IMPROVEMENT OF AIR TIGHTNESS OF COMMUNITIES

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ABSTRACT

From the beginning of year 2007 the buildings in Finland must have energy efficiency calculations, which requirements are now part of Building Codes, based on European Performance of Buildings Directive. According the renewed code, being into the force from July 2012, air tightness number q_{50} cannot be more than 4 $m^3/(h*m^2)$. Better air tightness can be shown by measurements. The air infiltration must be calculated in compensation calculations based on air tightness number 2.0 $m^3/(h*m^2)$. The energy efficiency requirements caused an immediate response in the building sector. Air tightness's have been measured since 70`s but new requirements launched a real boom. For example, in the city of Oulu building supervision authorities connected air tightness in their quality control programs of buildings - before that the authorities demanded the moisture management and control plan for multi-story houses and commercial both public buildings.

More than 30 years ago, the typical air leakage number n_{50} in one-family houses varied in the level of 6 – 7 1/h (changes/hour). In the turn of millennium the level was 2-3 1/h, but for instance in the city of Oulu the air tightness of new one-family houses has elicited to improve to the level 1 1/h or even below that. The best result since now is 0, 1 1/h, in the target where special attention has paid in air tightness, measured by three measurers and four different Blower Doors.

In this presentation the progress of air tightness especially in one-family buildings has been considered, and how a city can effect on the quality of new buildings. The best case of 0, 1 1/h is introduced, also the structural details. Air tightness is just one part of energy efficiency control – when air leak number will be in the level of 0, 5 – 0, 6 1/h – in the level of passive house – the effect of air tightness is not so crucial dealing with energy consumption and energy savings. Also calculations of the influence of air tightness for energy consumption in various cases will be introduced.

KEYWORDS

Air Tightness, Blower Door, Energy Efficiency of Buildings, Building Performance

1. INTRODUCTION

The function of the building envelope and building services is to maintain the goals of indoor environment and performance set for the building. Air tightness of buildings means how air-tight the exterior walls of the building are – how the incontrollable air flows through the structures has been prevented. Air-tightness of the structures of exterior walls interacts significantly with thermal comfort, and, if the building is intight enough, also with energy consumption.

Uncontrolled air leaks through building envelope can cause also health hazards and structural damages. This air leak flow comes about pressure differences caused by wind and temperature differences and also caused by insufficient function of ventilation system. The location of the building, the height of the building and the condition of building envelope has an effect on air leak flow.

Air tightness of a building is measured by specific device or set of devices; also the own ventilation system of building can be utilized. Tracer gas-method can also be used, especially when the controlled rate of ventilation must be separated from air leaks (concentration decay method). Air tightness measurements based on external fans demand measurable pressure difference across building envelope, and the air flow of fan will be determined. The air leak number is presented based on building air volume (n_{50}) or/and on area of building envelope (q_{50}) mainly at 50 Pa pressure difference.

2. AIR TIGHTNESS AND ORDERS OF AUTHORITIES

2.1 Air tightness and building codes

There has not been numerical scale-based requirements dealing with air tightness in Finland before 2008; the only indirect mention was in ventilation codes, in which the recommendable air leak number n_{50} was 1,0 changes/hour mostly intended to ensure the proper function of mechanical ventilation system. Also the air tightness of ventilation ducts was determined and classified. When requirements of energy performance calculation came into the building codes in 2008 (first version, the recent version from 2010), the interest of different parties of building trade grew rapidly in air tightness measurements. According the new code, being into the force from July 2012 [1], air tightness number q50 cannot be more than 4 m3/ (h*m2). Better air tightness can be shown by measurements. The air infiltration must be calculated in compensation calculations based on air tightness number 2.0 m3/ (h*m2). The valid standard SFS-EN 13829 is presented in the building code [2].

In the finnish building code [3] dealing with the evaluation of energy consumption and heating need typical air leak numbers of building enevlope and ratings has been presented:

Typical values (n_{50}) of air tightness			
Class	**Details**	**Building type**	**Typical values, n_{50} [1/h]**
Good		One-family houses	1….3
		Apartrments, offices	0,5….1,5
Average		One-family houses	3…5
		Apartrments, offices	1,5…3
Poor		One-family houses	5….10
		Apartrments, offices	3…7

Table 1. Air leak numbers by building type

In the new indoor quality classification [4] recommendation for the maximum value of one family houses n_{50} < 1 – 2 1/h and for other buildings n_{50} > 0,5 – 0,7 1/h. Air tightness for apartments is recommended n_{50} < 0,5 – 0,7 1/h (including external and both internal leaks through exterior walls, floors and intermediate walls).

2.2 Air tightness of one-family houses – previous results

VTT started air tightness measurements 1980. Air tightness of buildings has improved during 30 years – one can evaluate that the air tightness of one-family houses is more than halved. Nowadays the best houses will go under the limit of passive houses (n_{50} = 0, 6 1/h). Typical values of new houses are between 1-2 1/h. There are still problems.

VTT studied in 1981 air tightness level of some buildings [5]. The data included 42 one-family houses with various materials. Insulation material was mineral wool (32) and sawdust (12). Table1. Shows the results. The sample was relatively low and the results are therefore only suggestive. The air leak numbers concentrated between 7-9 1/h.

Type of building	Targets	n_{50} (mean value)
One-family houses, built before 1973	7	7,9
One-family houses, built after 1973	9	6,6
Row houses , before 1973	1	9,3
Row houses, after 1973	15	9,8
Log houses	10	9,7

Table 2. Air leak numbers according to building type (1981)

Type of building	Targets	n_{50} (mean value)	Lowest	Highest
One-family houses	56	5,3	1,6	18
Row houses	102	5,6	1,7	14,9
Log houses	13	10,7	5,3	14

Table 3. Air tightness of one-family houses 1981-1988

Table 2 shows the results of 171 one-family houses during 1981-1998 [6]. Main part of the houses has been reclamation cases. This means that the results can be worse than average or distribution of leak points has concentrated in that way, that it caused draft problems. Age of the buildings varies. Biggest group of one-family houses was between 3 - 4 1/h and of row houses between 4 – 5 1/h. There are also data available for Finnish housing fair which shows [7] that air-tightness has been improved and more attention has been paid to that topic.

Air tightness is totally depending on the solutions made during the construction and installation stage – to improve air tightness afterwards is extremely difficult. According to some single tests, air leak number will increase in the long run approx. 0, 5 1/h – 1, 0 1/h. By tightening the air leak number can improve 0,5 – 1,0 1/h, equal to the decrease of air tightness in course of time, depending on how the repair works has carried out and how wide the repairs have been.

3. MEASUREMENT OF AIR TIGHTNESS AND CERTIFICATION PROCEDURE

Air-tightness measurements of buildings in Finland have been done from early 70’s and more systematically from 1980 on. When building codes have been renewed, lot of serviced providers sprang up and also the measurements were certified – air-tightness measurer certification procedure and courses started 2008. Now it is also part of building thermographer-certification procedure. Building thermographer-certification started 2003. Many manufacturers and contractors have included air tightness measurements in their quality control procedures [8].

4. THE ROLE OF BUILDING SUPERVISION OFFICE (BSO) IN FINLAND.

4.1 Background

Every new building in Finland needs building permit and building supervision office to give that permit. In other words building supervision has contact to every builder when they start to design their project and before they can start to build. BSO has excellent possibility to give that kind of information they conceive important. We can fairly speak about some kind of momentum.

Almost in every municipality (ca. 330) has own building supervision office. Responsibility of the BSOs in Finland is to control, that houses to be built will be carried out according to law, rules and city plan, also taking care of the environment.

Recommendable task is also, that building supervision give advices and take care how builders can get better energy efficiency, better sustainability and longer life cycle. Normally building supervision offices in Finland do the minimum or only a bit more.

Building permit in Finland includes calculated energy certification, including among others goal of airtightness. Energy certification must be dated before dwellers will move in the house.

4.2 The role of building supervision office in Oulu, "BSO – Oulu - model"

BSO-Oulu tries to use this momentum effectively. The goal is that BSO-Oulu should do:

- Produce measureable added value to our customers and to City of Oulu,
- help customers,
- to have the courage give advices,
- to have willingness to be co-operative,
- to use public media,
- do development work together with designers and builders,
- To create network with local and national actors.

BSO-Oulu has done all those things during last ten years and the organization has employed a quality manager too for these tasks.

The main network of organizations consists of Oulu University of Applied Sciences (OUAS), VTT`s (Technical Research Centre of Finland) research team in Oulu, four biggest companies producing single-family houses in Finland and the Ministry of Environment. With BSO of City of Umeå (Sweden) BSO-Oulu had employee's exchanges in the year 2007 and 2008.

Last few years main focus has been to improve new buildings more energy-efficient and sustainable. In the near future BSO-Oulu will work with existing buildings to achieve the same. In the year 2010 started one project concerning existing buildings in co-operation of Ministry of Environment. During last ten years BSO-Oulu has arranged together with network of companies many seminars for professionals, designers, public authorities, responsible managers, foremen, builders and families together ca. 10 000 personal education days. For every builder of single family house in Oulu BSO arranges two or three times per year a course that includes minimum of 12 hours info sessions during six evenings. That happens after they have got the building site and before they start to design their project.

4.3 Examples of tools BSO-Oulu has produced and usde in everyday work

- Interactive application in Internet, www.pientalonlaatu.fi [9] (first price 2006-RIL-Finnish Association of Civil Engineers),
- Quality cards - http://www.ouka.fi/rakennusvalvonta/oppaat/laatukortit.htm [10] (figure 1, figure 2).

4.4. International activities and projects

BSO-Oulu is a partner in "Increasing Energy Efficiency in Buildings"-project (IEEB). The consortium of this EU-project constitutes OUAS, Luleå University of Technology (LTU, Sweden), Umeå University (UU, Sweden) and NORUT Narvik (Norway). Total value of IEEB-project is 1, 7 million €, see http://www.interregnord.com/fi.aspx [11].

In the near future the challenges will be big - passive houses and 0-energy houses. We all need new studied and documented information that will be suitable in northern Finland, Sweden and Norway.

In IEEB-project air-tightness is in very important role. BSO-Oulu's task is to help exporting the results of this project go into practice. When choosing the results going into practice one shall always be critical. Only those things/methods who are important, influential (energy-efficient, costs of life-cycle) and riskless (for example moisture risk) are acceptable for common use to all builders. Only in few "test-buildings" is acceptable to prove something unsure.

4.5. Examples of the results in Oulu –economical evaluation

In the year 2008 single-family houses in Oulu were more than 30% more energy-efficient in total average value compared with general regulations in Finland. In bigger dwelling-houses comparable value was over 25% and in other buildings approx. 20%. We have calculated that if we put money ca. 0, 1 M€, our customers will get back 20 M€ during next 50 year life cycle. Income value/investment is ca. 200. In the next few years this kind results are very difficult (maybe impossible) to achieve, because regulations will tighten/go forward very fast in Finland too.

5. RESULTS OF AIRTIGHTNESS IN OULU REGION.

In Oulu region air-tightness is now ca. four times better than seven years ago (4…6 --> 0.4...1, 9 1/h) and clearly better than average value in Finland. This variation of airtightness means ca. 20…25 % lower energy consumption. In Finland we calculate, that a change of 1 1/h in air leak number value means about 7 % in energy consumption (heated rooms in house). Cost efficiency is very good, in most cases the cheapest way to get houses more energy efficient.

Good airtightness is one of the most important factors, when constructing very energy efficient or passive houses. Poor air-tightness will cause moisture risks, increase energy consumption and indoor climate is uncomfortable. In city of Oulu, if air tightness in calculated energy certificate is 4 1/h at 50 Pa pressure difference inside-outside, measurement or other clarification are not needed. If goal of airtightness in energy certification is 2…4 1/h clarification according airtightness card or measurement is needed. If goal of airtightness is < 2 1/h, measurement is required.

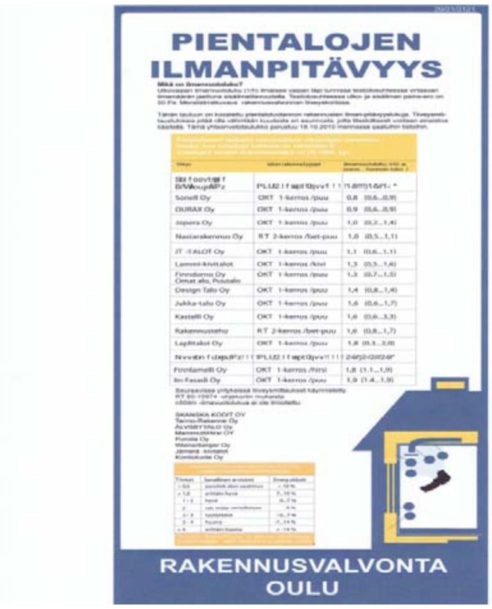

Figure 1 Air-tightness in Oulu Region

Figure 2 Air-tightness card /BSO-Oulu

6. CASE STUDY HOUSE LINNAKANGAS IN KEMPELE ECO-QUARTER, KEMPELE FINLAND

6.1 Demonstration building

This house is situated in north Finland ca. 15 km distance from city of Oulu in so called Kempele Eco-quarter (kempele is a neighboring community south of Oulu). The whole Eco-quarter is not connected in normal electrical network like almost all finnish single-family houses do. Eco-quarter consists ten single-family houses and "Powerhouse", where both electric energy and heat energy is produced for the whole quarter by CHP and a bit by windmill. Fuel is mainly wood chips and partly biofuel. Eco-quarter has won first prize in the year 2010 given by RIL - Finnish Association of Civil Engineers, see e.g.

http://www.ril.fi/en/main-page.html [12] ,
http://www.ril.fi/fi/etusivu/ajankohtaista-2/ril-palkinto-2010-kempeleen-ekokylalle.html [13]

Figure 3. Energy quarter

Figure 4. CHP "Powerhouse"

Figure 5. House Linnakangas in Kempele Eco-quarter

6.2 Structural details of House Linnakangas

Floor, ground based:

- coating (tile)
- reinforced concrete slab 100 mm
- polyurethane 160 mm, alongside ext. wall 190 mm
- washed coarse gravel with radon ventilation pipes
- U-value 0.103…0.107 W/m2K

External wall:

- stainless reinforced white concrete 80 mm
- polyurethane 170 mm with ventilation grooves
- reinforced concrete 100…120 mm
- U-value 0.15 W/m2K
- calculated life cycle 100 year

Roof:

- bitumen
- plywood board 15 mm
- wooden frame and ventilated space
- blowed heat insulation 600 mm
- bitumen coating
- reinforced concrete slab 200 mm
- U-value 0.07 W/m2K

Windows:

- partly fixed in ext. wall, U-value 1.0 W/m2K
- partly opening, U-value 0.85…1.0 W/m2K

Doors:

- partly sliding doors with window, U-value 1.0 W/m2K
- partly normal doors with window, U-value 0.8 W/m2K

Effiency of ventilation recovery (year): 73 %
Airtightness: 0.08 1/h. (0.07…0.08 1/h) -ca. 7x better than passive house limit 0.6 1/h

Heat transmission inside the house: waterpipes in floor/concrete slab

House automation:

- Ouman Oy, Kempele, www.ouman.fi [14]
- heating-, ventilalation-, moisture damage-, fire carbon monoxcide-warning/control.

Ventilation equipment:

- Enervent Pandion 2 pieces, SFP-value 1,6
- preheating/cooling with pipes 400 m in the ground
- all ventilations pipes inside envelope

Other equipments:

- hood with direct outflow (using only when preparing food)
- sauna stove, “fuel” /propellant piece of wood

Wideness, area and volume:

- 347 brm^2 (gross area)
- heated air volume 897 m^3

Calculated energy efficiency: ET-value 115 kWh/brm^2/year, Energy class A

Figure 6 Sliding window in living room


Figure 7 Fixed window in living room

6.3 How good airtightness has been achieved

Builder/owner has good experience in desingning constructions over 25 years. Based this experience the owner had designed and done himself all the most important details conserning air-tightness. Some examples of details:

- joint between floor and external wall tightened with elastic mass.
- almost all pipes inside envelope
- all perforations(some pipes and electrical cables) of envelope tightened with elastic mass.
- all joints between window/door frame and ext. wall tightened with polyurethan and elastic mass.

- all opening windows adjusted in building site after installation (sealings were not airtight)
- premeasuring of airtightness and repairing the critical points, result of premeasuring was 0,1 1/h.

6.4 Measuring of airtightness in house Linnakangas

Because the premeasured result was so good, it was important to check the final result not only by one measurer and one Blower Door. The final measurement decided to carry out with four different calibrated Blower Door and three different measurer. The result in all four measurements was the same 0, 08 1/h. (0, 07…0, 08 1/h). In spite of that the house is quite big (897 m^3), the air leakage was so low, that all the adjustments in Blower Door must be done manually. In the end of the tests was found out, that there was a small air leakage in Blower Door, see Fig. 12. In normal house it does not matter, but in so tight house the result should be better than 0, 07 1/h, if that leakage has been found before final measuring.

Figure 8. Company , 8.6.2010

Figure 9. Installation

Figure 10. Company 1, 8.6.2010

Figure 11. VTT 14.6.2010

Figure 12. Installation 14.6.2010

Figure 13. Air-tightness 0,07…0,08 1/h

7. CONCLUSIONS

It is possible to reach better airtightness by systematic work not only in pilot houses, but in every new house. To design details in advance is necessary, it is too late to design all the details in building site. Educating and training designers, responsible foremans, carpenters and others workers in building site is needed. Details shall not be too complicated and many different details in the same house shall be avoided. Measuring both air-tightness and thermographic survey is needed. Without the location of possible leak points it is impossible to make any repairs. The fact, that the house will be measured can influence a lot, even so that air-tightness sharpen from 4 --> 2 1/h. That kind of experience was in Oulu year 2005. When building passive houses, it is necessary to know in advance, that good airtightness (<0.6 1/h) is possible to reach. Many contractors have already reached the level 1…1, 5 1/h in Oulu region. Now the next step is <0, 6 1/h as wide as possible in normal or low energy house. Anyway, some new challenges will exist:

- house automation should be designed/developed so that using fireplace and hood is possible.
- in some parts of Finland there are no professionally skilled measurers nearby
- if outgoing air is 100, how much should incoming air be in very airtight house ?
- when house is very airtight and ventilation system break in some reason at night, do we need carbondioxide alarm ?

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