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# Building Physics for Light-Gauge Construction

## Physique du bâtiment pour la construction légère

## Bauphysik für den Leichtbau

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**SUMMARY**

This presentation introduces the main topics within the field of Building Physics. The transport of heat, moisture and air in the building envelope and its performance is discussed. The basic considerations for a proper Building Physics design are pointed out. Reference is made to light-gauge metal construction.

**RÉSUMÉ**

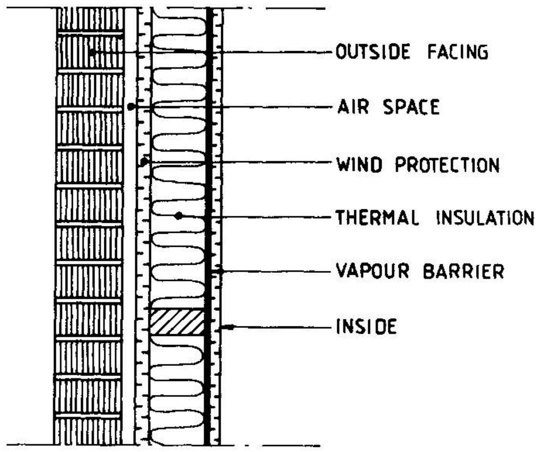
Cette contribution consiste en une brève introduction aux principaux sujets traités dans le domaine de la physique du bâtiment. Il y est question du transfert de chaleur, d'humidité et d'air dans l'enveloppe d'un bâtiment ainsi que des considérations de base pour une conception adéquate relatives à ces sujets. Des exemples propres à la construction légère en acier y sont mentionnés.

**ZUSAMMENFASSUNG**

Dieser Beitrag gibt eine Einführung in die Hauptgebiete der Bauphysik. Der Transport von Wärme, Feuchtigkeit und Luft in den Bauteilen und die Funktion der Aussenkonstruktion werden besprochen. Grundsätzliche Überlegungen für einen guten bauphysikalischen Entwurf werden aufgezeigt und Beispiele von Metall-Leichtbaukonstruktionen gegeben.

## Introduction

In Building Physics primary areas deal with the transport of heat, moisture and air in and around a building. Deficiencies in these areas can explain a number of the building damages known in many countries. Civil engineers often make advanced static calculations but treat the basic aspects of building physics in an inadequate manner.




The building envelope is primarily intended to give such conditions that a good indoor climate can be established, both for the use of the building and for the building materials and their durability. The requirements on the building envelope are clearly illustrated by the requirements on the different parts in a wall or a roof structure.

In a multi-layer structure the different parts have their specialized functions. The normal stud wall wall is an example of this (Figure 1).

Figure 1

1. The outside layer protects against rain and direct wind.

2. The air space gives a possibility of ventilating or draining out moisture.

3. A wind protection layer protects the thermal insulation from air movements from the outside.

4. The thermal insulation gives the structure its main thermal resistance.

5. The vapour barrier protects against moisture transport through the wall and also gives it its main air tightness.

6. On the inside of the wall a board is mounted to give the surface its required performance. This will generally increase the air tightness of the wall.

In a roof structure the corresponding functions will be found. In this case the roof covering will protect against rain and direct wind.

The above described situation is also true for a light-gauge construction. With this in mind the well known stud wall will be used as example in some of the following.

## Basics of building physics

The transport of heat, air and moisture that takes place in the building envelope will influence its performance. In general this can be illustrated as a flow depending upon a difference in potential and a transport coefficient for the material or the structural part and its area, i.e:

$$Q = k \cdot A \cdot \Delta p$$

The flow, Q, can be volume flow of air or moisture or the flow of energy. $\Delta p$ can be the difference in air pressure, vapour concentration, moisture content of material or temperature. The transport coefficient, k, can be permeability, vapour transmission coefficient or thermal conductance.

For the evaluation of the performance of the envelope other factors have to be considered as well. Such factors are the capability to store heat or moisture for a certain time. For the overall evaluation knowledge is also required about how air, moisture and heat are supplied to or taken away from the building or a part of the building.

## Heat transfer

The heat transfer through the building envelope can be described by

$$Q = \frac{1}{R} \cdot A \cdot \Delta\vartheta$$

where Q (W) is the heat flow through the area, A ($m^2$) at a temperature difference of $\Delta\vartheta$ (K).

The total thermal resistance of the strucutre (R) depends on the thermal insulation material used and on design details such as the presence of thermal bridges. These factors can be included in the calculation of the thermal resistance.

For a light-gauge construction the thermal bridges are of special importance due to the high thermal conductivity of metals. This will lead to increase in heat transfer and also increase the risk of condensation on cold surfaces in the structure.

The thermal bridges of interest in an insulated light-gauge structure are load-carrying studs and distance elements of metal as well as lead-throughs and fasteners through thermal insulation and surface layers.

The extreme difference in thermal conductivity between metals and thermal insulation makes it possible to evaluate the influence from a thermal bridge by calculating the thermal resistance in a number of separate heat transfer paths taking into consideration in what areas interaction between thermal insulation and the metal is the most dominant.

Ideally installed thermal insulation normally leads to a wellknown thermal resistance or U-value. In practice deviations from this are common.

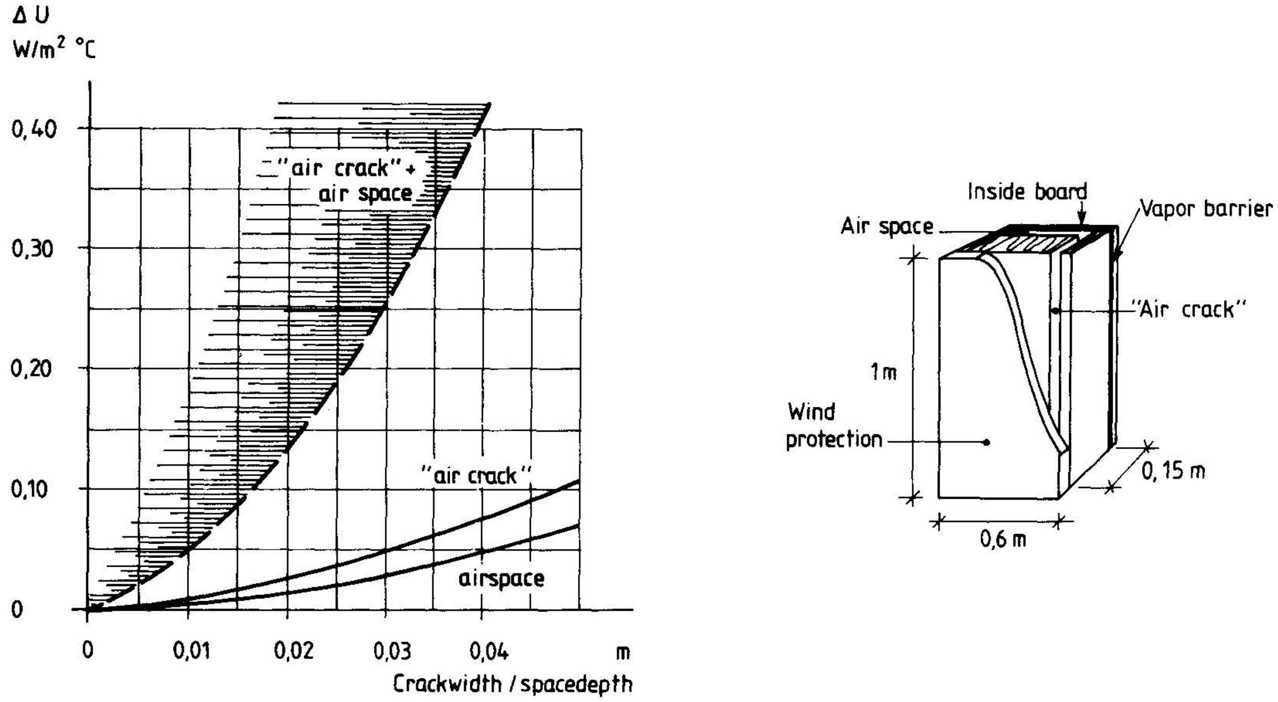



Figure 2

Deficiencies in the installation can often be attributed to the insulation not completely filling the space to be insulated. Cracks or air spaces may occur around the thermal insulation. Consequences of this is illustrated in figure 2 as increase in U-value for part of a wall where the insulation thickness is intended to be 0,15 m, giving a nominal U-value of 0,25 $W/m^2 {}^oC$.

The situation giving the largest, and most difficult to assess, increase in U-value is a combination of cracks and spaces around the thermal insulation. These difficulties will be more serious as the nominal thermal resistance of the structure is increased. Even small openings will degrade the thermal performance. Also the possibilities of air flow and its consequences on the thermal performance will depend upon workmanship for vapour barrier, joints and wind protection.

The thermal performance found in practice in a structure will be decisively influenced by workmanship and the airflow situation.

This is especially true for a structure with crossbars with high thermal conductance.

## Air movements

Air movements in a material or a structure may influence its functions. Because of this the permeability of the materials and the structural parts are of importance when evaluating the performance of the building envelope.

The air flow G ($m^3/s$) through a material depends on the pressure difference $\Delta p$ (Pa), over the material, its area A ($m^2$), thickness d (m) and permeability $B_o$ ($m^2$), i.e:

$$G = \frac{B_o}{d} \cdot \frac{A}{\eta} \cdot \Delta p$$

$\eta$ ($Ns/m^2$) is the viscosity of air. For a board or a a sheet its permeance B (m) is often used instead of $B_o/d$.

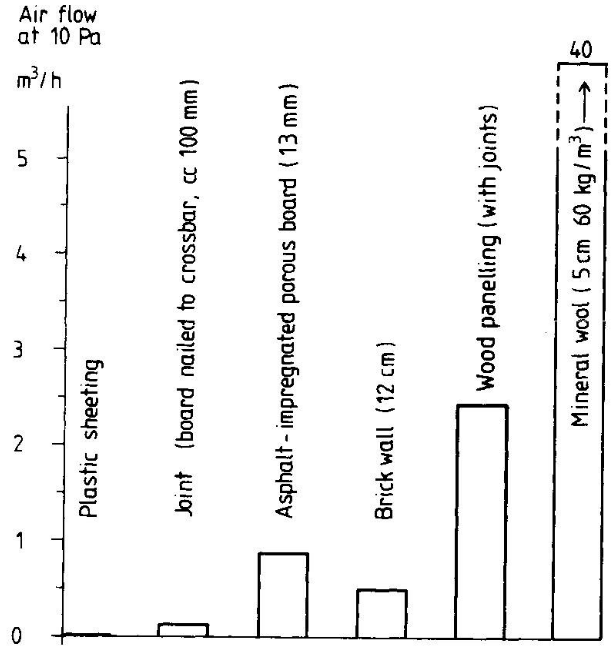



Figure 3 shows how a pressure difference will influence the air flow through different structural parts. The least permeable materials like plastic sheetings are used for the vapour barrier, the main air tightness layer in the building envelope.

Figure 3

Wind acting on a building envelope will lead to pressure differences and air flow in and around the structure. The actual situation will depend on wind velocity, building design, proximity to other buildings etc. Stack effect and mechanical ventilation will influence the pressure situation as well.

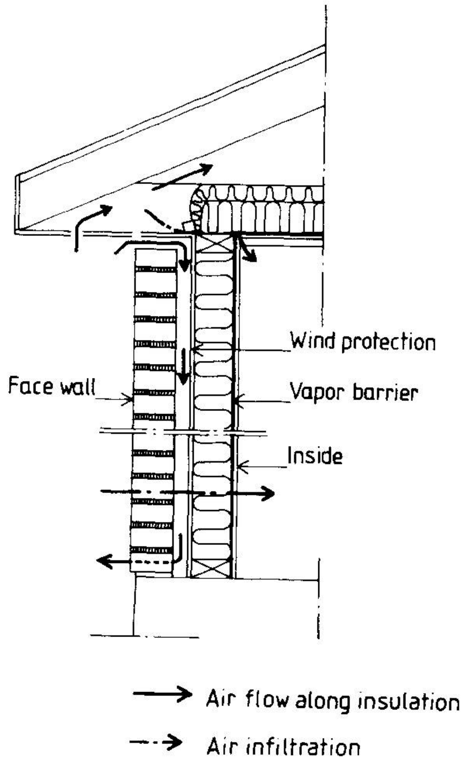
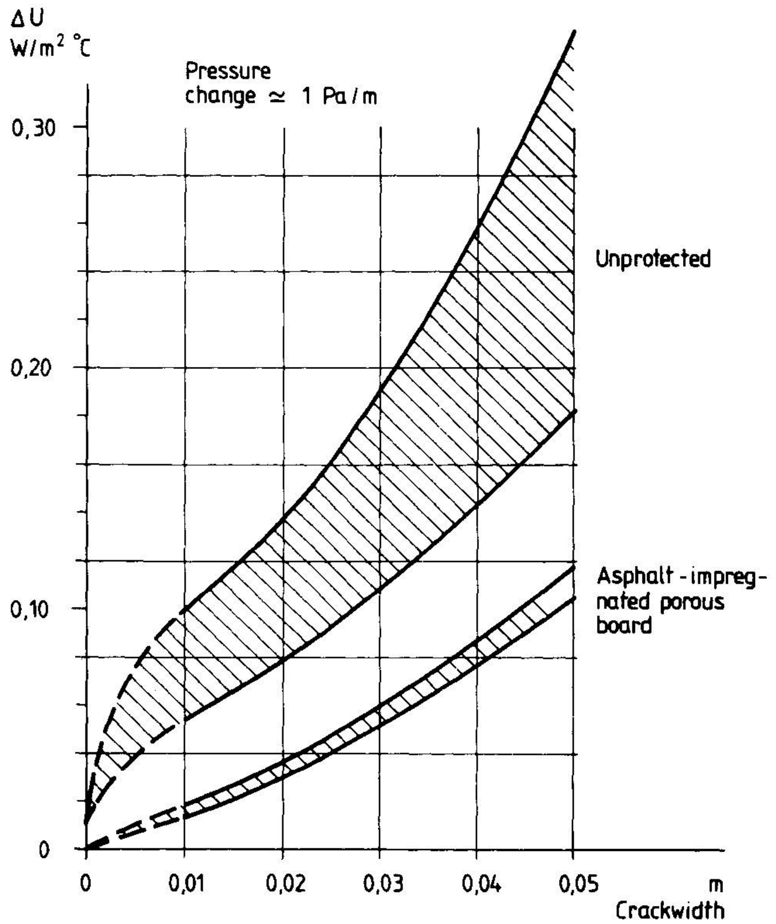



Figure 4

The air movements may influence the building envelope in different ways (Figure 4). In some cases air movements will ventilate spaces intended to be ventilated for example behind the outer facing of a wall. If deficiencies are present in the structure air movements may affect parts of the insulation. To protect against air movements in the thermal insulation some kind of wind protection is often used. The wind protection is especially important for parts of a building where pressure changes are large such as at corners, at eaves etc.

Another situation where wind protection is of great importance is when the installation of the insulation is deficient. This is illustrated in Figure 5, showing measurements on the wall section in figure 2.




The figure shows the increase in U-value at a pressure change of 1 Pa/m in the air space along the insulation when wind protection or no wind protection is used and when there is an insulation deficiency in the form of a crack in the insulated space.

For the unprotected thermal insulation with installation deficiencies the effects are very large. The figure shows the importance of good workmanship both for installation of thermal insulation and for application of wind protection.

Figure 5

In other cases air may infiltrate through the building envelope. In many cases this is necessary for the normal ventilation of the building. In modern designs this air leakage means an unwanted increase of the heat loss from the building.

The airtightness of a multilayer structure is usually designed into the structure by use of a vapour barrier and by specially designed joints between different materials and building elements. If unwanted air infiltration is to be avoided it is necessary that these measures be well designed and realized by good workmanship.

Defects in the air tightness layer, i.e usually the vapour barrier and the inside sheeting, will lead to an increase in air flow through the building envelope. This air flow is also of importance for the transportation of moisture through the building envelope. As a matter of fact this is one of the major factors when evaluating the moisture situation in the building structure.

## Moisture

One of the most important objectives of the building envelope is to protect against rain and moisture. At the same time the structure shall be designed in such a way that i does not deteriorate due to the moisture sitaution in the materials.

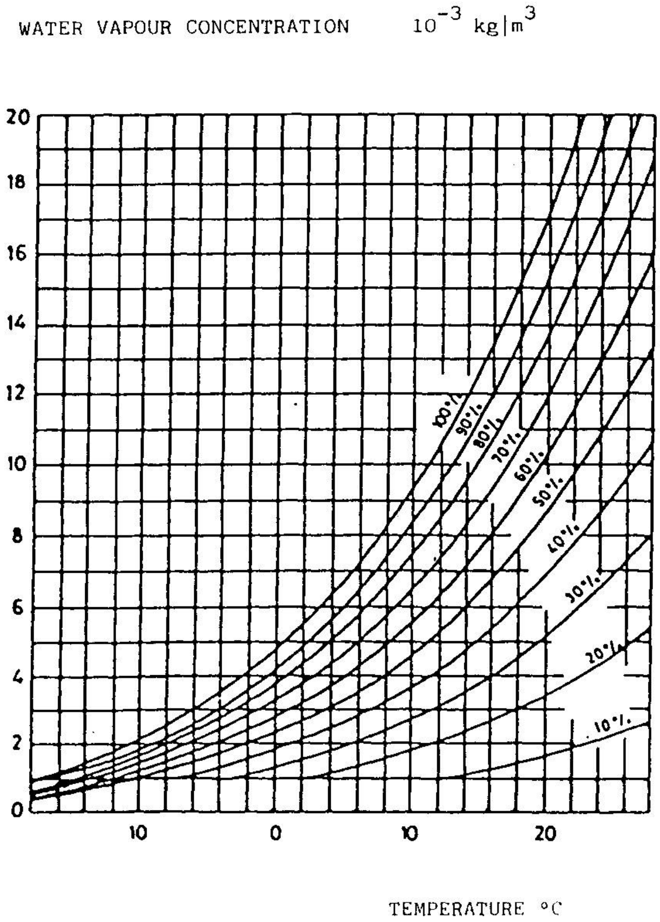
The building envelope can generally be influenced by moisture from different areas at the same time. Such areas are driving rain, moisture in the air, building moisture, water in and on the ground. Often one of these factors is the dominant one.

Building moisture is generally considered the amount of moisture that has to be dried out in order to reach an equilibrium between the material or the building part and the surrounding climate. This initial moisture content can vary depending on the material but also on how it was treated before it was installed in the building. The driving rain on the outside of a building can vary both depending upon the climatic situation of the area in question and upon the air flow pattern at the outside.

Moisture can be supplied to a building element through precipitation, through condensation of water vapour from the air, through absorbing ground moisture or through leakage. In addition most materials in contact with humid air will absorb a larger or smaller quantity of water (hygroscopic moisture).

The moisture condition of the building is determined by climatic conditions, by the structural design and by the materials included in the building. In order to design a building structure correctly and to be able to judge the cause of possible damage, it is necessary to have knowledge of moisture and moisture transport.

The water vapour concentration in the air is usually specified as the weight of the water per unit volume v ($kg/m^3$). An alternative method of describing the dampness of the air is to specify the partial pressure p (Pa) of the water vapour.




At a given temperature the air can not contain more than a certain volume of water vapour, the vapour concentration at saturation point. The saturation value $v_s$ (kg/m$^3$) is strongly temperature dependent. This is shown in figure 6. The relative vapour concentration (relative humidity, RH, %) is the ratio between the actual vapour concentration and the vapour concentration at the saturation point.

Figure 6

The indoor humidity is determined by the temperature and relative humidity of the outdoor air, temperature of the indoor air, moisture supplied indoors and the ventilation rate. Winter conditions are often the most interesting. Cold winter air outdoors often has a high relative humidity but since the vapour concentration at saturation point is low the vapour concentration is also low. Through ventilation such air enters the building and is heated to the temperature of the indoor air. Additional moisture may be added due to evaporation from people, washing, cooking etc. This moisture production creates a fairly constant difference between indoor and outdoor vapour concentration. For industrial premises however with "wet" manufacturing conditions more careful examinations must be carried out in order to determine the supply of moisture.

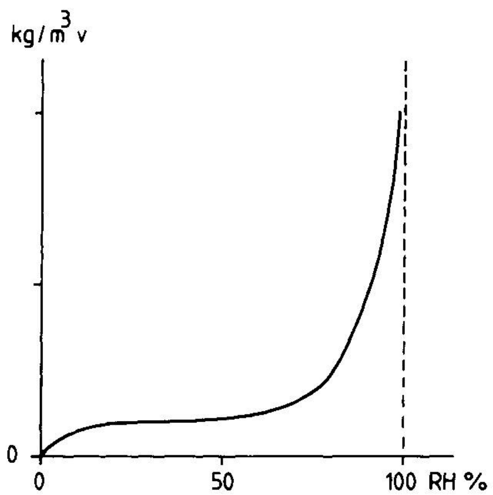


Figure 7

If a material is placed in an environment with a certain relative humidity the moist air will penetrate the pores of the material. A certain amount of moisture in the material will correspond to a certain ambient relative humidity. The state of equilibrium is called hygroscopic moisture content. An example of this is shown in figure 7.

The relationship shown is called a sorption curve. The sorption curves are different for different materials. They will also differ during dampening and drying but are as a rule fairly independent of temperature.

Materials with a wide moisture variation at varying relative humidities are said to be hygroscopic. Materials with little moisture variation are non-hygroscopic. Examples of the first type are concrete and wood of the other type cellular plastic and mineral wool.

To be able to evaluate the moisture situation in the structure the transport of moisture is of importance. Moisture can be transported both in vapour and in liquid phases. The moisture and temperature condition of the material as well as the structure of the material are of importance to moisture transport. Diffusion, convection or capillary suction dominate in ordinary cases.

Diffusion is a transport based on the efforts of a gas mixture to reduce local differences in vapour concentration. Diffusion is damped in a porous material and the vapour transport can be described as

$$g = \delta \cdot \frac{dv}{dx}$$

where g is the moisture flow ($kg/m^2 \cdot s$) and $\delta$ the vapour permeability ($m^2/s$).

At a difference in total pressure on either side of a structure air can flow through holes in the structure and carry moisture with it. If moist inside air is transported through the building envelope to its outer parts with lower temperatures there may be a risk for condensation.

In a house with natural ventilation a pressure difference is normally obtained if there is a temperature difference between indoor and outdoor air. The pressure difference will vary with the height of the house. Positive pressure will then be obtained in the top story and at the roof and indoor air can leak out through the envelope. It is therefore more common to find damp air flowing out of the upper part of a house and this is also where moisture damage on acount of convection will be found.

The amount of moisture transported by convection can easily be evaluated from the water vapour concentration in air and the volume flow of air. Diffusion of moisture is as a rule a slow process and the diffused amounts of moisture are often small. The amount of moisture transport through moisture convection can be appreciably larger particulary if cracks or other leaks occur. A situation with moisture convection against cold surfaces and condensation may well be disastrous for the structure.

Light-gauge wall construction

An insulated light-gauge wall construction is shown in figure 8. This type is used in heated industrial buildings.

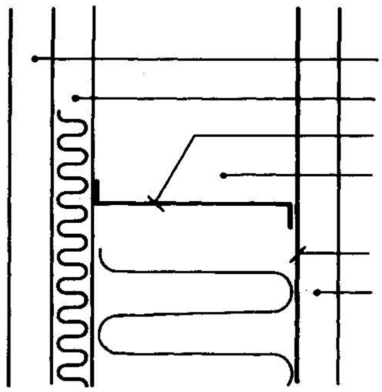



Figure 8

The wall is made of metal sheetings on steel studs, insulated with mineral wool with a vapour barrier on the inside and wind protection on the outside. In order to avoid cold bridges some kind of break in the cold bridge is necessary. Some of this can be supplied by the wind protection, which simultaneously protects the thermal insulation from air movements behind the outside sheeting. If the wall is made airtight by the use of a vapour barrier, for example a plastic foil on the inside of the insulation, there is no risk of condensation due to diffusion or moisture convection. It is also assumed that the outdoor sheeting is ventilated. Difficulties may arise when joining this wall airtight to e.g a roof. The plastic foil in the wall should join the vapour barrier in the roof with substantial overlap. It is also necessary to achieve an acceptable thermal resistance. By this it is also avoided that the surface temperatures locally on the inside of the wall will become so low that surface condensation may arise.

## Building physics in light-gauge construction

In designing a light-gauge structure a number of factors should be considered for good building physics performance. These factors should also be evaluated on the basis of the climate in question. A cold storage warehouse is different from a conventional industrial building. Design for a cold climate is different from design for a warm climate. Especially the following points should be observed.

- Built in moisture shall be dried out in an acceptable time period

- Precipitation shall not be able to enter the structure

- Airtightness is required to avoid moisture convection and condensation

- A vapour barrier shall be installed so close to the warm surface that the relative humidity at the vapour barrier is acceptably low

- Ventilation is required in order to ventilate out moisture that has entered the structure

- Cold bridges that on the cold side may lead to melting of snow and on the warm side lead to surface condensation should be reduced

- Thermal performance of the envelope will depend upon good workmanship when installing the insulation.

In order to protect from air movements a wind protection and an airtight layer in the structure are of importance.

## References

1.BANKVALL, C.G, Thermal performance of the building envelope as influenced by workmanship, ASTM-STP, Thermal Insulation, Materials and Systems 1986

2.BANKVALL, C.G, Air movements and the thermal performance of the building envelope, ASTM-STP, Thermal Insulation, Materials and Systems, 1986

3.NEVANDER, L E, ELMARSSON, B, Fukthandbok, Stockholm, 1981

4.NORDTEST, Field investigations of moisture problems in buildings, NT TECHN REPORT 041, 1984

5.JOHANNESSON, G, ÅBERG, O, Köldbryggor i plåtkonstruktioner, Lund institute of technology, Lund, 1981

6.KRONVALL, J, Air flows in building components, Lund Institute of technology, Report TVBH-1002, Lund 1980

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