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# Airtightness of residential buildings in Finland

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A B S T R A C T

Single-family buildings and apartments in multi-family apartment buildings have been studied in Finland in two large-scale studies between the years 2002 and 2009. This paper is based on the measurements of airtightness of 170 single-family detached houses and 56 apartments by fan pressurisation method at 50 Pa.

The mean air change rate of 10 autoclaved aerated concrete block, 10 shuttering concrete block, 10 concrete element, 10 brick masonry, 10 lightweight aggregate concrete block, 100 timber-framed, and 20 log single-family houses was 1.5 $h^{-1}$, 1.6 $h^{-1}$, 2.6 $h^{-1}$, 2.8 $h^{-1}$, 3.2 $h^{-1}$, 3.9 $h^{-1}$ and 6.0 $h^{-1}$, respectively. In concrete-built multi-storey houses, in which the intermediate floor was cast on site, the mean $n_{50}$-value of 23 apartments was 0.7 $h^{-1}$. The mean $n_{50}$-value of 20 apartments in multi-storey houses built from concrete elements was 1.6 $h^{-1}$. 16 apartments in timber-framed multi-storey houses had a mean $n_{50}$-value 2.9 $h^{-1}$.

Factors like construction method and insulation material (polyurethane insulation) in timber-framed houses, seam insulation material in log houses and ceiling structure in heavyweight buildings among others were found to have an effect on the average values of air change rates. The mean values of airtightness do not satisfy the recommended level of airtightness in Finland. Most important result, however, is that good airtightness of individual houses was reached within all house groups regardless of the choice of structure, storeys, ventilation system or technology of construction.



## 1. Introduction

Increased awareness of public on energetic and environmental issues has led to considerable development of research on improving the energy performance of buildings. The European Directives on the energy performance of buildings (EPB) [1] state the need for a correct energetic diagnosis to improve the performance of existing buildings and their facilities. EPB largely depend on the Heating, Ventilation and Air Conditioning systems (HVAC), which in turn affect the Indoor Environmental Quality (IEQ). The ventilation is also affected by the uncontrolled air leakage (i.e. airtightness) across the building envelope that can bring to excessive energy consumptions due to air infiltrations from the outside. Also, airtightness affects EPB because it influences the ability of heat storage of the building.

Several studies on the building airtightness and related measurement techniques are available in international literature; most of them have been carried out at cold climatic conditions such as in Northern Europe, Canada, and US [2–5]. Over the last years the studies on airtightness in building envelopes has included also in Southern Europe [6,7], and Northern Asia [8].

Tampere University of Technology and Aalto University (former Helsinki University of Technology) have carried out two large-scale studies between years 2002 and 2009. In a study “Airtightness, indoor climate and energy efficiency of residential buildings”, funded by Tekes (Finnish Funding Agency of Technology and Innovation) as well as 24 Finnish companies and associations, the indoor and outdoor climates, indoor moisture excess, ventilation performance, energy consumption and airtightness of 70 Finnish heavyweight single-family buildings and 56 apartments in multi-family apartment buildings were studied between years 2005 and 2009. This research project is closely related to a previous study “Moisture-proof healthy detached house”, in which the same field measurements were carried out in 100 lightweight single-family

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buildings between years 2002 and 2005. Current paper is reporting the measurements of airtightness of both abovementioned research projects.

Heavyweight buildings is an abbreviated phrase for buildings, in which the external walls are constructed using heavyweight construction systems. In this study heavyweight buildings is a common phrase for buildings with precast concrete element, masonry brick (calcium silicate and burnt clay), block (autoclaved aerated concrete (AAC), lightweight aggregate concrete (LWAW) and shuttering concrete) and log external walls. Respectively, an abbreviation - lightweight buildings - is also used; however the only example of lightweight buildings in current study is timber-frame buildings. Both single-family and multifamily apartment buildings in current study include either heavyweight or lightweight external wall structures.

The main aim of these studies was to determine the current level of airtightness in modern single-family houses and apartments in Finland to:

- determine airtightness values of single-houses and apartments and to compare airtightness of different envelope structures
- determine typical distribution of air leakages in single-houses and apartmens with different envelope structures

The influence of different comparison variables was studied as follows:

1) envelope structures (timber-frame, log, concrete element, concrete block, brick masonry, AAC and LWAC);
2) joints of ceiling and wall structures (timber-frame, concrete and AAC ceiling);
3) floor structures (concrete slab on ground, concrete with crawl space, timber-framed with crawl space);
4) storeys (single-storey, multi-storey);
5) age (year of construction);
6) ventilation system (mechanical supply and exhaust, mechanical exhaust, natural ventilation);
7) air barrier and insulation material (plastic film and mineral wool, paper sheet and cellulose, polyurethane);
8) technology of construction (on site, prefabricated large elements, prefabricated small elements, pre-cut elements).

Mechanical ventilation is dominating in modern Finnish dwellings. Natural ventilation is remaining mainly in the older houses. Indoor environmental quality is affected by outdoor air from every uncontrolled leaks of the building envelope.

In 2007 a revised National Building Code of Finland (part C3) introduced a recommendation for airtightness. The air change rate at 50 Pa i.e. $n_{50}$-value is recommended to be as near as possible to the value of one air change per hour in order to guarantee a proper function of ventilation devices [9]. The National Building Code of Finland (part D3) [10] takes into consideration leakage air flow in compensation calculation of heat loss. In new instructions the significance of airtightness of building envelope will be even more important than earlier. Therefore one aim of the research was also to determine the distribution of air leakages in buildings so that airtightness in problem places of each type of houses could be improved.

## 2. Studied houses

The measurements were performed in two different studies. The measurement methods were the same and the measurements were carried out by mainly the same researcher group. However the selection of type of houses had some discrepancies. The measured houses were recruited mainly from the databases of manufacturers of the houses. Some of the houses were recruited also by delivering brochures to the dwellers of suitable looking houses. The houses were located mainly in the Tampere and Helsinki region.

### 2.1. Lightweight (timber-framed) single family buildings

The group of 100 buildings were chosen in order to represent wide selection of different timber-framed dwellings. The whole group of houses is not a random sample of Finnish timber-framed housing stock because the purpose was to gather enough subgroups of different wall structures (water vapour permeable walls and walls with water vapour barrier). Timber-framed dwellings differed from each other, for instance, as of age, ventilation type and structural solutions.

Three of the dwellings were non single family (one semi-detached and two terrace houses) buildings and some of the two-storey buildings had a first storey built of shuttering concrete or LWAC blocks. 48% of the houses were one-storey. 60% of the houses had a mechanical supply and exhaust ventilation system with heat recovery, 30% houses had a mechanical exhaust ventilation system and 10% had natural ventilation. Half of the houses were constructed on site, one fourth from large prefabricated elements and one fourth from either small prefabricated elements or with pre-cut -method. Most of the dwellings were built rather recently. The mean age of the dwellings was five years and the median was three years. Timber-framed buildings included some older houses with natural ventilation which were built in the beginning of 1980's.

Half of the houses were situated in the Tampere region, and half in the Helsinki region. Measurements were performed in two sets, in the summers of 2002 and 2003 [11].

### 2.2. Heavyweight single family houses

The group of 70 heavyweight houses consists of 20 log houses, 10 houses built from blocks of autoclaved aerated concrete (AAC), 10 houses built from lightweight aggregate concrete (LWAC), 10 houses built from bricks (5 from calcium silicate brick, 5 from burnt clay brick), 10 houses built from shuttering concrete blocks and 10 houses built from concrete elements. The abovementioned materials describe the main construction material applied in external walls. Three studied log houses had internal and one had external supplementary insulation. The external walls of the other log houses (16) as well as AAC houses (10) were homogeneous. The log houses were selected so that they had different types of seam insulation materials. Rest of the houses (40) in this group had a thermal insulation layer between the inner and outer material layer at the external wall structure. LWAC and shuttering concrete blocks were prefabricated meaning that the insulation layer was included in blocks during the manufacturing process [12].

Ten (of 12) two-storey log houses had a timber-framed upper floor. Also four of the two-storey houses had a ground floor constructed of different construction material. 55 houses (of 70) had a timber-framed ceiling structure. Nine AAC external-walled houses (of 10) had also a reinforced AAC ceiling structure. Three houses with shuttering concrete block, two houses with concrete element and one house with LWAC exterior walls had a concrete hollow core slab as a ceiling structure [12].

65 houses (of 70) had a mechanical supply and exhaust ventilation with heat recovery while five houses had a mechanical exhaust ventilation system. The average internal volume used in pressurisation test results was in log houses 483 $m^3$ and in the rest of the houses 554 $m^3$. All of the houses were relatively new; the