

A Qualitative Model for Moisture Balance in Painted Vertical Wood Paneling

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ABSTRACT

On the basis of investigations of damaged houses and measurements of moisture conditions in painted wood paneling, it has been possible to set up a model of how moisture enters and exits. Not only were the moisture conditions in the wood studied but also the boundary conditions, i.e., whether and for how long different surfaces were exposed to water. The boundary conditions are of decisive importance for evaluating paint systems and for computer calculations.

INTRODUCTION

In painted wood paneling exposed to the outdoors, moisture does not normally reach excessive conditions but enters and exits without causing any problem. In some cases, however, a negative moisture balance appears, which means that the moisture content reaches excessively high values during longer periods of time. A negative moisture balance poses a risk of blistering problems or, if the moisture content in wood exceeds 20% for longer periods of time, a risk of wood rot. To ensure a positive moisture balance, it is of crucial importance to design the paneling with regard to moisture effects. Unfortunately, there has been a lack of knowledge of how this should be done.

Traditionally, the moisture balance of painted wood has been tested with simple methods in which the water absorption or the moisture permeability has been measured (according to standards ASTM D 1653-93 or DIN 52617). Such tests can provide interesting information—for example, when a study is made on the influence of an additive in the paint on the moisture transport through a paint film—but they do not provide enough information for evaluating the moisture balance in real building structures with joints and nails. Investigations of houses damaged by wood rot have shown that such places are critical locations with respect to the moisture balance and, consequently, to wood rot. Therefore, it is desirable to treat the moisture balance in a more complete way. The model presented here is based on experiences from investigations of houses and studies of moisture conditions in wood paneling,

and it provides a means of simulating the moisture conditions in real paneling. Methods for measuring the required material data and a two-dimensional computer program for calculating the moisture transport are presented in Hjort (1997a).

OBSERVATIONS OF ROT DAMAGE

Investigations of a great number of houses damaged by wood rot in the Scandinavian countries have been carried out during the last ten years (Hjort 1989, 1993). The findings have shown a strong correlation between the degree of damage and the orientation of the paneling with respect to driving rain. As much as 90% of the rot was found on the top board. Most problems appear in the neighborhood of the following extremities and in the following order:

1. The joints of the panel boards, especially where the top board overlaps the bottom board.
2. The very end of the paneling, especially where the top board overlaps the bottom board.
3. The nails.

These areas are illustrated in Figure 1.

OBSERVATIONS OF MOISTURE CONDITIONS

Several studies of the moisture conditions in painted wood paneling have been carried out, in both the field and laboratory; see, for example, Hjort (1989) and Hjort (1996).

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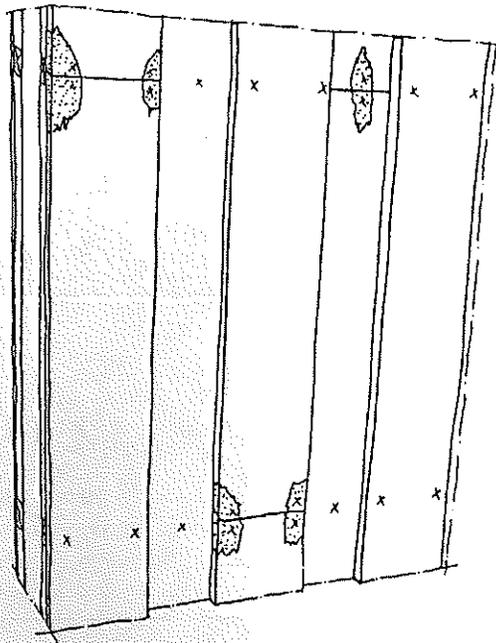


Figure 1 A typical paneling structure damaged by wood rot.

The picture obtained of the moisture conditions corresponds very well with the actual appearance of wood rot (Hjort 1996). The most susceptible parts of the paneling with respect to moisture have been found to be near the following extremities and in the following order:

1. The joints.
2. The very end of the paneling.
3. The nails.

The zone where the top board overlaps the bottom board has higher levels of moisture content than the middle part of the board. It is likely that this depends on the local moisture exposure because panel boards disassembled from damaged houses have had trapped, capillary-transported water in the zone between the bottom and the top board. The moisture content distribution in such a board has been determined (see Figure 2).

The highest value of moisture content ($u = 117\%$) was measured near the butt joint. The theoretical value of complete saturation is approximately 180%. Raised values of moisture content were also found at the overlaps, compared with the middle of the panel board. Another interesting observation is that the values are higher near the nails.

In a laboratory study, the moisture conditions in small samples of a paneling structure consisting of a top board and two bottom boards were measured by a nondestructive computer tomography scanning technique (CT-scanning); see Figure 3. This technique provides a three-dimensional picture of the moisture distribution. The technique is described in detail in Lindgren (1992). The top board was jointed, and special study was made of the area around the joint. Plastic

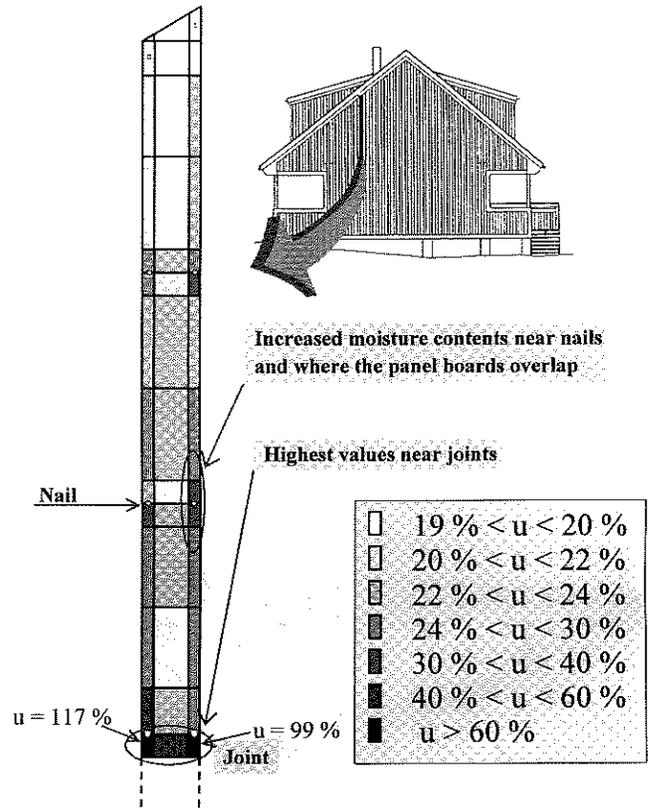


Figure 2 Moisture conditions in a disassembled panel board.

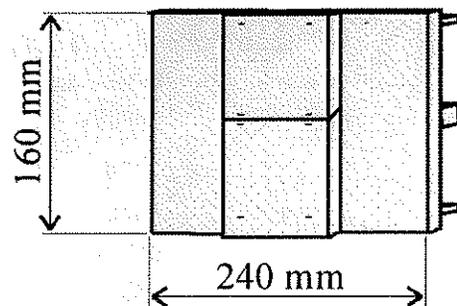


Figure 3 The paneling structure used in the CT investigations.

nails were used instead of steel nails in order to make the X-ray analysis possible.

In Figure 4, the results are visualized after a simulated rainfall. Free water is held in the overlap zone and in the joint, which means that water enters the panel not only from the three painted front surfaces but also from the end grain and from the back of the top board.

From the CT investigation it is also possible to evaluate the profiles of moisture content in the wood (see Figure 5). During the wetting phase the panelling was oriented vertically. These profiles (after 48 hours) show that the moisture not only enters from the end grain, but they also indicate that the moisture enters from the back of the top board because the

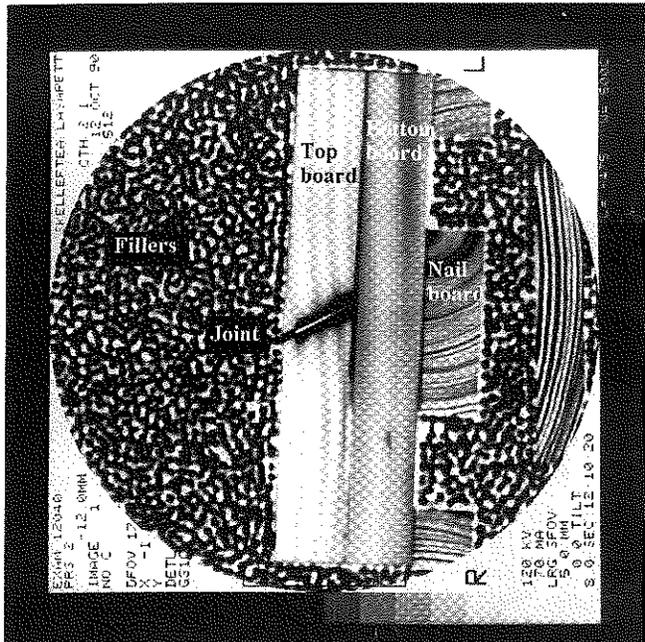


Figure 4 A section through the specimen. The dark color in the joint and in the overlap between the top and bottom board indicates high levels of moisture content.

moisture content is of greater magnitude near the back of the panel board than at the front.

THE MODEL

On the basis of the knowledge obtained in investigations of houses damaged by wood rot and from measurements of moisture conditions in paneling, it has been possible to formulate a qualitative model for the moisture balance in painted wood paneling. *Qualitative* refers to the main paths through which moisture enters and exits painted paneling. The time of wetness is not treated in detail. The most interesting area is around the joints because it represents the part of the paneling where the moisture balance is most complicated. Furthermore, and this is more important, the areas around the joints have been found to be the most sensitive part of the paneling for excessive moisture conditions and wood rot.

Wetting

In Figure 6, the most important paths where moisture enters a painted wood structure are shown. The different paths are discussed in detail below.

- a. *Moisture transport through the paint film, transverse to the wood fiber direction.* A transport of some importance occurs as long as there is a water film on the surface, which will last a while after it has stopped raining. Depending on the paint used, the duration of wetness will be different. There is a negligible risk that the moisture transport through the paint film alone causes any problem

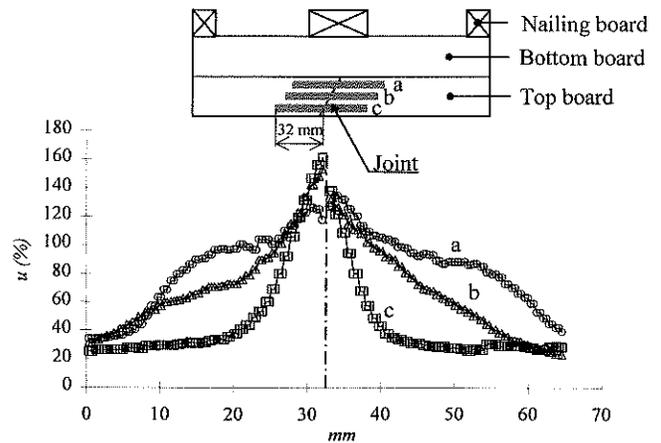


Figure 5 Profiles of moisture content in a paneling structure after 48 hours of wetting.

Wetting

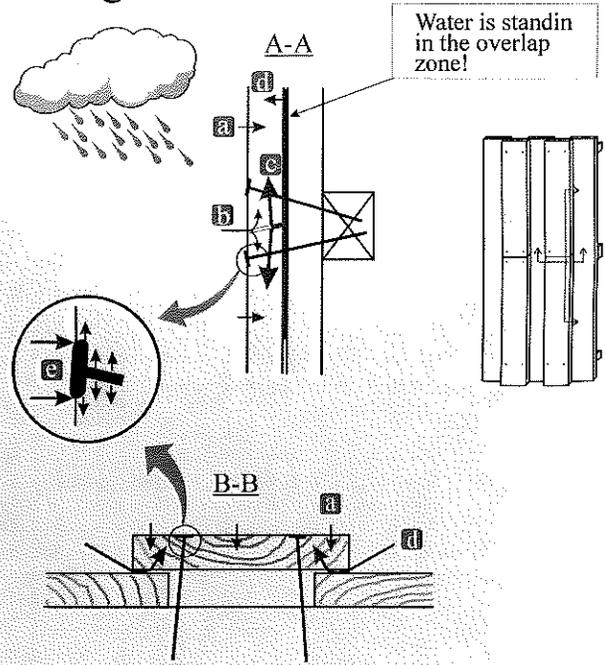


Figure 6 Important paths where water can enter the joint area of painted wood paneling.

because the wood itself has quite high resistance against moisture transport across the fiber direction and the painting makes the resistance more pronounced.

- b. *Moisture transport via the joint from the front of the paneling, along the fiber direction.* By capillary suction, water can be transported into the gap between the boards over and under the joint, and once it is there it can be easily transported into the wood. The transport into the wood is a rapid process due to moisture transport parallel to the fiber direction. It will continue as long as there is a feed

of water, which will stop soon after the rainfall has finished. The paint system used plays a decisive role; if a hydrophobic paint is used, the risk of capillary suction will be minimized.

- c. *Moisture transport via the joint from the back of the paneling, along the fiber direction.* The water standing in the gap between the top board and the bottom board functions as a reservoir, supplying the end grain at the joint with water. In investigations of houses, free water has been found in the gap several days after it stopped raining. The paint system used on the paneling plays a decisive role; if a hydrophobic paint is used, the risk of capillary suction into the gap will be minimized.
- d. *Moisture transport from the back of the paneling, transverse to the fiber direction.* In addition to the moisture transport phenomenon described under the previous point, there can be a moisture flow transverse to the fibre direction.
- e. *Moisture transport around the nails.* There is a risk of moisture transport along the nails, with a subsequent moisture transport in the fiber direction. The risk will be pronounced if the nails are driven very far into the board or if cracks appear.

Drying

Figure 7 shows the most important paths where moisture can exit from a painted wood structure. The different paths are discussed in detail below.

- f. *Moisture transport through the paint film, transverse to the wood fiber direction.* The moisture has to pass through the paint film, which is normally a rather slow process, depending on the paint system used.

- g. *Moisture transport from the back side of the paneling, transverse to the fiber direction.* Normally, there is a ventilated air gap behind the top board that allows the moisture to dry. The lack of paint film makes it possible for the wood to dry out faster, provided that the ventilation is in order.

In addition to the above paths, there is a possibility for moisture to be transported and redistributed in the longitudinal direction.

CONCLUSIONS

The findings show several paths for water to enter a painted wood structure. Depending on the paint system used, the paneling structure can be more or less protected against moisture during a rainfall. Normally, moisture does not cause any problem. In the Scandinavian countries, there are a lot of bare paneled structures and paneling painted with very permeable paints, e.g., Swedish barn paint, which has been working very well for hundreds of years.

The paths for drying are less complicated than for wetting, and drying is normally a much slower process. In some circumstances, if moisture does not dry out quickly enough, there can be problems and the risk of wood rot.

In order to give the paneling structure a positive moisture balance and to avoid moisture problems, it is most important to find a positive balance between wetting and drying. At some places, for instance where the top board overlaps the bottom board, it is easier for moisture to enter than to exit. This is the most probable reason why this is the part of the paneling where most damage occurs.

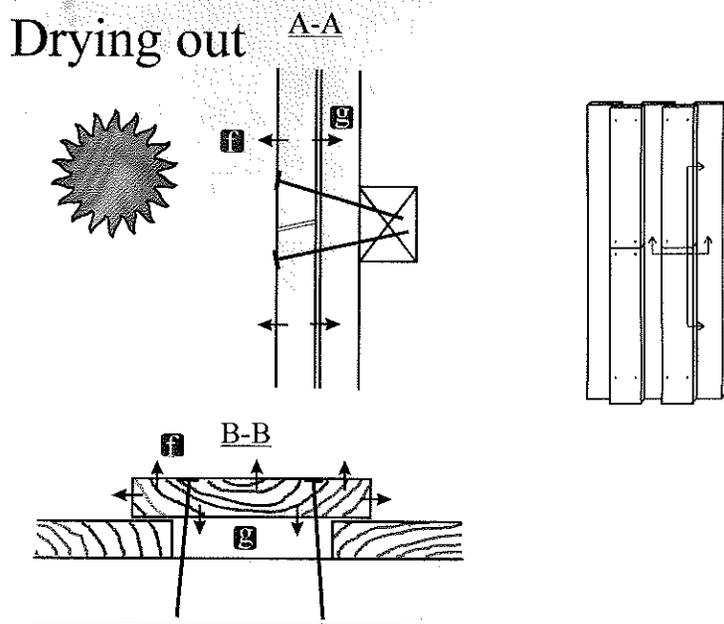


Figure 7 The most important paths where moisture can exit the joint area of painted wood paneling.

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