measuring the airtightness of a building has become more common lately, much due to the higher energy use in leaky buildings. The airtightness of a building can for example be measured in order to attain a certification, or on demand from a developer.

In some studies, there have been large seasonal variations in airtightness. In most cases, the buildings are more leaky in wintertime, but there are also some investigations that show the opposite. In the current project, the aim is to investigate how, and if, the airtightness varies over the year. The airtightness is measured, using a blower door, approximately eight times a year, in three different buildings. The air leakages in the buildings are also detected and the air velocities at a number of leakages are measured. Two of the buildings are one-family, two story, wooden frame houses and one is a multi-family, concrete building (where one apartment is measured). In Swedish wooden houses, the air barrier is often a polyethylene foil, which is also the case in these two buildings.

The measurements have been analyzed with respect to indoor/outdoor temperature and indoor/outdoor relative humidity. The trend in the measurements is that the airtightness is lower (more leaky envelope) when the indoor air is drier (low relative humidity). Consequently, the air leakage is largest during the winter measurements. The decrease in airtightness from summer to winter is in the order of 8-10%.

KEYWORDS

Airtightness, seasonal variation, air leakage, fan pressurization method

1 INTRODUCTION

The airtightness of a building has an impact on the energy use and on the moisture safety of a building. It also affects the thermal comfort, the air quality in a building, sound insulation and the spread of fire gases (Sandberg et al. 2007). Measuring the airtightness of a building has become more common lately, much due to the increased energy use in leakier buildings. The airtightness of a building can be measured in order to attain a certification or on demand from a developer. The consequences if failing the target can sometimes be severe. Therefore, it is of great importance to obtain a correct and representative measure of the airtightness.

The airtightness in a building is created by a continuous and airtight thermal envelope. The airtight layer in a thermal envelope can be either a thin layer, such as a polyethylene foil, a board, such as plywood, a homogeneous construction (e.g. a concrete component) or an outer coating, such as rendering. In all examples it is of great importance that the joints are properly sealed.

Airtightness measurements are usually performed in accordance with EN 13829:2000 (Fan pressurization method). In this standard there are limitations with respect to the climatic conditions during measurements. There is for example a limit on the maximum allowed wind speed and the maximum allowed temperature difference over the thermal envelope. The purpose of the limitations is to assure a correct measured airtightness. Nevertheless, measurements have shown that there is a variation in the measured airtightness with respect to the time of year for the measurement. Yoshino (2012) described variations of ±20% over the year. Boorsboom et al. (2012) analyzed airtightness measurements, from the 80ies, made on 21 window frames mounted in masonry or concrete walls. The average difference in air tightness between summer and winter was about 30% (higher leakage during winter) and the maximum seasonal difference was 120%. To be noted, some window frames showed a lower leakage rate during winter. Boorsboom et al. suggest measurements during three subsequent seasons in order to obtain correct values. Also Kim and Shaw (1986) showed increased leakages during winter time. The highest leakages occurred in winter and early spring, and the lowest in late summer and fall. Two wood frame constructions were studied and the effect was more pronounced in the leakier building. The measurements indicate that there is a correlation between indoor humidity and envelope leakage.

There are also measurements showing a higher leakage during the summer. An example is Dickinson et al. (1986) who, in one out of three residential, wooden frame houses, measured a lower air leakage in winter time. They speculate in the influence of snow and ice on the airtightness. Alev et al. (2014) also show a lower leakage in wintertime. The investigated houses are log houses in Estonia. They give as possible explanation that the weight of the snow in wintertime tightens the log house.

Bracke et al. (2013) measured the airtightness in two new buildings during almost four months (December to April). In the masonry building, there was an increase in air leakage over time. A possible explanation is the different thermal expansion of the masonry/concrete structure and the plaster that assures most of the airtightness in these buildings. This difference in thermal expansion could create cracks in the plaster. Another possible explanation is a gradual deterioration of the ventilation ductwork due to repeated dismantling for the preparation of the pressurization tests.

In this project, full scale measurements and numerical simulations have been performed in order to investigate the possible variations in airtightness at different seasons, and the relation to climate.

2 METHOD

The air tightness’ variation over season and climate is studied by measuring the air tightness of three buildings, during one year, and by performing numerical simulations on the climate and the effect on airtightness. The first measurements, on two one-family wooden buildings, started in June 2013. Measurements on a multi-family concrete building stared in March 2014. The measurements have been performed by SP, Technical Research Institute of

Sweden. Initial numerical calculations have been made on the influence of wind, and on air properties.

The first airtightness measurements were performed on two residential one family houses, both located in the south west part of Sweden, one house in Landvetter and one in Sevred, located outside Borås. The houses are light weight wooden houses in two floors (plain wood beams/joists in Landvetter and light weight wooden beams/joists in Sevred) and they both have slab on ground and cold, ventilated attics. Both buildings have mineral wool insulation and polyethylene foil on the inside (between insulation and interior board) as air barrier and moisture barrier. The house in Landvetter is built in 2004 and the house in Sevred is built in 1993. Both houses have mechanical exhaust ventilation systems. The multi-family concrete building was finished early 2014 and one apartment has been measured. The apartment has 3.5 external walls.

Figure 1. The tested wooden buildings, Landvetter (2004) to the left and Sevred (1993) to the right.

The airtightness quantity used is air permeability, q50 (l/sm^2). It is the amount of air that passes through the thermal envelope at a pressure difference of 50 Pa, per area of thermal envelope. The air flow is measured both when the building is pressurized and depressurized and the mean value is used. The airtightness measurements are made according to EN 13829:2000, using a Minneapolis BlowerDoor. Temperature and relative humidity, indoor and outdoor, is measured at each airtightness measurement occasion, as well as the outdoor wind speed. In addition, the temperatures and relative humidities are continuously logged, and these measurements will be analyzed at the end of the study. The airtightness measurements are performed 6-8 times a year to study the different seasons and climate conditions.

3 NUMERICAL SIMULATIONS

Simulations have been performed in order to study how the measured air flow is affected by different densities of the air. The density of the air is different due to variations in temperature and relative humidity over the year. Both high temperatures and high relative humidities result in low air densities. Numerical investigations have also been performed on the effect of wind.

During a pressurization test, the air is drawn into the building through leakages in the air barrier of the thermal envelope. These leakages can have different geometry and surface roughness and the air flow can also pass through an air permeable material. The magnitude of the air flow depends on the pressure difference over the leakage path, of the characteristics of the leakage path, but also on the characteristics of the air. The density of the air changes due to temperature and relative humidity, and is thus not the same for all measurement conditions. When measuring according to standard EN 13829:2000, the density change that affects the measurement equipment is corrected for. However, there is also the air flow through the leakages, which is slightly different at different air densities. This is investigated with numerical simulations.

The geometry of the building in the calculations is a box with an, initially, equal amount of leakages on all sides (including the roof), see Figure 2. The leakages are assumed to be long gaps, having a width of 2 mm, in walls with a thickness of 120 mm. The air leakages are calculated according to Hagentoft (2001). The effect of air temperature and relative humidity (RH) is determined by investigating two temperature conditions, -20°C and 30°C (RH = 40%), and two relative humidity conditions, 0 and 100% ($T_{mean} = 10°C$). A pressure of 50 Pa is used for the calculations and the resulting airtightness of the building is approximately 0.8 l/sm² (varying slightly in the different cases). By investigating extreme temperatures and relative humidities, the factors that possibly influence the airtightness measurements are determined.

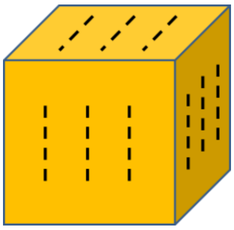

Figure 2: Simulated box with evenly distributed gaps.

The investigation shows that the temperature of the air can affect the measurements by affecting the air flow through the air gaps, see Table 1. Using -20°C, the measured airtightness is 0.76 l/sm² and at a temperature of 30°C the measured airtightness is 0.81 l/sm². Consequently, the difference between the two extreme measurement situations is 5.7%.

Different relative humidities, however, have minor importance. At 0% relative humidity the airtightness is 0.789 l/sm² and at 100% it is 0.791 l/sm². The difference is 0.14%, thus negligible. The effect of the air density on the measurement equipment (not leakages as above) is compensated for when measuring according to EN 13823:2000.

TABLE 1. Airtightness at different temperatures and relative humidities.

Air tightness at minimum temperature (l/sm²)	**Air tightness at maximum temperature (l/sm²)**	**Air tightness at minimum relative humidity (l/sm²)**	**Air tightness at maximum relative humidity (l/sm²)**
0.763	0.807	0.789	0.791
5.7%		0.14%	

The simulations on wind are made to investigate if different wind speeds give different airtightness results. Since the average wind speed can be different during different seasons of the year, this could be a part in explaining why different seasons have different airtightness.

In the standard, it is noted that if the meteorological wind speed exceeds 6 m/s or reaches 3 on the Beaufort scale, it is unlikely that a satisfactory zero flow pressure difference will be obtained. Three kinds of zero flow pressure is measured before and after the pressurization test and if either of these zero flow pressures is over 5 Pa, the test does not meet test conditions according to EN 13823:2000.

The shape of the simulated building is quadratic, with a flat roof. The shape factor C_p (-), that determines the pressure difference over a wall at a certain wind influence, is for the windward wall, 0.4, of the leeward wall, -0.2, and for the other walls, -0.3. The roof is -0.6 and the shape factor of the inside of the building, C_{pi}, is determined by a mass air flow balance. The pressure difference, ΔP (Pa), over a wall subjected to wind, v (m/s), is

$$\Delta P = (C_p - C_{pi}) \cdot \frac{v^2}{2} \tag{1}$$

The building is first simulated with equally distributed leakages, and then with a windward side that is twice as leaky as the other sides.

The results from the simulations show that there in many cases is a small difference in the measured airtightness values for pressurization and depressurization when wind is present. However, the average value is not affected until the wind speed increases. For example, at a wind speed of 9 m/s, the building is estimated 2% more airtight with wind than without wind. At a wind speed of 9 m/s, the zero flow pressure difference is most likely exceeding the value accepted in EN13823:2000. In the simulations, a higher wind speed resulted in lower calculated air permeability (more airtight building).

For the case of a non-uniform air leakage distribution, simulations were made for a wind speeds up to 9 m/s. The results are similar to those of the equal leakage distribution, i.e. unless the wind speeds are high there is little error due to wind.

4 AIRTIGHTNESS MEASUREMENT RESULTS

Full scale airtightness measurements have been performed in three buildings, two light-weight wooden buildings and one apartment in a residential concrete building. Only three measurements have, so far, been made on the concrete buildings, March, May and July 2014. Even though this is a newly erected building, there is no change in the air permeability. All measurement occasions showed an air permeability of 0.35 l/sm^2. This building will be further studied when more measurements have been made, in particular winter measurements.

The light-weight wooden buildings have, so far, been measured 5 or 6 times each. The lowest measured relative humidity outdoor is 54% (July, Landvetter) and it reaches 100% in November in Landvetter. Indoor, the relative humidity ranges from 23% (January, Landvetter) to 60% (September, Landvetter).

In the house in Sevred, there is a constant decrease in relative humidity indoor from July to November, while the house in Landvetter has the highest indoor relative humidity at the measurement in September. Both buildings have the lowest relative humidity indoor at the winter measurements. The wind speed is low during the measurements.

Both buildings have the lowest airtightness (highest air permeability) at the winter measurement (January-February). This coincides with the lowest indoor air relative humidity. The measured airtightness (expressed as air permeability) as a function of time is shown in Figure 3, and as a function of indoor air relative humidity in Figure 4.

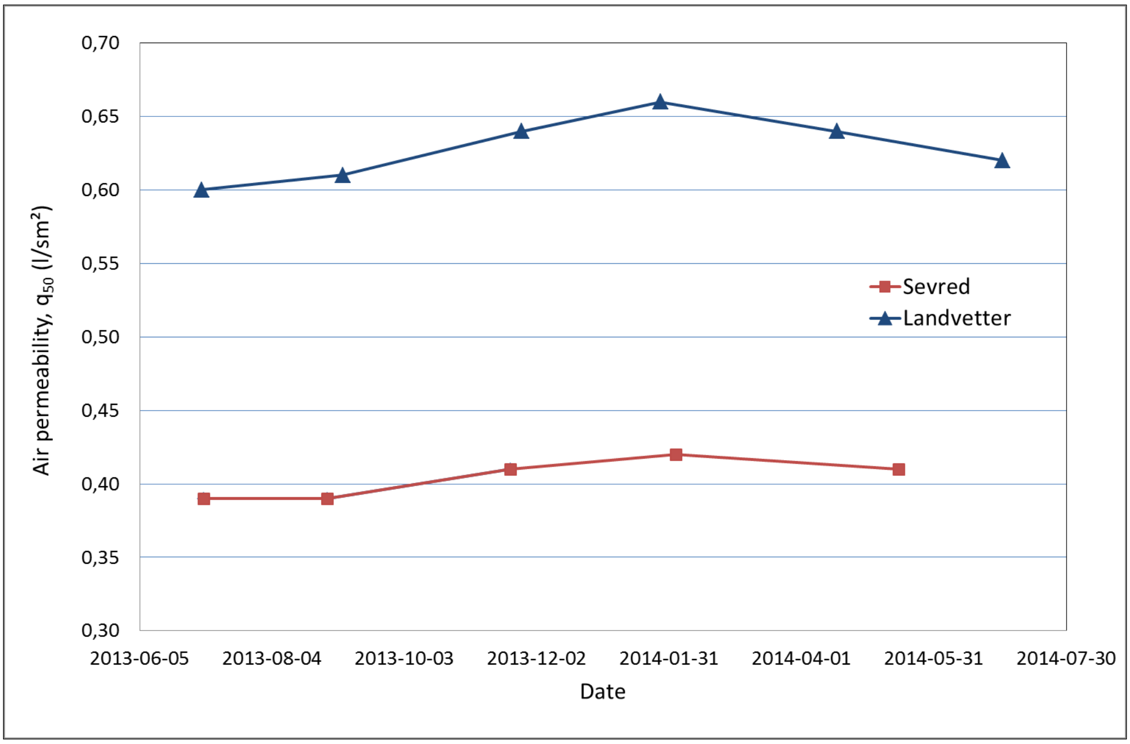

Figure 3: Measured air permeability as a function of time for the two wooden buildings.

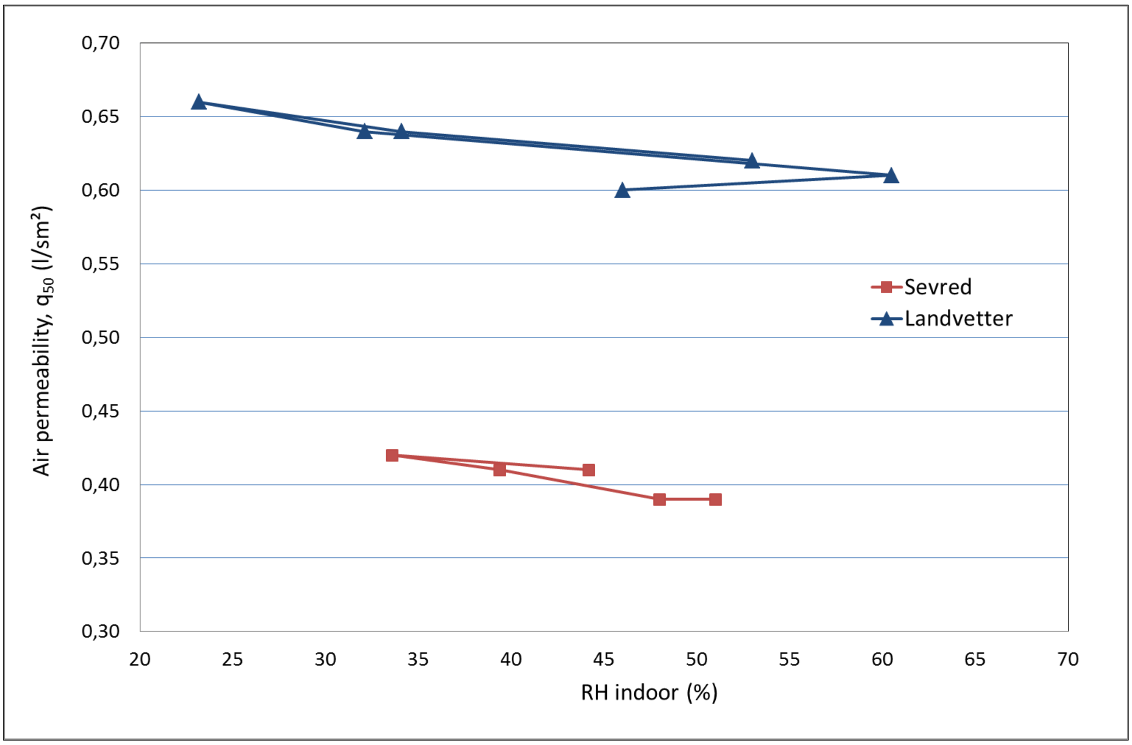

Figure 4: Measured air permeability as a function of relative humidity indoor.

There is an increase in air leakage from summer to winter. The increase from summer to winter is 10% for the building in Sevred and 7.7% for the building in Landvetter. For both buildings, the airtightness is less (higher air permeability) when the indoor relative humidity is the lowest. There is no clear correlation with indoor or outdoor temperature, or outdoor relative humidity. The correlation between air tightness and indoor air relative humidity will be more thoroughly investigated when the loggers that continuously measure indoor air relative humidity are collected. The variations in airtightness from summer to winter can be noticeable for stakeholders aiming for a certification.

In the two measured wooden buildings, the reason for the increase in permeability during winter could be that the wooden construction dries when the relative humidity indoor decreases. This, in combination with a poor connection to the polyethylene foil, causes the leakages to increase when the wood, exposed to indoor air, is dried.

The main leakages in the leakiest building (Landvetter) are found around the attic hatch, at the connection between the upper and lower floor (see Figure 5) and over a window in the kitchen at the bottom floor, Figure 6. The reasons are probably a poor connection between window and polyethylene foil for the windows, both a poor connection between hatch and polyethylene foil plus a leaky hatch (poor seal) for the attic hatch. The leaky connection between the upper and lower floor, that is evident in the stairs, is probably caused by a discontinuous air barrier that does not pass the floor/wall connection.

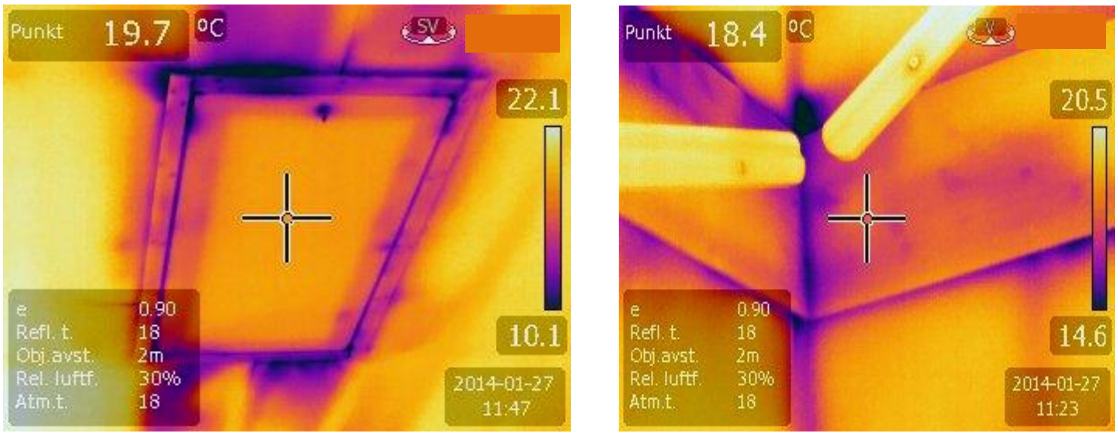

Figure 5: Thermographic image of attic hatch (left) and hand rail (right) in corner of stairs in January 2014. The hand rail is at the position of the connection between the top and bottom floor.

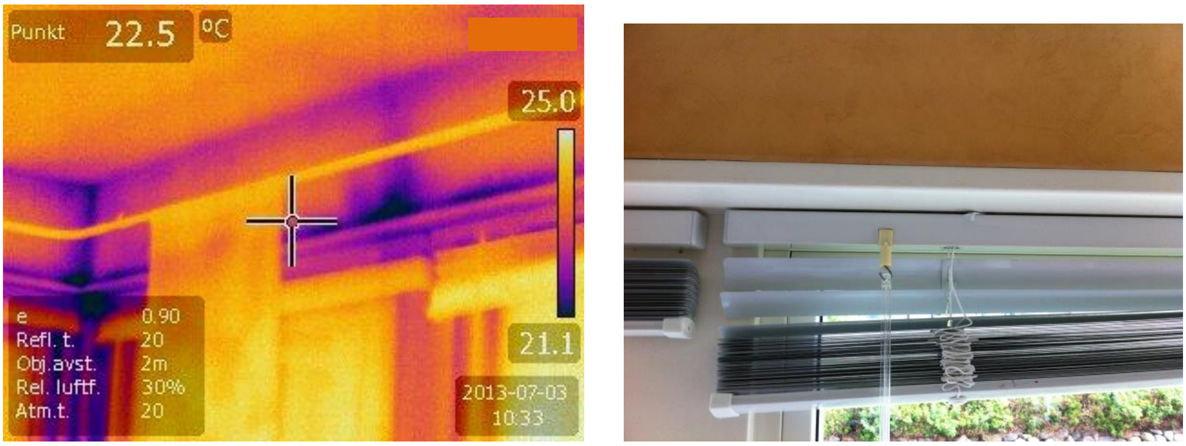

Figure 6: Thermographic image of kitchen window in July, and photo of the same.

5 CONCLUSIONS

Airtightness has been measured for ten months in two residential wooden buildings. The trend in the airtightness measurements is that the airtightness is lower when indoor air is drier. The winter measurements have the lowest airtightness of all measurements. The decrease in airtightness from summer to winter is in the order of 8-10% (from July to February). The measurements will continue so that a whole year will be covered for all buildings.

The numerical simulations show a small change in air flow through the leakages due to high or low air temperatures (affecting the air density of the air that flow in the leakages), but no change in air flow due to different relative humidities. The effect of the air density on the measurement equipment (not leakages) is compensated for when measuring according to EN 13823:2000.

6 ACKNOWLEDGEMENTS

The research and the measurements have been financed by SBUF, the Development Fund of the Swedish Construction Industry, and supported by FoU-väst (regional comittee), which is greatly appreciated.

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