FIELD MEASUREMENT TESTING OF AIR TIGHTNESS – EXAMPLE FROM A HOSPITAL PROJECT IN SWEDEN

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ABSTRACT

Over the recent years more effort has been given to air tightness of public buildings such as hospitals. The demand for well insulated buildings increases the importance for low infiltration air rates and thus the air tightness becomes more important. Besides, air infiltration is a quantitative way to put into requirements for the tenders to fulfill.

In this work we describe field measurement of air-tightness on site in early stage of production, as well as field measurement of a whole floor in a hospital building. Hospital buildings are large enclosures that sometimes are difficult to test. We describe some outcomes from evaluating the testing method and how qualitative results as well as quantitative results can be used to improve the building process. Early measurements are important to give input to the builders how to build correct and to give an understanding about the importance of the air-tightness of a building. The different techniques to measure air tightness and to find leaks in the building envelope has been part of a learning process, both for the builders as well as the design team.

The results show, after that the air-tight measurements was started, that the building process has improved. However, another finding from the project is that information should be given continuously and to all builders, as various work teams, has their own way of working with air-tightness.

Measuring building parts should be the first test to evaluate different constructions and how the construction has been sealed. In the work described in this paper the building was divided by a temporary construction made by plastic film, adhesive tape everywhere where the plastic film meets another material and where the plastic film is overlapping. Butyl-based adhesive strip was used under the floor joist, at the corners and under the ceiling joist. The measurements showed that there was an air-leakage between ceiling and outer walls. This air-leakage was evaluated by a small box for only that part. By this test a suitable method involving air-tight foam was used and the results from measurements after the action shows air-leakage close to zero.

The result from the whole floor measurement shows higher air-infiltration than the requirement. The contractor will take action to improve the air-permeability. From the

experience of the measurements one last conclusion is that a design that emphasise air-tightness is the first step to achieve an air-thigh building.

KEYWORDS

Air-tightness, Hospital buildings, early stage, field measurement testing.

1 INTRODUCTION

Health care environments are essential for a sustainable development of society, especially from a social point of view. Health care buildings, e.g. hospitals, are buildings that are built to stand for several years. They could therefore serve as good examples of sustainable architecture, and low-energy demand.

Due to increased need for health care and the fact that the main part of Swedish hospital buildings were built in the 60's and the 70's and need to be refurbished and there are several construction projects regarding new hospital buildings in Sweden. Most of them endeavour for high energy efficient standard. In new constructions there is often ambitious goal on air-tightness, as in a well-insulated construction infiltration rates is relatively more important. One part to achieve an air-tight construction is to measure the air- tightness continuously during the building process. Measuring the air- tightness is both a way to examine the construction and a way to learn for the project the air- tightness for different constructions. This paper describes the work with measuring air-tightness in one of the most energy efficient hospital buildings in Sweden. The measurements have been used for both qualitative and quantitative examination of the project.

This article describes field measurement of air-tightness on site in early stage of production of a new hospital building. Different kinds of measurements have been used and in this article we present 1) Spot-checks of parts of the building envelope, for example a floor divided into parts by temporary stud walls with plastic film. 2) Measurement of building parts. 3) Measurement of a whole floor and techniques to identify leakage sources with smoke machine and infrared camera.

2 SUSTAINABLE HEALTH CARE ENVIRONMENTS

Sustainable health care environments includes healthy indoor climate. Design of health care buildings is connected to regulations and standards but also, as in every project, there is a need for an integrated design between different professions. The scope of the energy profession is wide and connected to most other professions, such as architectural, construction, heating, ventilation and air conditioning (HVAC)-design.

Energy efficient measures will in most cases improve indoor climate. Especially measures of thermal insulation, air-tightness, heat recovery in ventilation systems, accurate control system and energy efficient lighting. Improved thermal insulation will decrease demand for heating power and improve indoor temperatures mainly during wintertime. In cold climates low ventilation rates or efficient heat recovery are essential to not exceed energy targets but still provide for fresh air supply. Accurate control system will improve temperature control in rooms, which will lead to temperatures that are closer to peoples comfort temperature. Energy efficient lighting system will decrease surplus heat that will cause over-heating problems during summertime.

2.1 Energy demand in hospital buildings

According to a survey study of energy demand in Swedish health care buildings (SEA, 2008) these buildings use about 2.8 TWh of heat, 63 GWh of district cooling and 1.7 TWh of electricity in 2008. Thus, the health care sector stands for about 3 % of the total energy demand for buildings in Sweden.

A survey of energy demand for hospitals in several OECD countries, made in the mid 90's, shows the energy demand per square meter and beds, respectively (Jakelius, 1996). The study shows that there is a great difference if floor area or amount of beds is used as unit. In Sweden floor area is usually larger than in other countries.

A comparison between a hospital in the UK and Sweden shows that the specific energy for space heating is similar, but if space heating is divided by patients the Swedish hospital uses almost eight times more energy. The two buildings are similar regarding thermal insulation.

3 PROJECT DESCRIPTION

The expansion of the University hospital in Linköping is a project with ambitious environmental goals. The building is of about 65 000 m^2. The project has a goal of total annual energy demand (including operational energy) below 100 kWh/m^2, which is one of the most energy efficient hospital projects in Sweden right now. The building fabric is well insulated with U-values for walls about 0.12 W/m^2, K. Ventilation heat recovery is using mainly recovery wheel, which gives a heat recovery rate of about 83 %.

In addition, this building also has a good floor area/volume ratio, about 0.6. District heating and cooling is supplied from a district heating network with a combined heat and power (CHP) plant. Cooling is produced by absorption chillers heated by district heating.

The requirement of air infiltration for the new buildings is set as a value of the air permeability at 50 Pa. The mean air leakage rate at 50 Pa should not exceed 0,2 l/s, m^2 envelope area. The envelope area is the surface for walls, floor and roof that border to outside air or rooms that's not intended to be heated above 10 °C. If this number converts into air changes per hour (n_{50}) it is equal to 0,116 h^{-1}. The total volume of the buildings is 245 849 m^3, total envelope area is 39 678 m^2 and the maximum allowed air flow infiltration is 28 568 m^3/h.

4 MEASURMENTS

The measurements done in early stage was indented to identify leakage sources, not to measure the air permeability. Some of the leaks that were identified in early stage were then later tested on site to find out a value of the specific air flow per identified leak. This was done as a basis for deciding whether to take actions or not with the systematic leaks that were found. Although the requirement for air infiltration is ambitious some leaks can be acceptable and this was very important for the contractors to know.

The air-moving equipment used was a Retrotech 3100 series Blower Door. For leakage seeking during depressurising an infrared camera, NEC Thermo Tracer TH 7800, was used together with Regin smoke bottles. When pressurising tests were performed a smoke machine, Martin Magnum 850 with training smoke fluid, was used to fill the enclosed area with thick white smoke and then examine the building for leaks from outside.

Measurements of individual building components and connections were made by pressurising and depressurising a small box that was mounted (pressed) very carefully and tight around the part being tested. The measuring equipment was a system consisting of a variable speed fan, a measuring tube (VEAB Elmicro) for small air flows (0.5-15 l/s) and a pressure-measuring device (TESTO 435).

4.1 Measurements of parts of the building, parts of a floor

In early stages it is not suitable to measure the air-tightness of a whole floor, instead the floor was divided into parts, for example a corner. The purpose of testing a part of the building in early stage is not measure the air permeability but to search for leaks.

Booth representative and critical parts of the building was picked out for testing. The areas suitable for testing were found by studying drawings and by visits on site. The areas were then chosen depending on if they were representative for different kind of constructions and/or if the construction was difficult to build with high air permeability.

As shown in Figure 1 below the constructor built temporary walls to divide the floor. The box was then depressurised to 50 Pa with the Blower Door equipment and search for leaks with infrared camera and Regin Smoke bottle (RFA 10) was performed.

Figure 1. Different temporary boxes made with a stud frame and plastic film for early stage testing

It is very important that the box is made as air-tight as possible. During the first test it was a lot of leaks in the box. Important things to get the box as air-tight as possible are to use a flexible multi-purpose adhesive tape everywhere where the plastic film meets another material and where the plastic film is overlapping. It is also important that there is a butyl-based adhesive strip under the floor joist, at the corners and under the ceiling joist.
It is also important that the building workers know the purpose of the temporary box and the purpose of the tests.

4.2 Smoke machine

When pressurising the temporary boxes it has been very effective to fill the box with smoke and to search for leaks from outside the building envelope. To have booth the building workers and the design team present during these tests has been very pedagogical for everyone. Figure 2 shows a temporary box that is filled up with smoke. In Figure 3 the smoke is finding its way out through the wall, indicating air leakage.

Figure 2. Temporary box filled with smoke for early stage testing and to identify leakage sources from outside of the building

Figure 3. Smoke coming thru the outer wall and connection to existing parts of the hospital during pressurising test at +50 Pa.

4.3 Measurement of individual building parts

One result of the early measurements was that there was an air leakage in the connection between ceiling and outer walls (Figure 5 below). As this was a common part of the building a program for measuring the air-tightness for this part was developed. The measurements equipment was including a box that was mounted to the ceiling. The box was connected to a duct with a fan (Figure 4 below). The air-flow pressure was measured and the air-flow was changed by the fan.

Figure 4. Equipment used for measuring air-leakages in ceiling along the outer walls

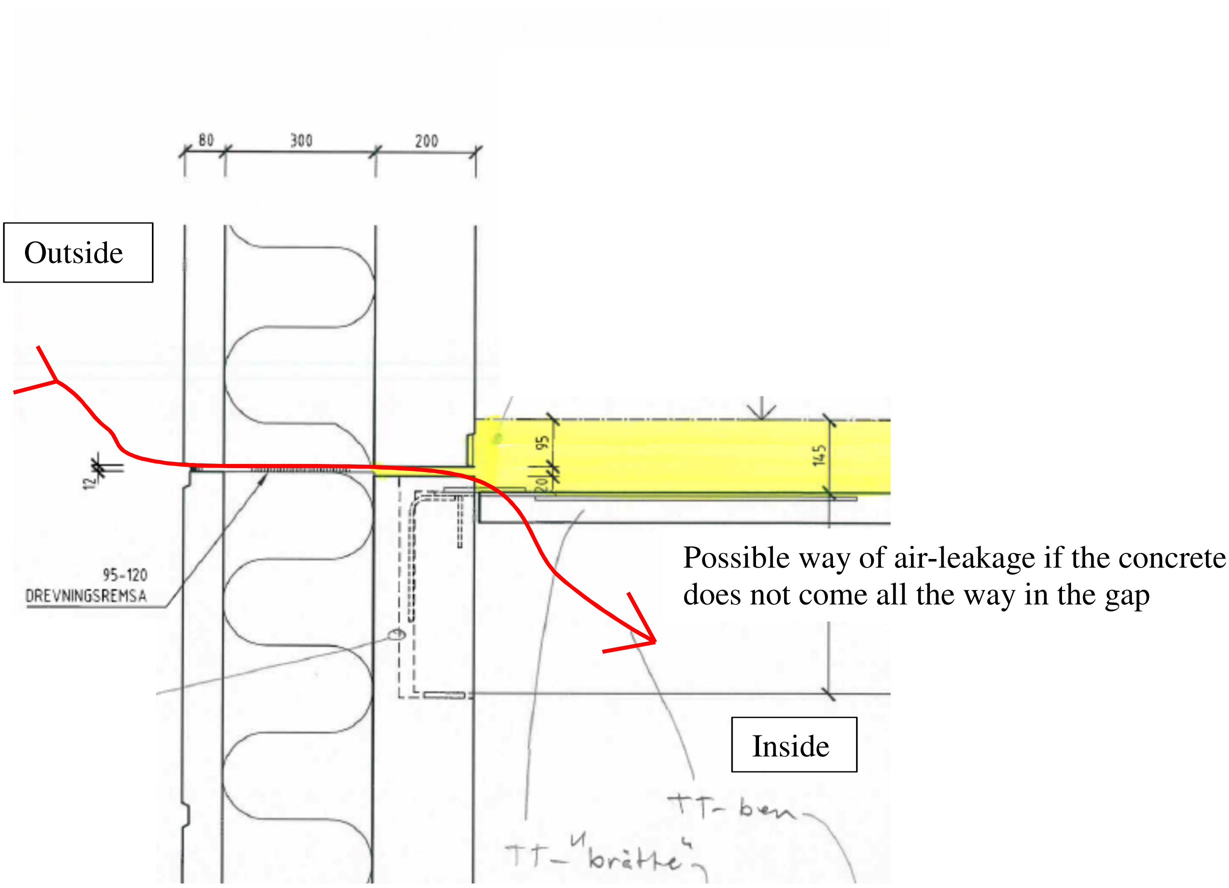

Figure 5. Outer wall construction drawing with possible air leaks in the gap between concrete elements

The first measurements of this building part show high air-flow rates in some places. Table 1 below shows the results from a couple of measurements.

Table 1 Results from tests of connections between outer wall and ceiling

Test nr	Building nr	Floor nr	Pressure in test box (Pa)	ΔP measuring tube (Pa)	Leakage flow (l/s)
1	443	12	-50	175	6,5
2	443	12	-50	25	2,5
3	439	15	-50	0-1	0
4	439	15	-50	2-3	<0,5

After that the construction was sealed with air-tight foam (see Figure 6 below) two new tests were performed, resulting in a very low air-infiltration rate (see Table 2 below).

Figure 6. Ceiling along outer walls after sealing with air-tight foam

Table 2. Results from tests of connections between outer wall and ceiling after sealing with air-tight foam

Test nr	Building nr	Floor nr	Pressure in test box (Pa)	ΔP measuring tube (Pa)	Leakage flow (l/s)
5	443	12	-50	0-1	0
6	443	12	-50	0-1	0

5 FIELD MEASUREMENT OF A WHOLE FLOOR

The measurements of whole floors were indented to measure the air permeability of a whole part of the building to check compliance with the airtightness specification. One floor is about 1500 m^2. As the test was adjusted to the building process inner walls was not finished and there were still some outer constructions that was not air-tight during the measurement. Thus, several temporary seals with foam and tape were used. For example, ducts, floor drains and shafts were sealed (Figure 7).

Figure 7. Temporary seals between different floors (ducts and floor drains)

The top floor of the building is a construction with light steel frame walls. The walls are built with 3 layer of insulation, a total of 310 mm of Rockwool. The plastic film is placed between two layers of insulation, 70 mm from the inside gypsum board. This is to create a space for installations and to minimise the risk of penetrating the plastic film.

The measurement of the whole floor was made during a weekend when the building site was closed (results are presented in Table 3 below). The gypsum boards where not put up and thus there still would be a chance of correcting errors found. Below are some pictures of the most commonly spotted errors (Figure 8, 9, and 10).

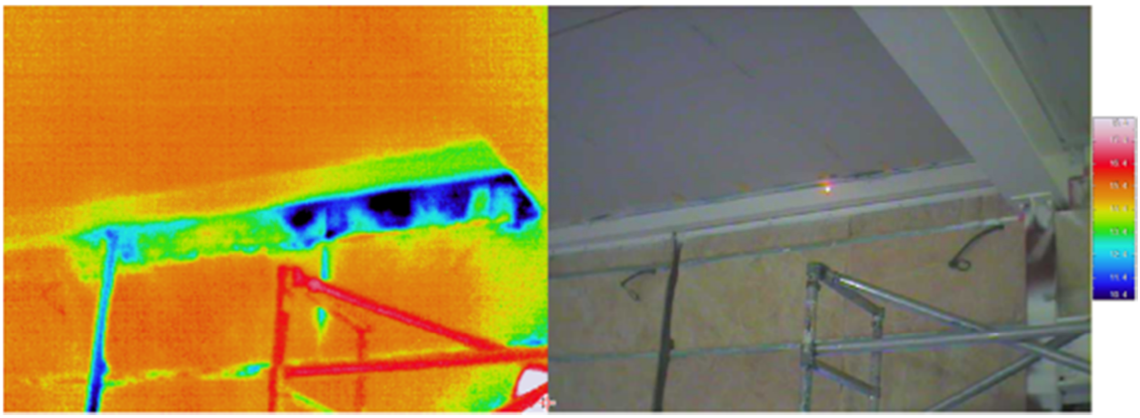

Figure 8. Air leakage in the ceiling angle

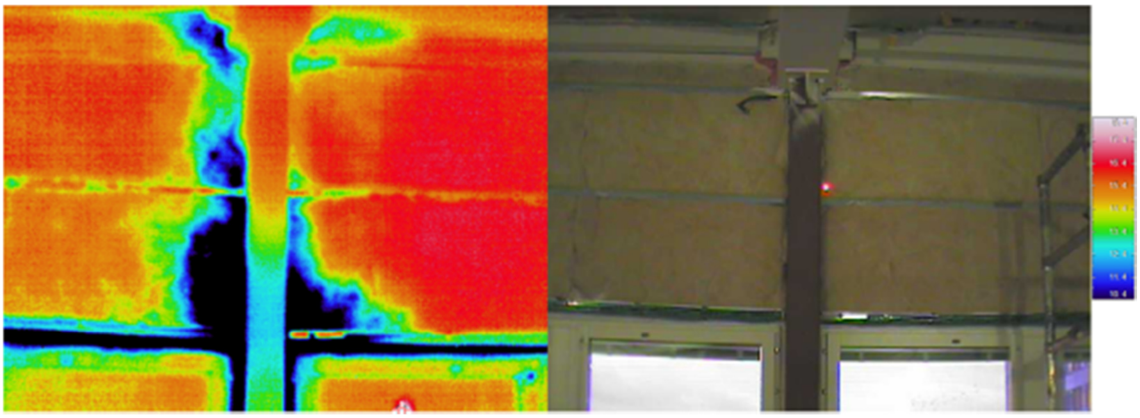

Figure 9. Air leakage where steel column connects to the light steel frame walls

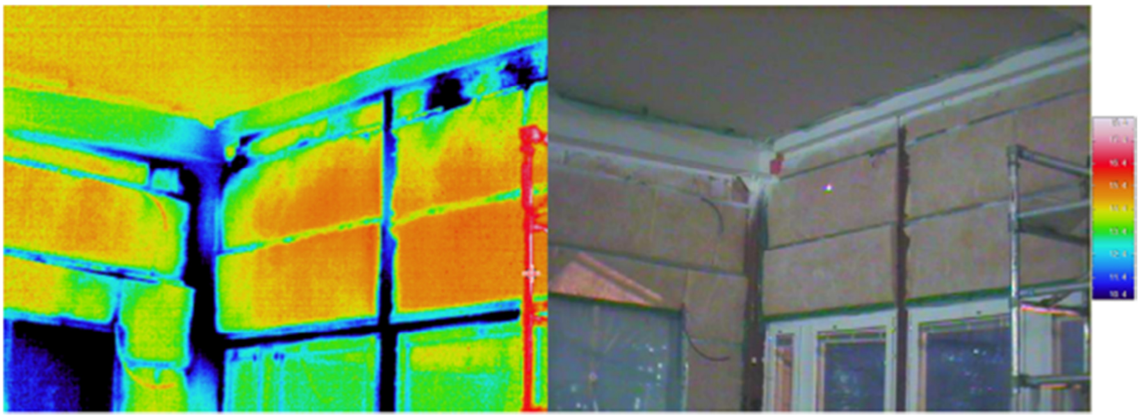

Figure 10. Air leakage in a corner

Table 3. Test results from measurement of a whole floor

Date	Floor nr	Envelope area	Pressure in test (Pa)	Leakage flow (l/s)	Air permeability at 50 Pa (l/s, m^2)
2014-02-09	15	2267	-50	930	0,41

Because the test was performed before the finishing gypsum boards were up the leaks could be fixed. Most of the leaks could have been avoided from the beginning if the design team had had focus on air-tightness and if work preparation descriptions had been better. The work preparation should include figures and photos that show how different constructions should be sealed and what should be done if the plastic is broken.

6 CONCLUSIONS

Outcomes from evaluating the work that has been described in this article are that qualitative results as well as quantitative results can be used to improve the building process. Qualitative results give an understanding for builders, designers, and project leaders were there is air leakage. Smoke visualisation in combination with thermal imaging gives a good understanding for most people were the leakage is and if it is large or small. However, smoke can be hard to see if the air leak is large and thus the air velocity is low. Qualitative results does not relate to the goal for air-tightness that the project aim to achieve. Quantitative results are easier to communicate and can be related to the goal for the project but are sometimes difficult to calculate appropriate at early stages. In the project described in this article quantitative results have only been reported for whole floor measurements and measurements for building parts, e.g. the connection between the ceiling and outer walls.

The builders understanding of the air-flow through air-leakage is important. Both thermal imaging and smoke have been used to visualise the air-flow and have been found to be a very good way to achieve understanding for the builder.

Measurement if air-tightness of a whole floor is connected to some major difficulties as the potential leakage area is large and possible air-leakage to other floors through shafts etc. are many. The results from the measurement can be improved if it possible to perform back pressure on the adjacent floors. The Blower Doors that are used in such a test should be connected and it should be possible to control and read the results for all equipment simultaneously.

The results show, after that the air-tight measurements was started, that the building process has improved. However, another finding from the project is that information should be given continuously and to all builders, as various work teams, has their own way of working with air-tightness. A clear work preparation description can be a way to achieve a better standardization of the work. The work preparation should include figures and photos that show how different constructions should be sealed and what should be done if the plastic is broken. If the builders go through the work preparation together with the foreman while actually doing the sealing of a real construction, and not only read it through, it will probably improve the air-tightness of the building.

Another problem to achieve an air-tight building is that nevertheless the building is air-tight after the construction work, there is still a problem with other entrepreneurs that provide electrics or ventilation that might broke the air-sealing.

The result from the whole floor measurement shows higher air-infiltration than the requirement. The contractor will take action to improve the air-permeability.

Last, a design that emphasise air-tightness is the first step to achieve an air-thigh building.

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