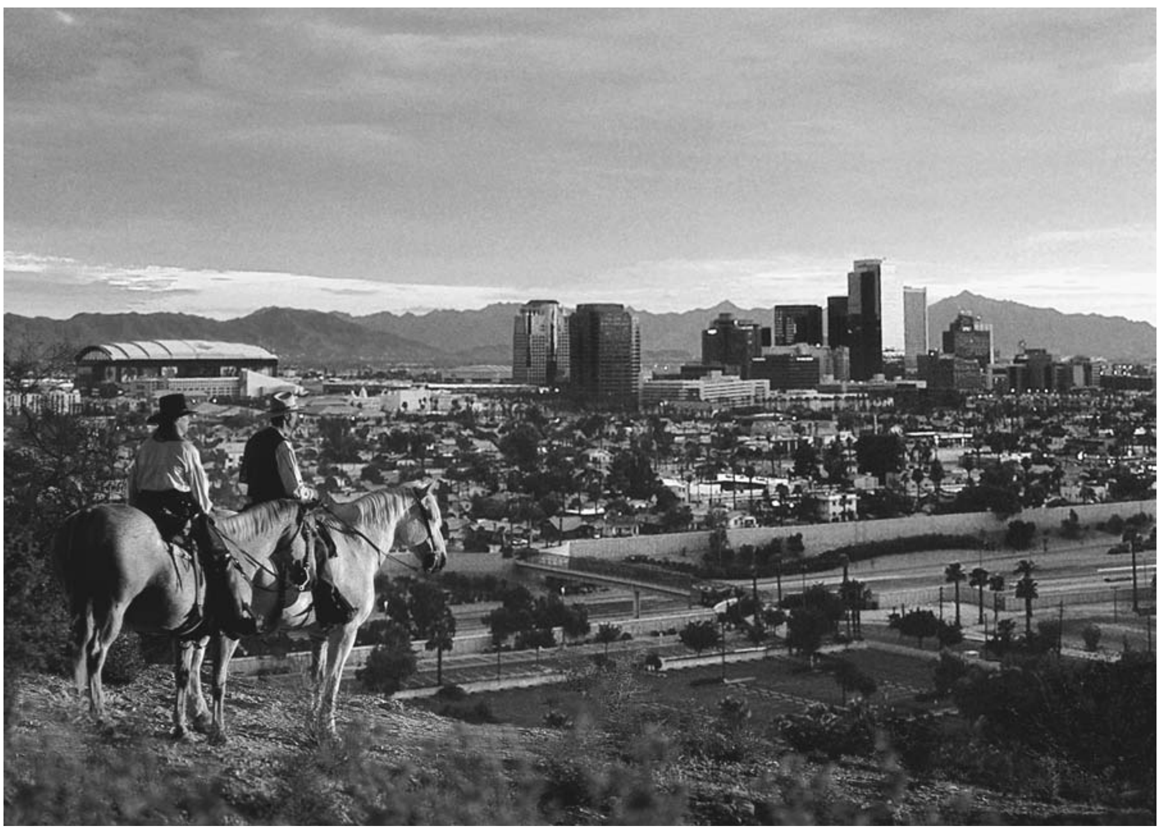
Mold in Building Constructions in the Nordic Countries – With Emphasis on Roofs

Erik Brandt
Danish Building Research Institute (SBI)
Tommy Bunch-Nielsen
Danish Roofing Advisory Board (TOR)



Roof Consultants Institute

ABSTRACT

For the last 12 -15 years, mold growth in building constructions has been considered, more and more, to be a severe problem in the Nordic countries.

This paper gives a brief introduction to mold growth in general and the types of problems seen in different parts of buildings under Nordic weather conditions. Emphasis is given to mold growth seen in roof constructions.

Examples are given to demonstrate the different failure mechanisms. These include problems seen in ventilated roofs with "sub-cooling" of inner surfaces due to increased thickness of insulation, and problems with unventilated roofs constructions with so called "intelligent" vapor retarders (e.g. Hygrodiode), leading to increased moisture content of wood if not exposed to sunshine. Finally, examples are given on more basic mistakes, such as vapor barriers not being airtight and lack of sealing joints between roof elements after assembling and condensation during the building process – all leading to increased moisture content, and, eventually, mold growth.
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SPEAKER

ERIK BRANDT is with the Danish Building Research Institute (SBI), Hoersholm, Denmark. He is a member of CIB and RILEM, and is involved with ASTM standard development.

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INTRODUCTION

During the last 12-15 years, more and more attention has been paid to mold growth in all the Nordic countries, as it has been recognised that it might cause significant health problems. During the same period, large amounts of money have been spent for remediation. A number of severe cases have been caused by lack of maintenance, especially regarding roofs. The consequences have often been very costly, requiring repairs or even replacement of entire roofs. However, problems are not restricted to roofs but are seen in many different constructions, such as crawl spaces, bathrooms, façades, basements, etc.

A prerequisite for mold growth is humidity in the environment; consequently, it is often seen where construction is plagued by problems with water penetration or high humidity. Most mold species require more than 70% relative humidity to grow.

The main reasons for mold growth are rising damp condensation inside a building, built-in moisture (i.e., moisture from the building process), constructions that are changed/insulated without paying attention to the risks of jeopardizing the ventilation, etc. Also the behavior of the user might in some cases cause problems, e.g., due to lack of ventilation or the drying of clothes in closed spaces.

Finally, mold growth is seen after accidents, e.g., pipe breakage or fire, where constructions are soaked and if not dried very fast, are vulnerable to attack.

Renovation after mold growth is very costly as it often requires major repair to get rid of the mold.

TYPICAL CONSTRUCTIONS PLAGUED BY MOLD GROWTH

A few examples of mold growth in constructions are given here, with typical reasons for the problems. Mold growth in roof construction is dealt with separately later in the paper.

Facades

Most often, attack of mold is seen in lightweight facades, i.e., ventilated facades with board materials – especially gypsum board – and an outer skin of metal or natural stone. For such a façade to function properly, it is a prerequisite that any water penetrating to the ventilated cavity must be drained out again. Problems typically occur where the drainage is insufficient or where the wind barrier is not protected from direct (driving) rain.

Figure 1 – Example of a ventilated façade with mold growth on the wind barrier (made by gypsum boards). Often mold growth in façades is due to water penetrating behind the cladding without being drained out (fast enough).

Lightweight bathrooms

For the past 30+ years, so-called lightweight bathrooms have been used quite extensively, as they are cheap, easy to install, and without built-in water. Most of these constructions are made from board materials, e.g., gypsum boards, calcium silicate boards, or plywood. In order to perform satisfactorily, the must be protected by a watertight membrane.

Mold growth in lightweight bathrooms is most often seen where a watertight membrane is either missing or is not made properly. Problems are often seen at details like joints between wall and floor and pipe penetrations. Any leaks in bathrooms provide excellent growing conditions, with favorable temperature and humidity for mold growth, and might eventually be followed by fungi and dry rot.

Crawl spaces

Ventilated crawl spaces have been used extensively in the Nordic countries for many years and have been considered to be very safe constructions. However, problems with old crawl spaces are increasing due to mold growth.

Old crawl spaces are usually not well insulated and the users therefore apply additional insulation in order to save energy and to increase the thermal comfort. Additional insulation will quite often block – totally or partly – the ventilation openings to the crawl space. Such insulation work leads to increased humidity in the crawl space, partly due to the blocked ventilation that jeopardizes removal of moist air, partly due to the lower temperature – resulting in increased RH resulting from the insulation.

Crawl spaces often rely on a fine equilibrium between humidity supplied from the environment and humidity removed by ventilation. So, even small changes might change the equilibrium in an unfavorable direction. Increased humidity leads almost inevitably to growth of mold and, in severe cases, to deterioration of the wood. The failures are most often due to difficulties analyzing the complex changes in temperature and humidity occurring when a crawl space is insulated and/or the ventilation gaps are partly blocked.

Figure 3 – Roof element in a new school with massive mold growth. The roof elements are prefabricated and meant to be sealed immediately after assembling. Lack of sealing, however, leads to penetration of water and eventually mold growth. The renovation included opening of the prefabricated elements, removal of insulation, and cleaning of the wooden surfaces in the elements. Afterwards, the elements were restored with new insulation and vapor barrier.

MOLD PROBLEMS IN ROOFS

During the last 30 years, many changes regarding roofs have occurred in Denmark. Some of these are due to still more strict energy saving measures now calling for the use of about 300 mm insulation in a roof construction. This naturally makes the outer part of the roofs very cold in winter, increasing the risk of condensation. Besides, new building components and materials have been introduced in flat as well as in sloped roofs, resulting in a number of problems. Typical examples are described below.

Figure 2 – Severe attack of mold on the backside of a gypsum board partition in a bathroom due to lack of a watertight membrane (the wall was tiled directly on the gypsum board).

The main reasons for mold growth in roofs are:

1. Built-in moisture in roof elements/components and wooden materials.
2. Condensation due to leaking vapor barrier and/or inefficient ventilation.
3. Condensation in the construction period due to drying out of the building before installing the vapor barrier.
4. Moisture accumulation in roof elements with "intelligent" vapor retarders.
5. Sub-cooling of surfaces inside roofs due to radiation to the sky.
6. Leaking roof coverings.

1. Built-in moisture in roof elements/components and wooden materials

Quite a few of the mold problems in roofs are due to built-in moisture; i.e., moisture coming from moist materials or from rain during the building process.

In some cases, materials or components for the roof are stored on the building site where it might be soaked if not properly protected. Other problems have been seen with materials left wrapped in plastic. When the sun shines, moisture is released from the wood. When it cools down again, the moisture condensates on the plastic, leading to mold growth during the storing period. For roof elements assembled on-site, the major reason for failure is lack of sealing the joints between elements immediately after assembling.

Some constructions are capable of drying out moisture, but quite often, materials are too wet to dry out fast enough to avoid mold growth.

2. Condensation due to leaking vapor barrier and/or inefficient ventilation

Problems with leaking vapor barriers are seen on flat as well as on sloped roofs. This is an example of a technical problem with an easy and well-known solution: namely, introduction of a decent airtight vapor barrier (if necessary) and use of existing directions on how to design the roofs.

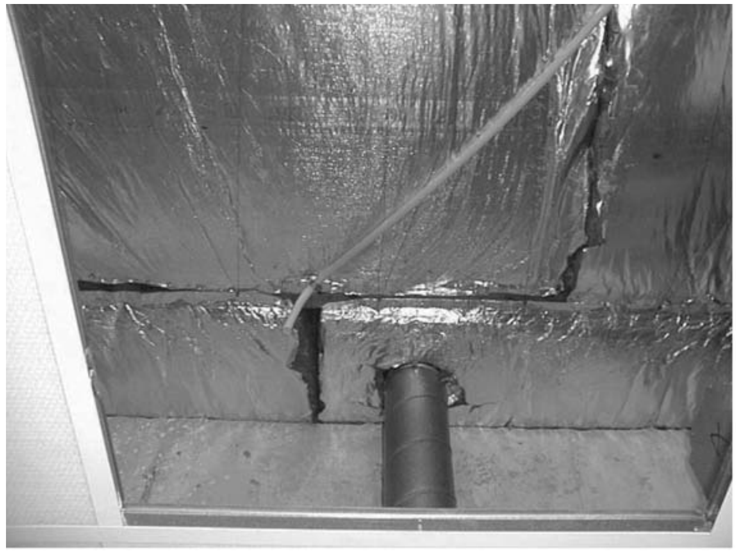

Figure 5 – Vapor barrier with leaks at joints and pipe penetration in a school. The entire school was built in the same way. The consequence was that there was massive mold growth in all roofs and that a major renovation was necessary to remove the mold.

For sloped roofs, problems have increased with unventilated constructions, which have a growing market in the Nordic countries. These constructions rely on the ability of vapor-permeable roof tile underlays (sarking felt) to remove moisture coming from the interior of the building. Two conditions must be fulfilled for such a roof to perform satisfactorily:

Figure 4 – Mold growth and deterioration of plywood in a sloped roof made from wood-based elements assembled in situ. Due to leaks in the interior joints between elements in the corners - and consequently also leaks in the vapor barrier – humid air has penetrated into the construction, where it condensates on the cold surfaces above the insulation.

1. The roof tile underlay must be very open to water vapor - and at the same time watertight!
2. The vapor barrier must be made airtight. Note that the resistance to vapor transmission is less important as the major transport mechanism is convection of moisture through leaks in the vapor barrier (a factor of 1:100 between moisture transported by diffusion and convection is not unusual)

3. Condensation in the construction period due to drying out of the building before installing the vapor barrier

In some cases, the vapor barrier is not installed until very late in the building process, i.e., after the entire roof construction has been completed. This allows for transportation of moisture into the roof. Especially in winter, the moisture might condensate when stopped by relatively vapor tight layers in the roof construction,

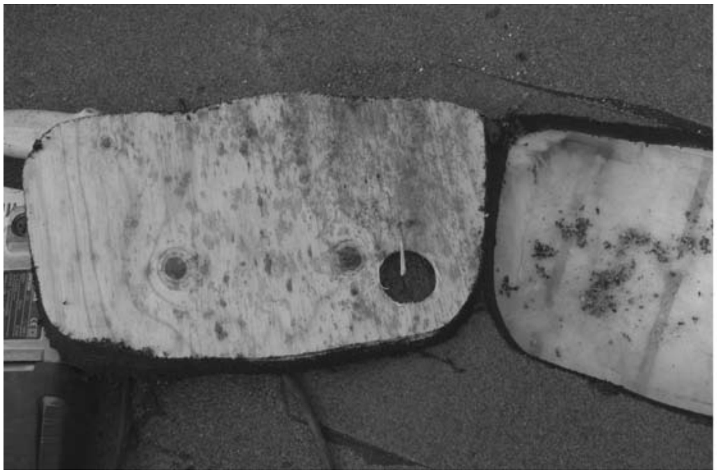

Figure 6 – Mold on plywood in roof element with Hygrodiode. This roof element was in the shade from a higher part of the building and consequently was not heated sufficiently to force the moisture down to the inner surface.

thereby leading to increased moisture content and risk of mold growth on vulnerable constructions.

The lesson to be learned from this is to install a proper vapor barrier as soon as possible in order to avoid moisture from entering the roof construction.

4. Moisture accumulation in roof elements with "intelligent" vapor retarders

The "intelligent" moisture retarder Hygrodiode has been used to a great extent in Denmark for the past 15+ years. Hygrodiode can function as a vapor retarder as well as allow transportation through the inner surface of the roof by capillary suction. Under winter conditions, small amounts of moisture will normally accumulate in the roof due to moisture transport from the interior of the building. Under summer conditions, the moisture will be forced down to the underside of the roof by the sun heating the roof surface. The Hygrodiode allows the moisture to be transported by capillary suction to the inner side of the roof, where it evaporates.

Several million square meters of roofs have been made with Hygrodiode – in most cases with good result.

However, it is necessary for a proper functioning that the moisture is actually driven down in the roof in summer time; i.e., it is dependent on the sun to get a decent temperature gradient over the roof. In practice, this means that the roof must not be in the shade, either from other buildings, or from roof coverings laid with a ventilation gap underneath.

A number of fairly large projects have been constructed without paying attention to the requirement for solar heating. The result has always been the same - in the shaded parts of the roof, the moisture will gradually build up to a level where mold (and eventually also fungus and dry rot) can grow.

Figure 7 – Mold growth on plywood substrate for roofing felt in a ventilated roof due to sub-cooling caused by radiation to the sky. Plywood is more vulnerable to mold growth than boards, probably due to the treatment during production.

5. Sub-cooling of surfaces inside roofs due to radiation to the sky

In ventilated roofs, the inner side of the roof is quite often boards or plywood. In recent years when still more insulation has been used, the inner side of the roof has become very cold (it receives almost no heating from the building). Radiation to the sky on clear nights might (under winter conditions) result in sub-cooling of the inner surface, bringing the temperature below the dew point where condensation will occur.

The condensation facilitates the growth of mold, and especially on plywood, the growth can be considerable. In Finland and Sweden, plywood for roofs is now treated with wood preservatives in order to avoid the problem.

6. Leaking roof coverings

Quite a few of the most severe cases of mold growth in buildings have been caused by leaking floor coverings. The reasons might be either that the leak(s) is not seen until the penetrating water has caused additional damage, or that maintenance is neglected. There have been some examples where maintenance meant buying more buckets to catch the water rather than repairing the roof!

No matter what the reason is, penetration of water to the interior of roof construction might cause considerable mold growth.

HOW CAN FAILURES BE AVOIDED?

The causes for failures are almost unending. The question to answer is how can this be changed and the number of failures reduced?

Quite a few of the failures are caused by not using existing knowledge. Considerable benefits should be easy to gain, as there are no technical problems. The key is more relevant information, addressed not only to specialists, but to the persons performing the work on the building site. It sounds like an easy task, but actually it is assessed to be very difficult. In Denmark, for example, a fair number of publications have been issued regarding good practice for roofing. This includes two-page information sheets about common failures, why they occur, how they can be avoided, and how failures can be fixed. Unfortunately even these short publications are mostly read by architects or engineers and not by the contractors or building owners who need it most. The reason is believed to be that these people are neither used to looking for information nor to reading technical language. To overcome this problem, it has in Denmark been discussed to write publications in everyday language and with many illustrative figures addressed directly to the workers.

Another big problem is the use of well-known materials and constructions in new ways. Many changes that at first appear to be minor turn out to lead to quite different conditions for the materials/constructions, e.g., with reduced ventilation increasing the risk of moisture accumulation, or reduced temperature increasing the risk of condensation in the construction. In both cases the result might be mold growth or even deterioration of organic materials in the construction. Changes in the use of materials should consequently always be assessed/analysed in order to verify that the working conditions are not affected in a negative way.

Finally, the introduction of new materials is quite often associated with failures. Not because the products are of bad quality but because their potential is overestimated - by marketing persons especially - or they are used incorrectly. This is actually a very different matter, as only one little mistake can lead to considerable failures. A prerequisite for the introduction of new materials without in-use experience is that the performance properties be documented and that the properties fit with the performance requirements for their use. Ideally, such information should be given by the manufacturer/supplier, but, unfortunately, information is often missing. It is proposed that manufacturers should not only give guidance on what the products can be used for, but should also provide information on limitations in their use. The supplier should also provide the information necessary to assess whether a product is suited for its intended purpose or not. Finally, the designers should be encouraged to ask for documentation - from independent institutes/bodies - and to make their own assessments prior to the use of unknown materials.

The tasks mentioned above are so large and difficult that they are best dealt with in cooperation between countries. Preferably, such work should be financially supported - especially when taking the huge amounts of money used on building failures into account. If this is not possible, sharing knowledge on a voluntary basis would at least be worthwhile.

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