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# Crawl Spaces in Arctic Climates

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## Abstract

Crawl spaces in concrete are the most common foundation method in the Arctic area, but from a moisture point of view this construction is very problematic and problems with mould growth are abundant.

The main problem is water penetration from rock at the bottom of the crawl space and from earth surrounding the building as well as inadequate ventilation of the crawlspace.

Crawl spaces are the most obvious foundation method in the Arctic area and can often not be avoided. The task is therefore to improve construction methods to make them function under Arctic conditions. The improvements involve drainage, mechanical ventilation, insulation and the right combination of materials.

This paper will point out the problems in the crawl space construction method and point out possible solutions.

## 1. Introduction

In most Arctic areas without permafrost the foundation of buildings is constructed directly on underlying rock. Due to high wind pressure in the Arctic area part of the walls in the building have to be constructed in concrete. This leads to cold bridging, and in some cases mould growth on the lower parts of the walls.



Figure 1: Typical apartment building with crawl space foundation

In practice a large number of inspections in crawl spaces in the Nuuk area have shown

significant problems with mould growth in the crawl spaces and in some cases so intense that they influence the indoor climate of the building through leaks in the concrete or wooden deck over the crawl space

Concrete crawl spaces cannot be avoided so we need to set up requirements for this part of the building leading to healthy buildings.

## 2. Water penetration

Water penetration in the crawl space often comes from the ground/rock under the building as the underlying rock is not water tight. Surface water is also a source of dampness in the crawl space, primarily due to lack of perimeter drains.

The bottom surface of the crawlspace is uneven and there are often large puddles .

The concrete walls around the crawlspace are often not water tight and surface water

from melting snow and rain may permeate into the space.

The bottom of the crawl space can contain soil that absorbs the water. The water in the soil will evaporate into the crawlspace.

The relative humidity in the crawl space is often 90 – 100 % most of the year, if no alternatives are introduced.



Figure 2: Pumping water from the bottom of a crawl space

### 2.1 Materials in the crawl space

Some materials are more sensitive to mould growth than others but concrete has normally a good resistance to mould growth due to its high pH value and mould growth will not start until approx. 90 % RH. The risk of mould growth will increase over time as the pH value decreases due to carbonisation of the concrete

Other materials such as wood and gypsum boards are much more sensitive to mould growth and the mould will start from approx. 75 % RH. These materials should therefore be avoided as decking over a crawlspace.

Mineral wool is normally used to insulate the underside of the flooring and the walls to prevent cold bridging. Fortunately mineral wool has a high resistance to mould growth and growth will not start until 90 % RH with temperature conditions that are likely to occur under Arctic conditions.

Material storage in damp crawl spaces such as cardboard boxes, furniture and textile materials is another problem. These materials have a very low resistance to mould growth and storage of such materials should be avoided.



Figure 3: Wooden structure in the crawl space and gypsum boarding on the underside of the flooring. These materials will easily lead to mould growth which was also the case in this building.

### 3. Climate in crawl spaces

The climate in a crawl space depends on many parameters:

- Water penetration
- Ventilation
- Floor and wall insulation
- Outside climate
- Cold bridges
- Services

If the insulation of the floor over the crawl space is poor, the temperature in the crawl space will be higher thereby reducing the relative humidity.

To save energy crawl spaces in the future will be insulated better than today and the problem with high relative humidity and mould growth will thus increase.

Heating the crawl space with heat transfer from the building cannot be used as a solution in the future and other means must be found. The reason for this is partly the

need for energy saving, and partly the comfort factor due to risk of cold flooring.

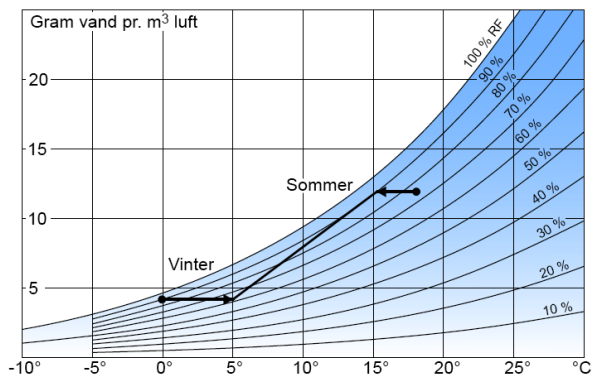


Figure 4: Water vapour diagram showing the effect of cooling (summer) and heating (winter) outside air penetrating into the crawl space.

#### 4. Mould growth

Mould growth is regularly recorded in crawl spaces, when the conditions in the crawl space allow it. The main parameters that have to be present for mould growth are:

- Organic material which supply nutrient for growth.
- Moisture content in most materials must be above 75% RH.
- Temperature between 5-30°C depending on mould type.

If one of these parameters are lacking, the growth will stop and the mould will form spores. The spores can survive frost and drought and will grow if the correct conditions re-occur.

The typical signs of mould growth are the musty smelling moist air and the discoloration of materials. The discoloration is often seen as a milky white layer on the surface of plywood and black or green spots on gypsum boarding or wooden beams.



Figure 5: A typical mix of white and black mould on the underside of plywood flooring in a crawl space.

It is often seen that the crawl space is filled with stored objects that do not belong in a crawl space. A major problem is remnants of building materials from construction work and all sorts of garbage strown around by workmen.

They provide good growth conditions for mould.



Figure 6: Typical organic objects left in a crawl space.

Mould growth is recorded on the surface of various materials in crawl spaces using for example the Mycometer®-surface test. The test divides the result into three categories (A, B and C) which explains the degree of mould growth on the surface.

The categories are defined as follows:

A: The level of mould is not above normal background level.

B: The level of mould is above normal background level. This is typically due to high concentrations of spores and hyphal fragments in dust deposits, but in some cases indicate the presence of old mould growth.

C: The level of mould is high above normal background levels due to massive mould growth.

Three scenarios are most often experienced in Arctic crawl spaces:

1. Visible mould growth and a RH above 75% on the material surface. Mycometer-Surface test results in category C.

2. Visible mould growth and a RH above 75% on the material surface. Mycometer-Surface test results in category B.

3. Visible mould growth and a RH below 75% on the material surface. Mycometer-Surface test results in category B.

Common for the three scenarios are, that the crawl space has insufficient ventilation and drainage.

In the first scenario the crawl space will typically have ponds of water which indicates that it is wet all year around. The flooring is poorly insulated and is not air tight which will provide higher temperature in the crawl space. The overall climate in the crawl space will be ideal for mould growth all year around. This can typically be expressed as a category C in the Mycometer-Surface test.

In the second scenario the mould growth will be slow and periodical due to low temperatures in the crawl space most of the year. In the summer period the temperature will rise sufficiently to give optimal growing conditions for mould and spores in a short period. This can typically be expressed as a category B in the Mycometer-Surface test.

In the third scenario the mould growth will typically be slow and periodical due to low RH in the material and air most of the year. Typically in the spring with temperature change and thawing and in periods with heavy rain, the crawl space will be filled with

water. Much of the water will be absorbed by the materials in the crawl space and thereby give good growing conditions for the mould and spores in a short period. This can typically be expressed as a category B in the Mycometer-Surface test.

Although the mould growth in scenario two and three could not be detected as extensive, the problems in the crawl space can be just as important to take care of. Generally the detection of mould growth should be seen as an indication that there is a problem in the crawl space.

Due to the extreme weather conditions in the Arctic, it is important to stress, that a single mould investigation in a crawl space is a snapshot of the conditions at that time.

Investigations of the same crawl space during a whole calendar year are usually performed, and show large variations in the crawl space climate depending on the season and even on the weather at the time of the investigation.

## 5. Ventilation

The Danish requirement for ventilation openings has by tradition been set to 1/500 of the ground area along the crawl space perimeter. This figure has not been chosen on a scientific background but has developed by tradition, a rule of thumb, and has in time proven to be justified.

Ventilation is mainly driven by the surrounding wind with pressure on the windy side and suction on the opposite side. This cannot be directly transferred to Arctic climates as the ventilation openings will be covered by snow during a long winter period.

The Thermal stack effect over the crawl space flooring and the pressure will in a leaky deck construction cause convection of air from the crawlspace to the rooms above.



Figure 7: Typical ventilation opening with a covering to prevent snow and driving rain from entering the crawl space.

Heavy mould growth located in a crawl space will give a risk of infiltration of polluted air from the crawl space into the indoor climate of the house.

To prevent this, the deck structure must be as air tight as possible. As a supplement it is an advantage to have a lower air pressure in the crawl space.

This can be provided by natural ventilation with a ventilation pipe going through the floors ending above the roof (above snow level).

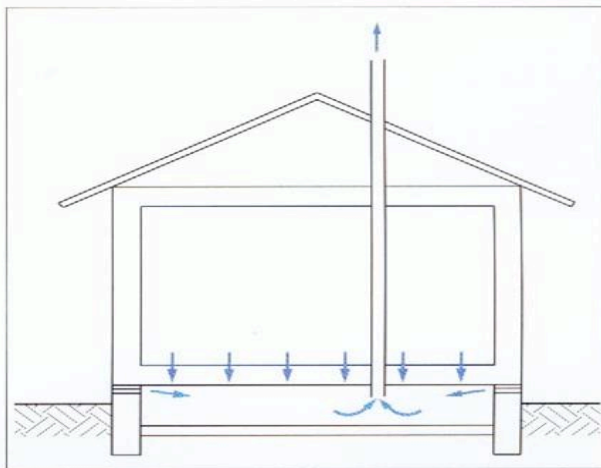


Figure 8: Natural ventilation over the roof to introduce negative pressure in the crawl space to prevent infiltration of air to the rooms above.

Another solution is to create negative pressure by mechanical ventilation of the

crawl space. This can be obtained by means of an automatic control that creates a negative pressure dependant on the local weather conditions of e.g. 5 Pa. This will typically be higher than the thermal stack effect of one to two storey buildings.

## 6. Cold bridges

Cold bridges will typically occur along the perimeter of the crawlspace and at the partition walls in the crawlspace.

These cold bridges can be simulated using a computer program and the thickness and the size of the necessary insulation can be determined

Typically the insulation must be installed both inside and outside to a position of at least 600 mm below the floor.

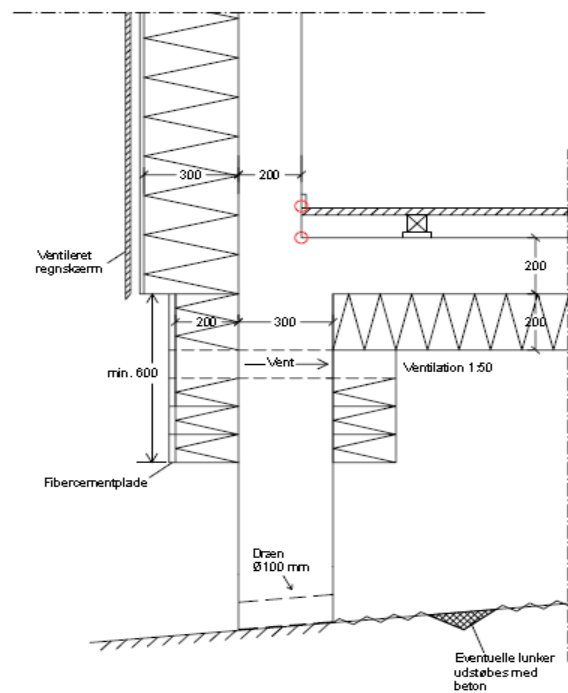


Figure 9: Typical section of the perimeter of a new crawlspace structure. The red circles indicate the most critical areas for mould growth. The simulation is made so that 75 % RH at these points are considered sufficient to avoid mould growth. The temperature outside and in the crawl space is -10°C and indoor temperature 20°C.

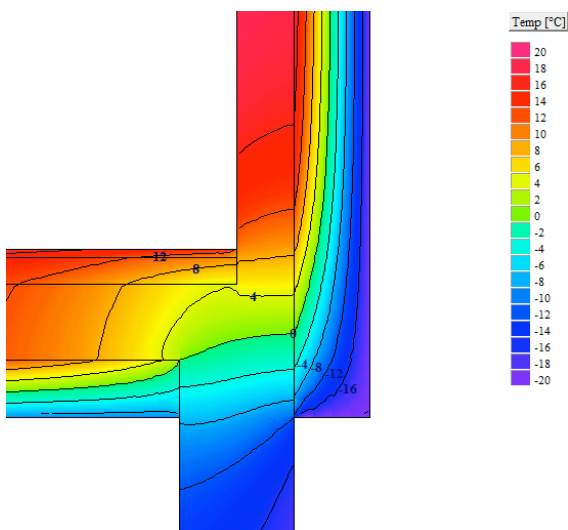
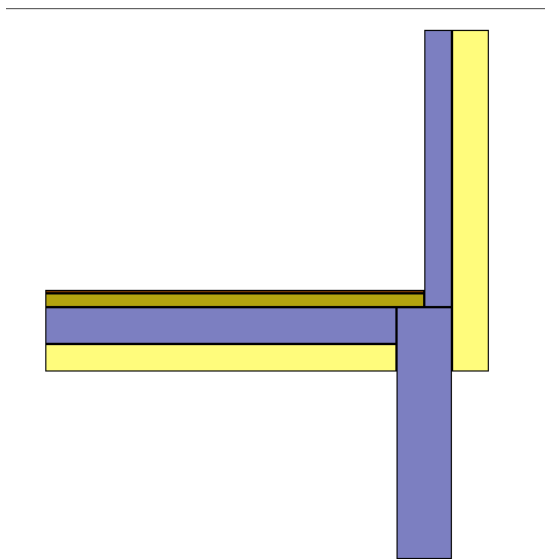


Figure 10: Calculation with the temperature simulation programme HEAT of the temperatures at cold bridge in a situation where the insulation stops just below the deck.

## 7. Drainage

It is important to drain the crawl space to avoid ponding of water and this is a difficult operation due to the great variation in the ground level of the rock.

If possible the bottom must be levelled out by means of concrete in order to create a slope where drain pipes leading to the outside may be installed.

This way of dealing with the problem may course e.g. blasting of part of the rock in the bottom of the crawl space.

## 8. Conclusions

Based on inspection of more 100 crawl spaces in the arctic region in the last two years the following conclusion can be drawn.

The crawl space structure has to be redesigned and new requirements set up for the design incorporating:

- Effective Ventilation
- Adequate Insulation
- Drainage
- Air tightness of deck
- Non organic materials
- Regular inspection, moisture and mould control
- No storage allowed

The only other alternative is to ban crawl spaces

Where effective ventilation cannot be obtained by natural ventilation a mechanical system must be added and controlled by the pressure difference over the crawl space deck or the relative humidity.

The concrete walls must be insulated at least 600 mm below the underside of the floor to avoid cold bridging. The floor must also be insulated and air tight throughout the building.

The bottom of the crawl space must be drained so that ponding of water is eliminated. If this is not possible pumps must be added in the low areas.

The flooring between the crawl space and the rooms above it must be as airtight as possible to stop infiltration of polluted air from the crawl space.

It is crucial to avoid organic materials in the crawl space such as cardboard boxes, paper and textiles. Gypsum boarding as a wind barrier is a very bad idea.

By inspecting the crawl space once or twice a year in the critical periods of the year, problems can be recognized before it develops into critical mould growth problem.

As mentioned earlier the majority of crawl spaces in the Arctic area are damp and can be described as "ticking bombs" in relation to the indoor climate. An easy and cheap alternative is to build on stilts, as seen in some Arctic areas.

## **Acknowledgements**

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