Methods and Materials for an Airtight Building

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ABSTRACT

This paper summarizes three projects which deal with important aspects required to achieve an airtight building. The major themes are: problematic areas with respect to airtightness, how to find leaky areas and make them more airtight, good and airtight solutions, and durability of airtight layers and joints.

First, critical details for airtightness have been identified and analyzed. A poor airtightness is often caused by lack of consideration for airtight details in the design phase, by inferior workmanship, or by lack of understanding of airtightness during construction. The consequences of poor airtightness is described.

Second, different methods to perform air leakage search have been investigated and evaluated. Air leakage search during the construction phase is a good measure to improve airtightness since the airtight layers are more accessible during the erection of the building than when the building is completed.

Third, several buildings with very good measured airtightness have been investigated in order to provide airtight solutions to designers and builders. A number of important details and constructions have been collected and presented to the building industry.

INTRODUCTION

During the last ten years the interest in airtightness has increased in Sweden. A reason for this might be the increasing focus on energy use and passive houses. Airtightness is linked to energy use in different ways, depending on whether the air passes through the building envelope or moves inside the envelope.

If air is allowed into the building envelope, the performance of the insulation can be decreased and it can also lead to cold inner surfaces. Cold surfaces, for example floors, can result in an increase in indoor temperature and, consequently, to an increase in energy use. Furthermore, if the building is not airtight, the

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ventilation rate can be increased, in particular in windy and cold weather.

Apart from energy, there are other reasons for having airtight buildings. If humid air is allowed into the building envelope, this can lead to high moisture conditions and, as a result, to mould, deterioration and increased emissions. In Figure 1, an attic with mould growth due to moisture convection is shown.

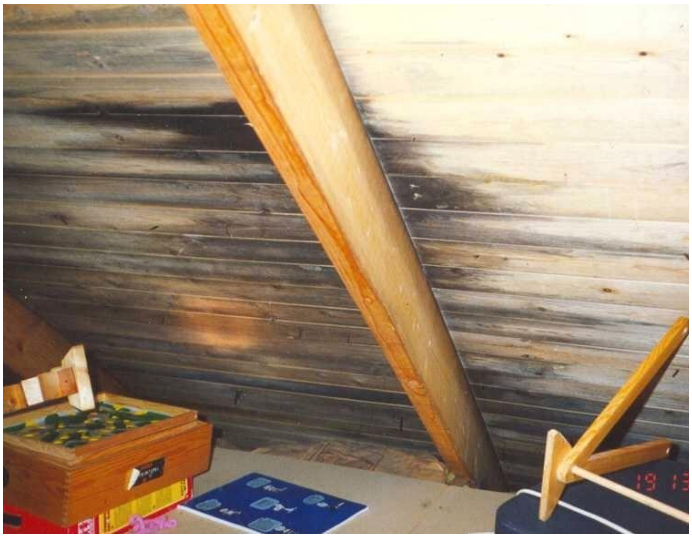


Figure 1. Mould growth in a cold attic.

Another reason for having a good airtightness is that it is a prerequisite for a well functioning ventilation system. Without an airtight envelope it is difficult to filter the air, to stop gas- and particle transport inside the building and through the building envelope, and to ensure an adequate ventilation rate in all parts of a building (in particular in windy weather). Critical parts of a building envelope have been identified by Sandberg (2005). The leakage parts are illustrated in Figure 2. In addition to the leakages in the figure, there are also air leakages in joints in the air barrier.

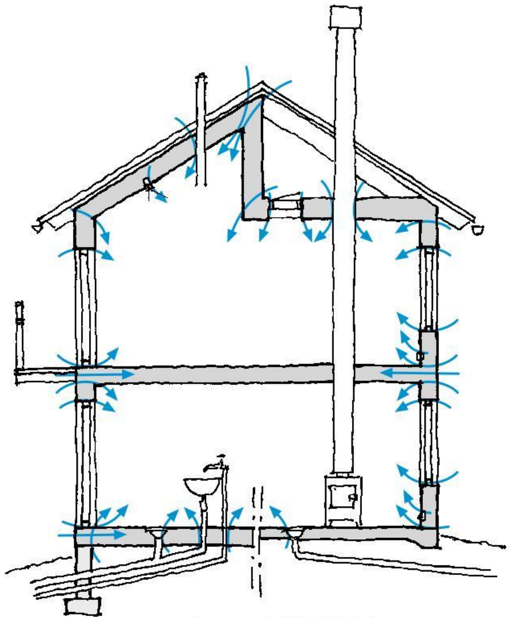


Figure 2. Common air leakages in a building envelope (Eric Werner).

The airtightness can be described as air permeability at 50 Pa, q_{50} ($m^3/(h{\cdot}m^2)$). Air permeability at 50 Pa is the air leakage rate per envelope area at a reference pressure differential across the building envelope of 50 Pa. Currently, there is no demand for maximum air permeability for Swedish buildings. In the Swedish specification for passive houses, the maximum permeability for a passive house is 0.3($m^3/(h{\cdot}m^2$). Formerly, Sweden had a maximum demand for air permeability of 0.8 ($m^3/(h{\cdot}m^2$). In order to find out the existing permeability of Swedish newly constructed buildings, a collection of the air permeability of 100 buildings has been made (Svensson, 2009). The study includes apartment buildings, schools, one-family residential houses, and wooden and concrete structures. As seen in Figur 3, the air permeability varies from 0.18 $m^3/(h{\cdot}m^2$ to 2.5 $m^3/(h{\cdot}m^2)$. Many buildings are in the range of 0.8 $m^3/(h{\cdot}m^2)$ (former Swedish demand). The passive houses and the buildings with high demands regarding airtightness all have an air permeability of less than 0.3 $m^3/(h{\cdot}m^2)$.

Lufttäthet i USA

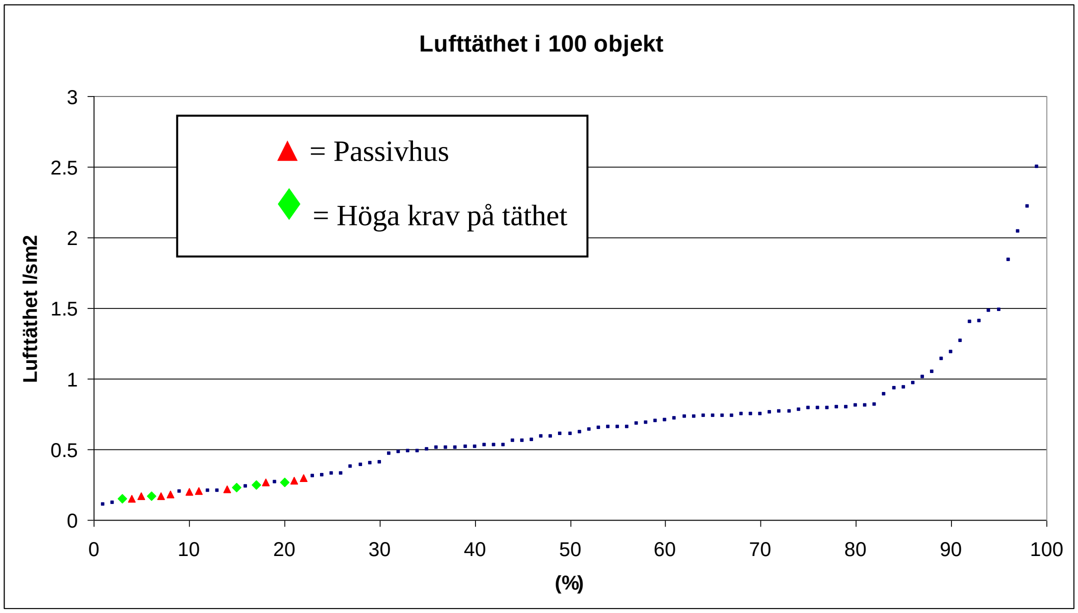


Figure 3. Airtightness in a hundred Swedish buildings (Svensson, 2009).

This is the situation in the Sweden today. The work described in this paper aims at supporting the construction of airtight buildings. In several joint projects with SP Technical Research Institute of Sweden and Chalmers University of Technology, the "Convection Group" has worked with airtightness, air movements, building envelopes and related issues since the beginning of the century. In Sandberg et al. (2007a) and Sandberg et al.(2007b), the consequences (both physical and economical) of poor airtightness were investigated. The projects described in this paper aim at showing examples of good and airtight constructions (Wahlgren, 2010) and also to demonstrate construct a method to find the air leakage paths during the construction phase (Sikander et al. 2008).

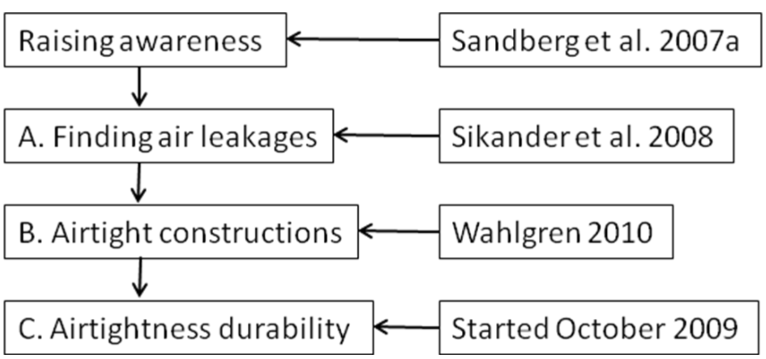


Figure 2. Projects aiming at improving building airtightness

FINDING AIR LEAKAGES

Project A in Figure 2 aimed at finding a methodology to search for air leakage before a building is completed. In Knight et al. (2003) a similar approach is used as part of a Quality Assurance System with instructions for several phases. A gathering of methods to evaluate the building envelope, including airtightness and air leakage search, is found in Wray et al. 2002

In this project, the idea is to find an easy to use method that can be used at the building site, by the construction workers, with access only to written instructions. The equipment and instruments should also be easy to use and to find (buy or rent). In order to develope such a method, following steps were taken: inventory of possible ways to detect and measure air leakage, interviews with airtightness test engineers in order to select good methods, and testing of the different methods using field testing. After a first round of testing, the construction workers were interviewed and improvements of the method were made. A second round of testing and evaluation was also made.

The resulting method is to be used before the inside claddings are in place so that improvement of the air barrier can easily be made. The method is described below.

Instructions for early air leakage detection

Aim of the air leakage detection

The air leakage detection is performed in order to find air leakage during the construction phase, so that leakages can be easily sealed. This instruction

(ÖVERSÄTTARE

This method is a part in the work to facilitate the construction of airtight buildings. Another challenge, when it comes to building airtight, is the design of the details and the construction. This is investigated in the project "Good examples of airtight details and constructions"described below.)

GOOD EXAMPLES OF AIRTIGHT DETAILS AND CONSTRUCTIONS

This work is brought about by the difficulties that designers and contractors have to ensure airtight building envelopes. Previous projects found that airtightness was seldom given proper consideration and also highlighted that there is a major need for information regarding airtightness in general, its importance and how an airtight building envelope can be accomplished. The client has a great influence on the airtightness of a building through the formulation of their requirements, and it is the responsibility of the designer and contractor to fulfil these requirements. In Knight et al. (2001) a Quality Assurance Program for the air barrier is described that is divided into the different construction phases.

Our project aims at facilitating for designers and contractors to fulfil the developers' airtightness requirements. Particular care is taken to describe airtight details and constructions. Following steps have been made to select airtight details.

1. Literature reviews.

2. Gathering of laboratory measurements of the airtightness of constructions. Selection of good details.

3. Interviews of airtightness test engineers, designers and contractors.

4. Evaluation of successful building projects that have resulted in airtight buildings. In this study, most of the selected good examples are from buildings with a measured air permeability of 0.3($m^3/(h{\cdot}m^2)$ or better. A majority of these are even better than 0.2($m^3/(h{\cdot}m^2)$).

5. Report with airtight details, sealing methods and constructions. Some other factors that have been identified as important to the building airtightness are also described, such as information at building site.

The collection of good example of airtight detail and constructions (Wahlgren, 2010) is divided into critical parts according to:

1. Skarvar (Joints in flexible air barriers?)
2. Wall to floor connection
3. Wall to roof connection
4. Wall to window connection
5. Service penetrations

In this paper, examples of joints, service penetrations and some principle connections will be shown. The materials that are recommended for joints or for connections are:

Översätt gärna detta stycke. Jag skall lägga bädda in det i materialet imorgon.

Plastfolie mot plastfolie: överlapp, klämt eller tejpat. Om plastfolien kläms mellan trä och trä finns det risk att klämningen blir ofullständig när trät har torkat.

Plastfolie mot annat material: fogmassa, tejp, tätningsband samt sviktande material (gummi, extruderad polystyren etc.) som kläms.

Som tidigare nämnts så skall de ingående materialens egenskaper beaktas så att de inte påverkar varandra negativt. När fogmassa, tejp eller dubbelhäftande tätningsband används skall ytorna vara väl rengjorda och häftningsegenskaperna säkerställda för de material som det skall fästa emot.

Joints in flexible air barriers

A very common air barrier in Swedish buildings is plastic foil. There are several measures that can help ensuring a high performance with an air barrier made of plastic foil.

1. Minimize the amount of service penetrations.
2. Joints in the plastic foil overlap two joists, Figure Y. Preferably, the plastic foil is placed between two solid layers so that skarven kläms over hela längden.

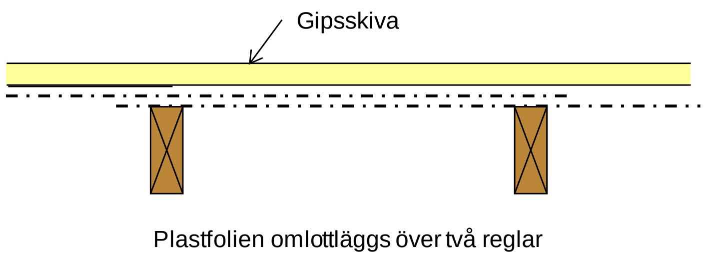


Figure Y. Skarven lags omlott over två reglar.

3. The plastic foil joints should be placed in line with the joists if doable. If it is not possible to have an overlap of two joists, the overlap should be at least 100 mm. The joints can be taped, clamped (klämd?) or dubbelhäftande material such as fogmassa or butylband can be used. When adhesion is wanted, care should be taken so that the plastic foil is clean and not folded. The durability of the sealing materials shall be considered.

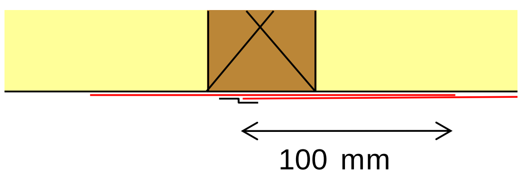
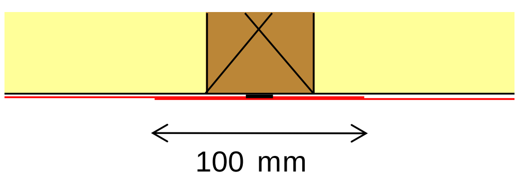


Figure X. Taped overlap.



Var är butylet??

Figure X. Butylband??.

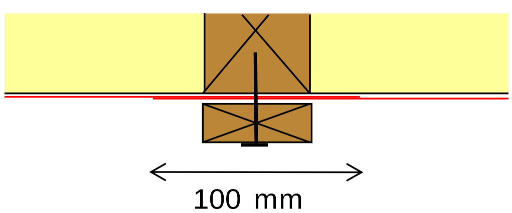


Figure X. Clamped overlap.

4. Use double layers of plastic foil to improve airtightness.
5. Use extra thick plastic foil (0.4 mm instead of 0.2 mm). In particular when

there is a risk of damaging the plastic foil, this is important.
6. Protect the plastic foil during the construction phase. If the foil is damaged, the foil shall be repaired by first encircling the damaged part with tape and then adding an extra piece of plastic foil over the damage. The overlap shall be at least 100 mm in all directions.

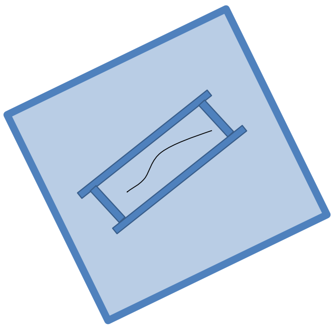


Figure X. Damaged plastic foil shall be repaired in two stages.

7. Finally, installationsskikt should be used when possible. This is a good way to protect the air barrier and to minimize service penetrations.Care should be taken so that the plastic foil (also moisture barrier??) is not located to close to the cold side of the construction since this can result in moisture damage. The installaitonsskikt is not only of use in walls but also in ceilings…… bla bla

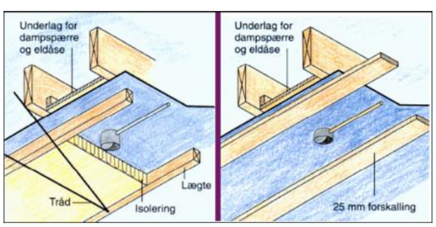


Figure X.

Service penetrations

Following advice is given regarding the service penetrations in a flexible air barrier.
1. Minimize the amount of service penetrations
2. Sealing of penetrations in plastic foils are preferably made with stosar and as second choice with fogmassa, butylband eller godkänd tejp.

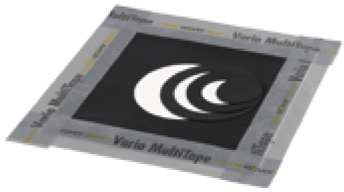


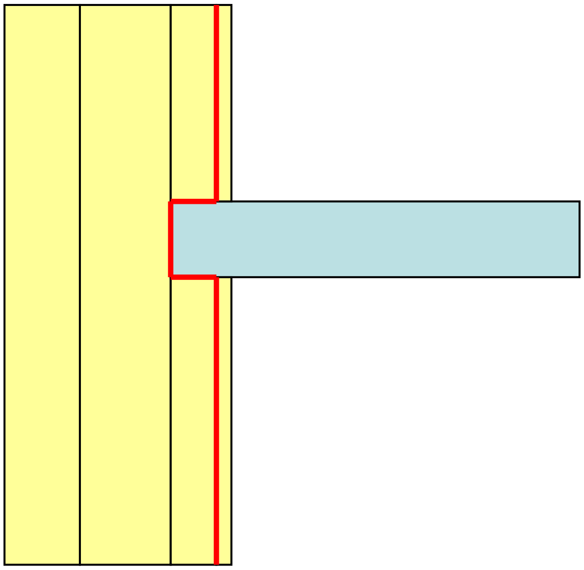
Figure Z. Example of stos made of EPDM-rubber.

3. Spot lights (down lights)……

Connections

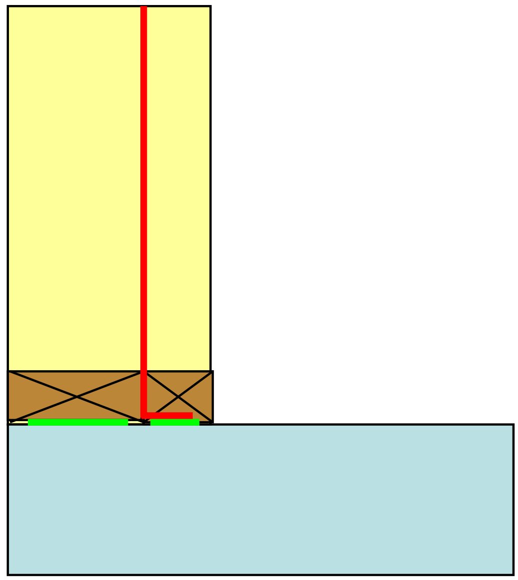
Anslutning av plastfolie mot tak eller golv görs ofta genom att klämma plastfolien. Där plastfolien kläms bör också anbringas en flexibel och lufttät tätning såsom gummitätning, extruderad polyeten eller tätningsband eller en dubbelhäftande tätning. Detta gäller både lätta och tunga konstruktioner där plastfolie utgör tätskikt. En flexibel tätning rekommenderas i träkonstruktionen eftersom krympning av trät pga torkning kan resultera i att plastfolien inte längre kläms. Vid anslutning mot betongplatta skall betongen vara slät och rengjord. Mellan betongplatta och syll bör syllisolering användas eftersom den kan formas efter eventuella skevheter så att luftläckage undviks. Det betyder att syllisolering inte bara har en fuktskyddande funktion utan även säkrar lufttäthet. Det betyder också att den bör användas både till träsyll och till plåtsyll.

Nedan följer fyra exempel där lätt konstruktion möter tung konstruktion samt ett exempel med lätt konstruktion.

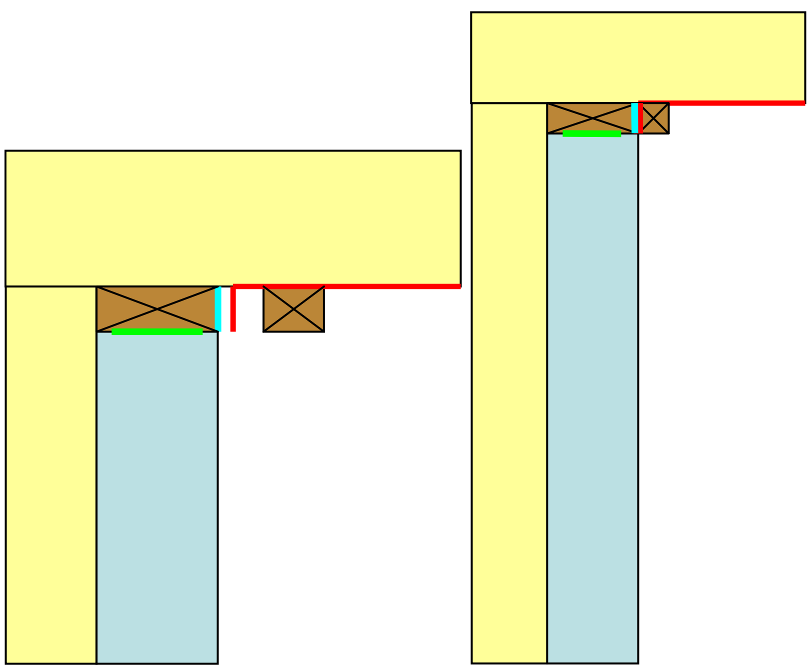


Figur X. Lätt yttervägg mot tungt mellanbjälklag. Plastfolien är kontinuerlig och förs förbi anslutningen.

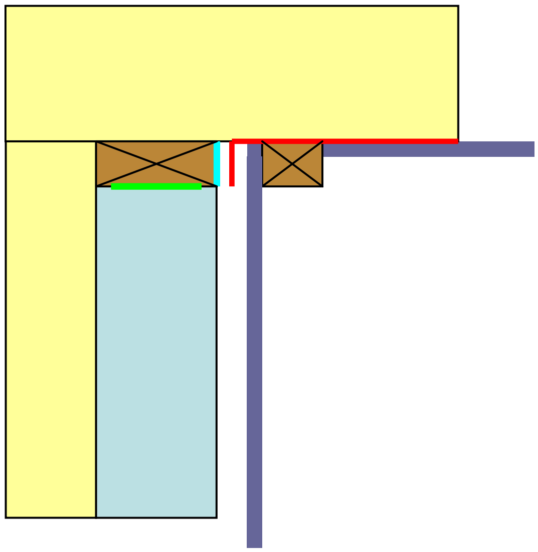
Figur 1 Exempel på lufttät anslutning mot golvkonstruktion. Plastfolien går bakom installationsskiktet, under plåtregel (som har pålimmad flexibel syllisolering) och därefter fogas plastfolien mot betongen.



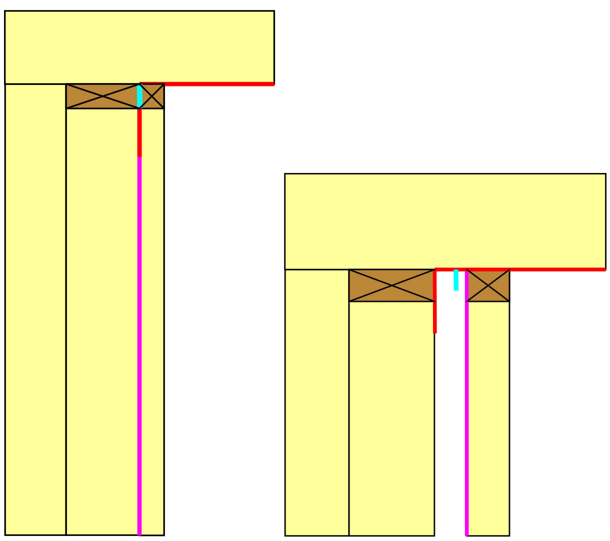
Figur X. Anslutning lätt yttervägg mot bottenbjälklag av betong. Plastfolien kläms mellan syll och regel. Grönt- gummilist. Vid klämning krävs att reglarna är helt raka och inte krymper, därför ansluts plastfolien även emot gummilisten.



Figur 2 Tung yttervägg mot lätt bjälklag. Bjälklagets tätskikt klistras mot regel med butylband. Mellan betongvägg och regel finns en flexibel tätning såsom gummi eller extruderad polystyren. (Höger del är förstoring där mellanrummen bara är till för att förtydliga var tätningarna finns.)



Figur 3 Som Figur 2 men med elinstallation. Den styva bärläkten delas för att lämna utrymme för elinstallationen (lila) i hörnet. Installationen går här inte igenom det lufttäta skiktet



Figur 4 Anslutning lätt yttervägg mot lätt mellanbjälklag. Röd- takets plastfolie, rosa- väggens plastfolie, turkos- butylband. (Höger del är förstoring.)

ADDITIONAL MEASURES TO INCREASE AIRTIGHTNESS PERFORMANCE.

In addition to construction details, other valuable knowledge has been gathered in the project.

First, when designing the building envelope, it is important to identify where the air barrier is. This is important, in particular when it comes to connections between components. Questions to be answered are: where is the air barrier, how are the materials put together and where should the joints be?

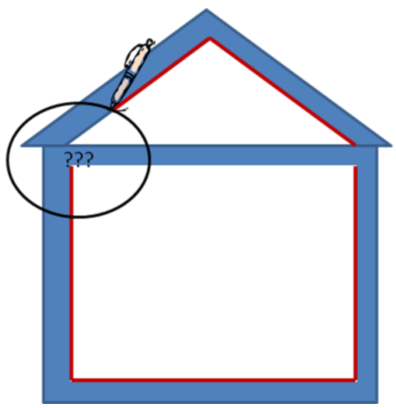


Figure X. Identify the continous air barrier.

Secondly, describe the connections and joints. Unusual or difficult details deserve extra attention. Examine the design. Are there any difficult details? Can they be made easier?

Thirdly, raising the awareness of airtightness issues during the construction phase is essential for a good airtightness. Information and education can be given in many different ways. When visiting building sites/projects where the airtightness was good, many different ways of communicating information and education were presented.

One project had an ambitious program that started with a demonstration building. In this first building, different wall constructions were built and examined in order to choose the best wall with respect to energy, airtightness and workmanship and courses for the construction workers were held. Each worker attended courses for 1.5 days in total. They also aimed at having the same workers for all the buildings in the project. The airtightness was tested with the Fan Pressurization Method in each apartment in this project. One person was responsible for the pressurization tests but each construction worker attended at least one test, which also included searching for air leakages.

Another project sent a number of construction workers, team leaders and project managers (snickare, projektledare och platschef) on a course where they built a test wall (mock-up?) that included a window. The construction workers that had participated were later responsible for the air barrier work and also took part in Fan Pressurization Tests.

Information transfer can also be in the form of excursions to good and airtight projects, or lectures by construction workers who have previous experience from building airtight houses. An important part of education when it comes to airtightness, is knowledge feedback (kunskapsåterföring?). The designer can visit the building site when the building is more or less finished and get feedback on the workability of the designs and of air leakage data. There is a large diversity in the level of knowledge on airtightness. Therefore, knowledge transfer (written or oral) to and within different groups that take part in a building project is of great importance.

A fourth measure to improve airtightness is to perform air leakage search (as previously described), to measure the air permeability and to have an airtightness demand. When air leakage search is performed continuously during a building project (for example for each apartment), new knowledge is gained each time and improvements in the construction and in work methods can be made.

FUTURE WORK

This work is continued in two parts. One part concerns the durability of the airtightness. The aim is to show how the airtightness changes in time and to show good and durable details and constructions.

Utvärderingen av består av tre delar: 1. Inventering av täthetslösningar, 2. Utvärdering av täthetslösningar där de ingående materialens åldringsegenskaper är kända, 3. Provning i laboratorium av material och materialkombinationer med avseende på åldring,

4. Täthetsprovningar på byggnader som tidigare täthetsprovats och dokumenterats.

1. En inventering av vilka täthetslösningar som skall undersökas görs. Både vanliga täthetslösningar och täthetslösningar som används i byggnader där tätheten prioriterats (t.ex. passivhus) undersöks. Inventering görs genom intervjuer med täthetsprovare/projektörer/konstruktörer/entreprenörer, ritningsgranskning, byggplatsbesök och litteratursökning. Vid behov av provning utreds provmetod för de olika täthetslösningarna.

2. Utvärdering av täthetslösningar. Först utvärderas och beskrivs de täthetslösningar det är känt hur materialen åldras i kontakt med varandra (t.ex. skadas vissa plastmaterial av alkali i betong). Befintliga provningsresultat sammanställs.

3. Provning i laboratorium av material och materialkombinationer med avseende på åldring. För exempelvis skarvmaterial för flexibla material (såsom skarvmassa och tejp) används SP-metod 1380. Olika materialkombinationer kräver olika typ av åldring. Åldring kan åstadkommas med exempelvis värme, fukt eller alkali (material i kontakt med betong). Utvärdering av lufttätheten efter åldring utförs med t.ex. dragprov, styvhetsmätning, eller tryckprovning (dvs luftläckageprovning).

Another part concerns the Quality Assurance program for the air barrier. The Projektets målsättning är att utveckla en generell metod för byggande av lufttäta byggnader som omfattar kravformulering, projektering och produktion (ByggaL). Metoden bygger på att kvalitén säkerställs genom att arbetet löpande dokumenteras, kommuniceras, kontrolleras och verifieras med hjälp av kvalitetsstyrande rutiner och tillhörande checklistor. Checklistorna är ett medel att föra ut den kunskap som förvärvats i tidigare SBUF-finansierade projekt i praktisk användning.

ByggaF som tidigare utvecklats inom SBUF kommer att utgöra mall för struktur och upplägg av metoden ByggaL.

Syftet är att metoden ByggaL skall hjälpa byggsektorns aktörer, framförallt entreprenadföretag, att säkerställa att byggnaden uppfyller de funktionskrav som definierats. Med väl formulerade funktionskrav och en kvalitetssäkrad byggprocess så ges mycket goda förutsättningar för att byggnaden blir lufttät.

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