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Moisture conditions in passive house wall constructions

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Abstract

Buildings for the future, i.e zero emission buildings and passive houses, will need well insulated building envelopes, which includes increased insulation thicknesses for roof, wall and floor constructions. Increased insulation thicknesses may cause an increase in moisture levels and thereby increased risk of mold growth. There is need for increased knowledge about moisture levels in wood constructions of well insulated houses, to ensure robust and moisture safe solutions.

Monitoring of wood moisture levels and temperatures have been performed in wall- and roof constructions of 4 passive houses in three different locations representing different climate conditions in Norway.

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1. Introduction

Buildings that are designed to meet the high energy performance requirement of the future, require well insulated building envelopes, with increased thicknesses of roof, wall and floor structures. Increased insulation thicknesses in the external structure could lead to increased moisture level and thus increased risk of mold growth. There is a need for increased knowledge and documentation of moisture levels in passive house constructions to ensure moisture safe and robust solutions.

An increased moisture amount in the external structures for well insulated envelopes compared to "traditional" structures is mainly due to the following mechanisms[1]:

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• The outer part of the construction becomes colder, therefore the relative humidity (RH) in this area will increase.

• Drying time for built-in moisture increases when the insulation thickness and the amount of wood increases.

• Increased insulation thickness provides increased potential for internal convection in the insulation layer.

Geving and Holme[1] found that the risk of mould growth in the outer part of the structures increases with increased insulation thickness. However calculations showed that other factors than increased insulation thickness often had greater significance for the risk of mold growth, such as water vapor resistance of the wind barrier and moisture content in the indoor air.

In a study conducted by[2] there were uncovered large risk of mould growth in bottom sills and studs that was exposed to water bath and rain influence. However there was not found the same risk of mold growth on wood exposed to brief rain that dried up during a day.

In order to start mould growth, the presence of moisture, temperature, time, nourishment, oxygen and spores is necessary. Fungi and bacteria are relevant degradation mechanisms[2]. Most of the mould species need dead organic material. Normally there is enough nourishment to start mould growth in common building materials. According to[4], when the relative humidity is above 85 % and the temperature is between 10-40 °C there is a risk for establishment of mould[3].

According to[5] the most common mould species demands 80-85% relative humidity (RH) on the material surface or in the pores of the material surface in order to grow. For wood this corresponds to a moisture content of about 20 weight percent of wood at 20 ° C. As Figure 1 shows the mould growth rate is increasing with increasing relative humidity. Optimum temperature for most species is around 25-30 ° C. Several species can grow well at lower temperatures. When it gets too cold (down to 0 ° C), the activity stops, but the mould is still present.

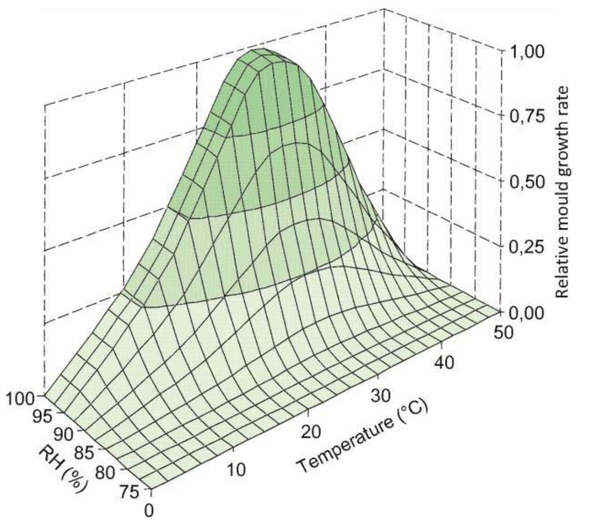

Fig. 1 Relative mould growth rate for the most common mould species as a function of temperature and relative humidity [5]

Mould growth conditions and decay development of a typical brown rot fungus in Scots pine and Norwegian spruce is reported in[5]. In ambient air the critical relative humidity condition for decay development was above 94-95%. The lowest relative humidity condition for decay development lay around 97% when the temperature was kept between 0 and 5 °C[6].

Because of low temperature and i.e. high relative humidity the exterior, cold parts of the wall construction and in particular the wind barrier is considered to have the most critical mould growth conditions. Wind barriers containing organic materials such as the wood fiber boards or plaster boards can be subjected to mould growth, especially in the construction period before the cladding is installed. Mould growth on board-based wind barriers was investigated by[7]. The results showed that the wood-fiber (hardboard) based wind barriers had comparatively greater resistance to mould growth than plasterboard-based wind-barrier boards at RH 100 % and temperature 15°C and 32,5°C.

[8]and[9] recommends a maximum moisture content of 20 weigh percentage before the wood structure can be insulated and vapour barrier mounted. After closing the construction (including insulating and mounting of vapour barrier) when the building is heated up, the moisture will start to redistribute inside the wall cavity leading to a moisture accumulation in the exterior parts of the wood structures during the heating season[10]. Some of the moisture will diffuse through the vapour open wind barrier. Moisture can also condensate on the wind barrier, and consequently be transported down the wind barrier and possibly cause moisture problems in the bottom sill. Field investigations indicate that the built in moisture is dried out during the first or second summer[11,12].

2. Scope

The aim of the work is to investigate moisture conditions in selected walls in four passive houses.

3. Method

3.1 Monitoring equipment

The houses were instrumented with Hygrotrack measuring system consisting of a receiver (base station) and small loggers. The loggers are logging both temperature and relative humidity in the air as well as wood moisture content by two screws into the wood. Air temperature and relative humidity are logged through two holes in the logger casement. The accuracy of the loggers is reported to be ±0.4°C/±3.5%RH. The loggers were installed after the wind barrier, and the windows were mounted in the houses, but before the installation of insulation.

The wood moisture loggers are positioned 10 mm from the wind barrier in the bottom sill, the top sill and in a location of 100 mm from the top sill in the stud, see Figure 2. All the four main walls in the house were instrumented in a similar way.

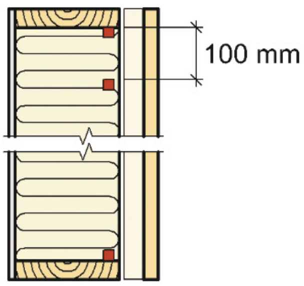

Fig. 2 Location of wood moisture loggers in the outer walls, Red rings showing the location of wood moisture monitoring system

3.2 Mould growth potential

Based on the measured values for temperature and relative humidity, and the correlations given in Figures 3 and 4 a mould growth potential is calculated. The mould growth potential is given in hours and corresponds to the number of hours with maximum growth potential which theoretically gives the same growth potential as the actual conditions. The calculated mould growth potential for each recorded hour is summarized for a year[13].

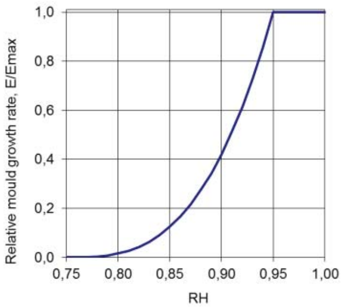

Fig. 3 Relative mould growth velocity is dependent of the relative humidity. For RH<75% it is assumed no mould growth. For 75<RH<95 the growth velocity is calculated according to E/Emax= $((\phi-0{,}75)/2)^3$. When RH>95% the velocity is maximal for the given temperature[13].

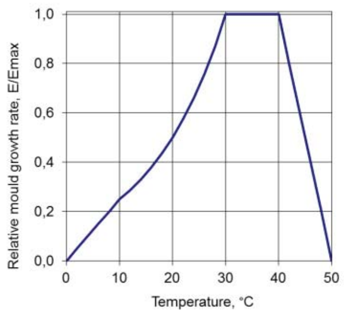

Fig. 4 Relative mould growth potential is dependent of the temperature. When the temperature is below 0 ℃ and above 50 ℃ the mould growth velocity is set to 0. Between 10-30 ℃ the velocity is doubled per 10 ℃ temperature increase. In the remaining intervals the velocity has a linear correlation with the temperature[13].

4. Results

The constructions of the instrumented walls are shown in Table 1.

Table 1: Project 1 description of the wall.

Built-up/ Construction		U-value	S_d-value windbarrier	S_d-value vapour barrier
		W/m²K	m	m
Project 1-wall	400 mm double wall; 148 mm timber frame, 150 mm insulation 98 mm timber frame	0,10	0,22	70
Project 2-wall	200 mm Iso 3-profiles + 48 mm interior insulated wooden frame	0,15	0,22	70
Project 3-wall	300 mm I-profiles + 48 mm interior insulated wooden frame	0,12	0,22	70
Project 4-wall	300 mm wood studs + 48 mm interior insulated wooden frame	0,12	0,13	70

Figure 5 shows a typical example of the development of the wooden moisture content at the outer/cold parts of the wall. The example is taken from the wall facing towards north in project 1, situated at Snåsa in the Middle part of Norway.

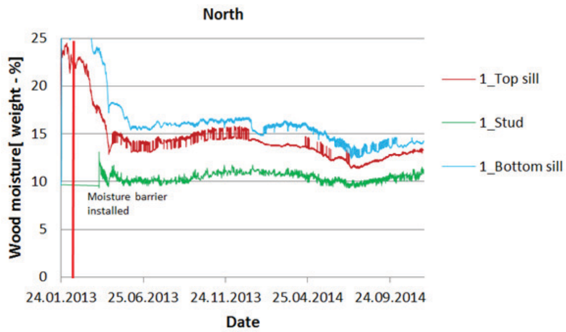

Fig. 5 Development of the wood moisture content in the wall facing north in project 1.

Figure 5 shows that the wood moisture content is rather high (above 20 weight-%), when the monitoring system is installed. During the spring the wood moisture content is decreasing partly because of diffusion through the vapour open wind barrier and partly by redistribution in the wall. After about 5 months the wood moisture is stabilized at an uncritical level with small seasonal variations.

Mold growth potential [h] calculated according to [13] for the monitored walls in the 4 projects are shown in Figure 6.

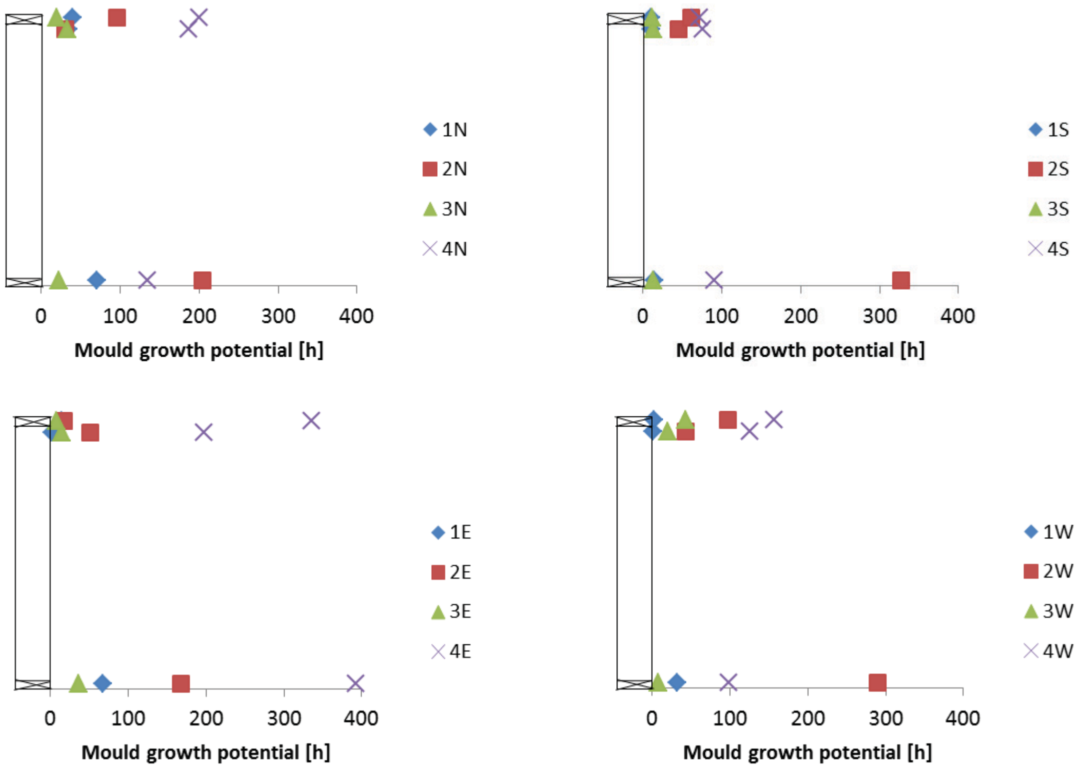

Fig. 6 Mould growth potential in the walls in the four projects (labeled 1,2,3 and 4). Mould growth potential for the sensors in the bottom and top sill as well as in the stud are shown. Upper left: Walls facing north, Upper right: Walls facing south, Lower left: Walls facing east, Lower right: Walls facing west.

As Figure 6 shows the yearly mould growth potential in hours is spanning from 0 to almost 400 hours. Different orientations of the walls are affecting the mould growth potential of the walls to a little extent. There are also small differences in the mould growth potential between the bottom sill, stud and top sill. Project 2 and 4 have the largest mould growth potentials. Project 2 and 3 have identical geographical locations and wall constructions. Still the mould growth potential is generally larger in project 2 compared to project 3. Possible explanations can be different moisture levels when the building was insulated or air leakages through the wall. Large mould growth potential in the bottom sill in project 2 can indicate water leakages through the wind barrier, caused by driving rain, which is accumulated in the bottom sill.

5. Conclusion

Mould growth potential cannot be used as an absolute measure to predict mould growth occurrence. It is difficult to set a limit for the mould growth potential in a specific case. According to [4] mould growth can occur after 2-3 consecutive weeks of favorable temperature and moisture conditions. This corresponds to a mould growth potential of approximately 350 h. However the calculated mould growth potential for the 4 projects above are cumulative values for a period of one year. This implies that continuous/consecutive periods with favorable conditions are not likely to occur. This decreases the risk for mould growth and thus the risk of mould growth in the monitored walls in the passive houses can be expected to be small.

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