



## Moisture risk in prefabricated wooden wall elements (TES-elements) with a vapour retarder of OSB/3

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### Abstract

Both for structural and environmental reasons, there is an increasing interest in using OSB/3-boards (Oriented Strand Board) as water vapour retarders and/or wind barriers in prefabricated wooden wall elements (often referred to as TES-elements) in new and renovated buildings and also in passive houses.

Still, the water vapour resistance and airtightness of different qualities of OSB/3-boards are often questioned. The aim of this work has been to increase the knowledge about water vapor resistance and air permeability for OSB/3-boards used in prefabricated wooden wall elements and verify criteria of performance related to moisture risk.

The objective of this research has been to experimentally determine the water vapour resistance for a selection of OSB/3-boards and evaluate the moisture performance of wooden wall elements with OSB/3-boards suitable for passive houses.

Wetcup-/drycup-tests have been performed on 12 mm OSB/3-boards from 4 different producers. The results show differences in measured vapour resistance for the boards from the different producers. For one of the producers, also large differences between test specimens were found.

All the boards have  $s_d$ -values<sup>1</sup> > 0,5 m for all conditions. According to SINTEF recommendations, this indicates that the vapour resistance is too high for the board to perform as a wind barrier for well insulated constructions. OSB/3-boards should rather perform on the warm side of the wall construction as a vapour retarder or in combination with a separate vapour barrier. Both for wind barriers, vapour retarders and vapour barriers the vapor transport properties are essential. Use of boards with too high  $s_d$ -value as a wind barrier may cause moisture problems and risk of mold

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<sup>1</sup> The  $s_d$ -value (water vapour diffusion-equivalent air layer thickness) represents the thickness of a motionless air layer which has the same water vapour resistance as the board. The  $s_d$ -value is calculated by multiplying the  $\mu$ -value (the water vapor resistance factor) with the thickness of the board.  $s_d = \mu \cdot d$

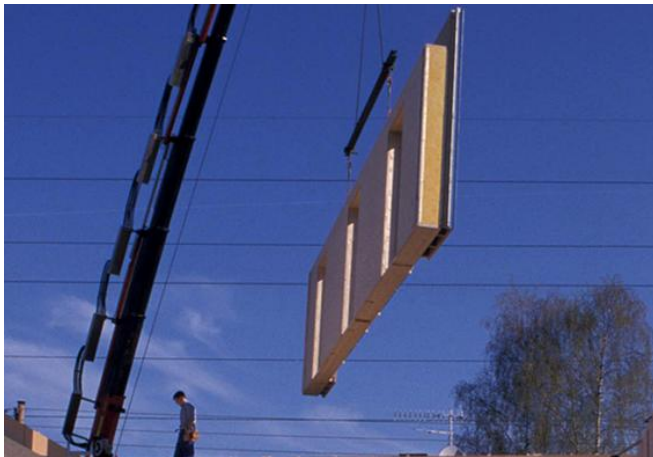
growth within a wall construction on the one hand, and on the other hand use of boards as a vapour retarder with too low  $s_d$ -value may also cause moisture problems and risk of mold growth.

A numerical investigation of a wall element construction has been performed in order to investigate the performance of the wall related to moisture risk applying a vapor retarder of OSB/3-boards. Application of real measured vapour resistance data and correspondingly values from [NS-EN-13986/-ISO 10456] have been explored. The measurements show that the water vapour resistance of OSB/3-boards given in [NS-EN-13986/-ISO 10456] is significantly lower than real measured values.

The results from this work show that it is of real significance for assessing the potential moisture performance of a well insulated wall to have knowledge about the actual vapour resistance of the OSB/3-boards (measured data). The tabulated values from [NS-EN-13986/-ISO 10456] and also tabulated values from the Norwegian handbook; *Moisture in buildings* [Geving and Thue 2002] is misleading.

**Keywords:** Moisture risk; vapour retarder; water vapour resistance; air permeability; WUFI 5; OSB/3

## Introduction



**Figure 1** This research is part of the SmartTES-project which concerns prefabricated wooden wall elements (TES-elements) used for renovation projects [Smart TES]. (Photo: Technical University Munich)

The use of OSB/3-boards as water vapour retarders and/or wind barriers in TES-elements (prefabricated wooden wall elements) is of interests both for environmental reasons but mainly because of the structural advantages of boards in prefabricated elements (stiffness).

Unfortunately moisture performance of such wall elements is often questioned, because there is a lack of knowledge and relevant information about the water vapour resistance and air permeability of such boards. There is reason to believe that the tabulated values given in [NS-EN-13986/-ISO 10456] and e.g. in [Geving and Thue 2002] are deviating from real measured properties of OSB/3-boards. Also, properties of boards from different producers can vary substantially depending on how the boards are produced. In this study the vapour resistance of OSB/3-boards from four major producers in the Norwegian and European marked are measured to document the vapour resistance of the boards and to evaluate whether the boards are suitable as water vapour retarders and/or wind barriers in TES-elements for passive house levels.

A numerical investigation of a wall element construction has been performed in order to investigate the performance of the wall related to moisture risk applying a vapour retarder of OSB/3-boards. Application of real measured vapour resistance data and correspondingly values from [NS-EN-13986/-ISO 10456] has been explored. The water vapour resistances for OSB/3-boards given in [NS-EN- 13986/-ISO 10456] are significantly lower than real measured values.

The results from this work are of importance to both prefabricated wooden wall elements, referred to as TES-elements and also "built on-site" wall constructions, both for renovation projects and also for new buildings.

## **State of the art**

Tabulated values for vapour resistance for OSB/3-boards can be found in [NS-EN- 13986/-ISO 10456].  $\mu$ -values are 50 for dry conditions (relative humidity in the range of 0-50 %) and 30 for wet conditions (relative humidity in the range of 50-100 %). For a typically 12 mm board used as sheeting in a prefabricated wall element this imply a vapour resistance or  $s_d$  -value of 0.60 m for dry conditions and 0.36 m for wet conditions.

[Ojanen and Ahonen 2005] studied the properties of OSB-boards in relation to the water vapour resistance and air tightness. They measured  $s_d$ -values for a selection of boards in the range of 0.36 m to 4.53 m depending on the relative humidity. For 12 mm OSB boards the range of variation were 0.38 m (wet cup) – 2.43 m (dry cup). As appose to this research their study concerned OSB-boards mainly as wind barriers (exterior sheeting) and not vapour barriers as is a more common area of use in Norway.

In general there are few available references publishing research on moisture- and water vapour measurements for OSB/3-boards, the authors assume much of this work are commissioned reports which are not necessarily available. However, the hygrothermal performance of timber-framed external walls in general are well documented i.g. [Vinha 2007] and [Geving and Holme 2013].

## **Water vapour resistance measurements of OSB/3-boards**

### **Specimens**

The measurements include OSB/3-boards from four major producers in Europe. Test specimens for each of the 10 measurements series performed in this work was sawn randomly out of the supplied material.

### **Method**

The measurements have been performed according to [NS-EN ISO 12572] at the accredited moisture laboratory of SINTEF Building and Infrastructure in Trondheim.

The cups applied in the experiment have a diameter of 174 mm a depth of 10 – 15 mm. They consist of an aluminum frame, in which the specimen is placed, and a cup made from the same material, in which the salt solution is put. The aluminum is furnished with a protective coating inside to prevent a chemically reaction with the salt. The specimens are mounted as a lid to the cup and sealed both

around the edges and thereafter sealed to the frame. Both sealing compounds consists of 70 % plasticine and 30 % bees wax.

Parameters taken in to account:

- Variations in the relative humidity.
- Variations in the temperature
- Variations in the barometric pressure.
- Surface resistance at the specimen's upper side.
- Vapour transport through the overlap zone at the seal between specimen and test box.
- Resistance of the air layer in the cup, including the effect of increasing air layer thickness due to water evaporation

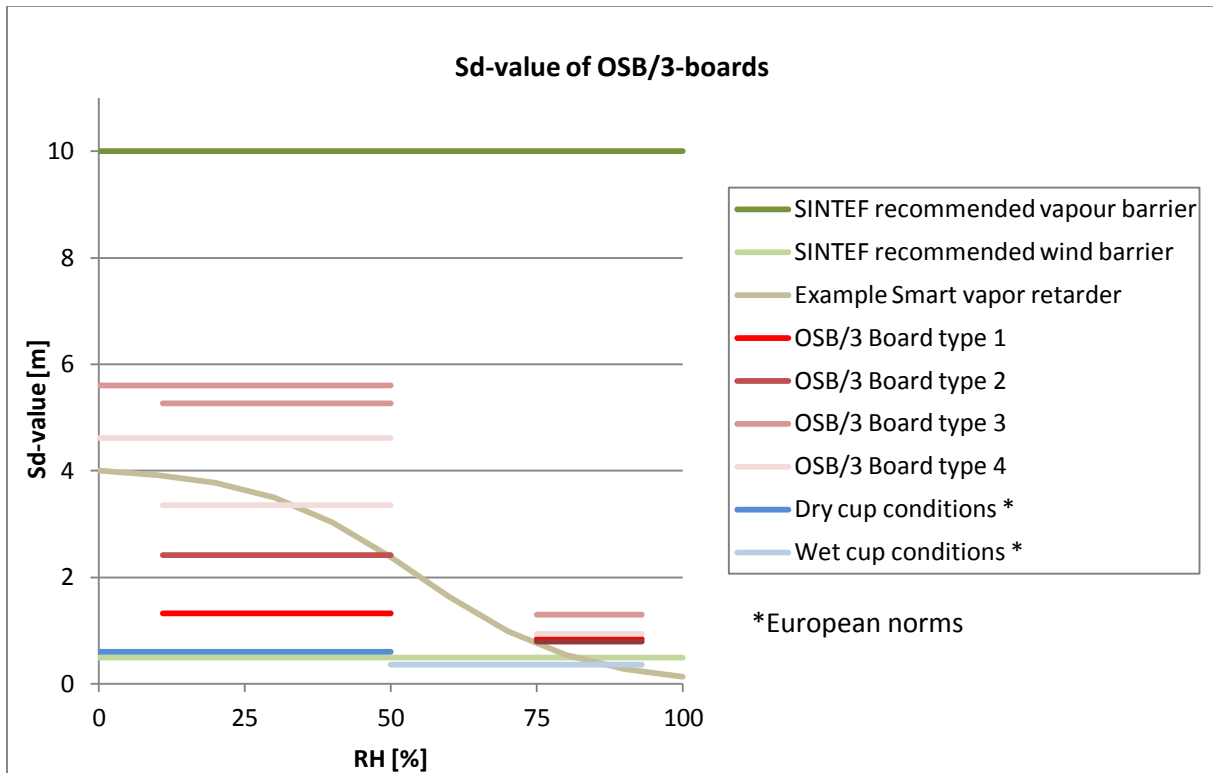
## Measurements and results

**Table 1** Test conditions and results

| Series | RH-level in the room (%) | RH-level inside the cup (%) | Temperature (°C) | Average thickness of specimens (mm) | Number of test-cups in the experiment | $s_d$ -value from measurements (m) |
|--------|--------------------------|-----------------------------|------------------|-------------------------------------|---------------------------------------|------------------------------------|
| 1      | 50                       | 11                          | 23               | 11,6                                | 5                                     | 1,326±0,107                        |
| 2      | 75                       | 93                          | 23               | 11,8                                | 3                                     | 0,838±0,082                        |
| 3      | 50                       | 11                          | 23               | 12,3                                | 5                                     | 2,424±0,603                        |
| 4      | 75                       | 93                          | 23               | 12,3                                | 3                                     | 0,795±0,058                        |
| 5      | 50                       | 0                           | 23               | 12,6                                | 5                                     | 5,601±0,404                        |
| 6      | 50                       | 11                          | 23               | 12,6                                | 5                                     | 5,263±1,367                        |
| 7      | 75                       | 93                          | 23               | 12,8                                | 5                                     | 1,306±0,098                        |
| 8      | 50                       | 0                           | 23               | 12,1                                | 5                                     | 4,621±0,519                        |
| 9      | 50                       | 11                          | 23               | 12,1                                | 5                                     | 3,358±0,481                        |
| 10     | 75                       | 93                          | 23               | 12,5                                | 3                                     | 0,943±0,145                        |

Measurements have been performed for both dry-cup conditions and wet-cup conditions. Dry-cup conditions can be said to resemble indoor conditions and the achieved value indicate the resistance/property as a vapour retarder, while wet-cup conditions can be said to resemble outdoor conditions and the achieved value indicate the resistance/property as a wind barrier.

The test cups were placed in rooms with a temperature of 23 °C and RH at either 50 % or 75 %. The water vapour transfer rate through each specimen was determined by weighing the cups every second or third day, until the weight loss/-gain per time was constant.



**Figure 2** Average  $s_d$ -values from measurements, European norms [NS-EN- 13986/-ISO 10456] and recommendations from SINTEF [SINTEF Building Research Design Guides 2003] as a function of RH.

The results presented in figure 2 shows that the  $s_d$  -value for the 4 different types of OSB/3-boards is higher than the tabulated values in [NS-EN- 13986/-ISO 10456] for both dry- and wet-cup conditions. The results also show that there is a rather large difference in  $s_d$  -value for the different boards, particularly for the dry conditions. For dry-cup conditions the measured  $s_d$  -values for the boards ranges from 1.33 m to 5.60 m, a difference between the products of a factor 4.2.

Recommended values from SINTEF [SINTEF Building Research Design Guides 2003] for a vapour barrier and a wind barrier are also shown in figure 2 for comparison purposes. The recommendation states that vapor barriers should have an  $s_d$ -value  $> 10$  m and wind barriers should have an  $s_d$ -value  $< 0.5$  m.

A graph representing measured values for one of the most used smart vapour barrier Difunorm Vario [Künzel 1996] is also shown in figure 2 for the purpose of comparison. We can see that the moisture performance of the measured OSB/3-boards has similar characteristics as a smart vapour retarder.

While a vapour retarder has a given constant vapour resistance, smart vapour retarders (sold on the European and North American market) have adaptable vapour resistance in regard to what is actually needed. The physical behavior of these products varies, but the main idea and principle is that the vapour barrier should function as an ordinary vapour tight vapour barrier most of the time, preventing vapour diffusion into the construction from the indoor air. If, on the other hand, the construction is wet, for example due to built-in-moisture or leakages, so that the relative humidity (RH) on the exterior side of the vapour retarder gets high, the vapour resistance will be reduced so that there may be possibilities for drying inwards. See also [Geving and Holme 2013].

## **Numerical simulations of a wall element with a vapour retarder of OSB/3**

The aim of the numerical investigation has been to assess the moisture situation in a wall element construction where different moisture resistance values ( $s_d$ -values) for the OSB/3 vapour retarder has been used. The moisture conditions at the inside of the wind barrier have been studied, since this is the most vulnerable place in the construction concerning condensation and possible mold growth.

*The wall element construction, described below, has been chosen based on previous work with similar simulations for a pilot renovation building [Vågen et. al. 2012]. They performed simulations of a wall element with a vapour retarder of OSB/3 for four different climates, different orientation and with different ventilation rates of the air gap behind the cladding.*

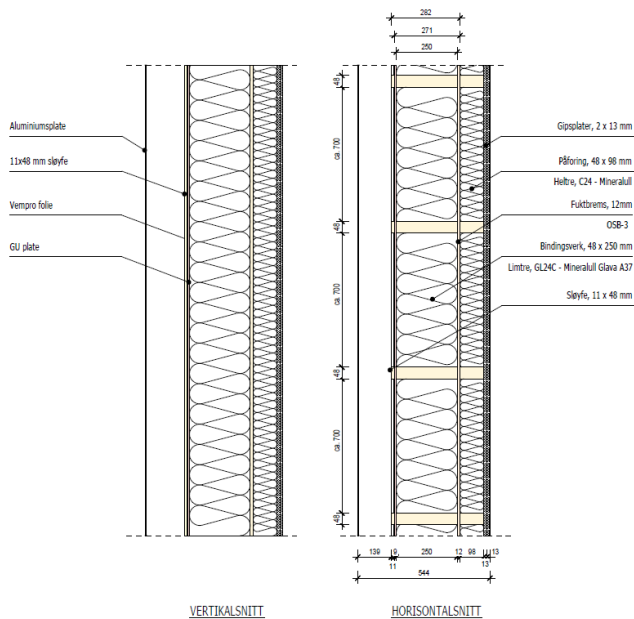
### **Calculation tool - WUFI**

The calculations have been done using [WUFI 1D 5.1.]. WUFI calculates the transient coupled heat and moisture transport in multi-layer building components exposed to natural weather. The climatic differences across a building element are handled as a moisture transport by means of diffusion, capillary moisture transport in the component and sorption capacity. Air leakages through the construction are not included in these calculations.

### **Climate**

Calculations have been performed using MDRY (Moisture Design Reference Year) climate data from a coastal city in the southern parts of Norway, Bergen. Hourly values are interpolated from 3-4 measurements per day. For more information see [Geving and Torgersen 1997]. The wall element is calculated both for the south and the north direction.

## Wall construction



**Figure 3** Cross-section of the wall element construction, vertical cut (left) and horizontal cut (right). (Drawn by the producer, Trebyggeriet AS)

The investigated wall construction is built up as follows from the cold side

- Aluminium cladding
- 139 mm air (ventilation) gap behind the aluminium cladding
- Wind barrier 9 mm gypsum board and PP-foil
- 250 mm mineral wool
- Vapour retarder 12 mm OSB/3 board with varying  $s_d$ -value according to table 3
- 100 mm mineral wool
- 2 x 13 mm gypsum boards.

## Input parameters

In [Vågen et al. 2012] it has been shown that for a this wall element , the climate of Bergen with a ventilation rate of 1 air change per hour for the air gap behind the cladding is the most unfavorable. This is a rather low ventilation rate, compared to the findings of [Nore et. al. 2011], and represents a "worst case scenario" in terms of relative humidity.

The indoor moisture load is set to Humidity Class 1 according to [NS-EN ISO 13788], which is representative for an office building. This means that the moisture load is  $2 \text{ g/m}^3$  when the outdoor air temperature is below  $0 \text{ }^\circ\text{C}$ , and  $0 \text{ g/m}^3$  above  $20 \text{ }^\circ\text{C}$ . Between 0 and  $20 \text{ }^\circ\text{C}$  the moisture load is decreasing linearly. Indoor temperature was set to  $20 \text{ }^\circ\text{C}$ , and the relative humidity in the construction at start was set to 80 %. The simulated calculations include 3 years, starting October 1<sup>st</sup> 2011.

The  $s_d$ -values of the OSB/3-board used in the calculations is given in table 2. Three different  $s_d$ -values has been selected to represent the highest and the lowest value from the measurements and the values listed in [NS-EN- 13986/-ISO 10456].

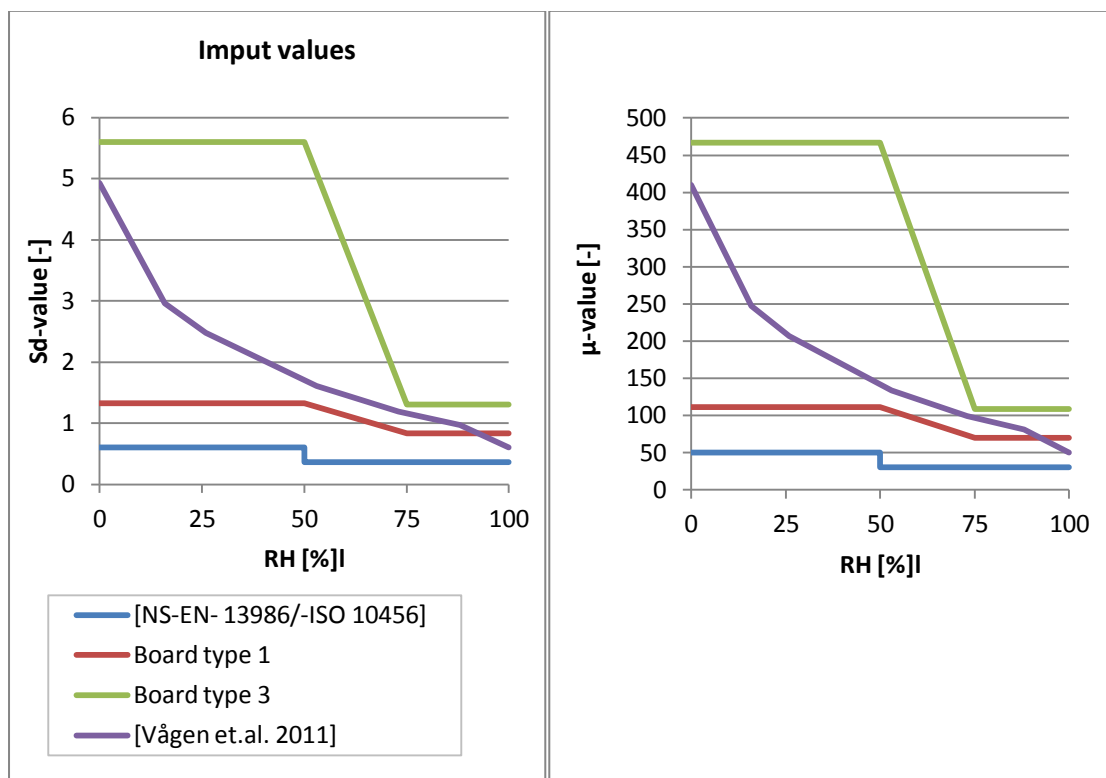
Figure 4 shows the  $s_d$ -values and the (corresponding  $\mu$ -values) as they are entered in WUFI, and the values of the OSB/3-board used in the calculations by [Vågen et al. 2012].

Input parameters of the different materials in the wall element are given in table 3.

**Table 2** Three different  $s_d$ -values (and corresponding  $\mu$ -values) used for the calculations

|   | $s_d$ -value [m]   |                    | $\mu$ -value [-]   |                    |
|---|--------------------|--------------------|--------------------|--------------------|
|   | Dry cup conditions | Wet cup conditions | Dry cup conditions | Wet cup conditions |
| OSB/3 Board type 1<br>(Resemble the lowest values from the measurements)  | 1,326              | 0,838              | 111                | 70                 |
| OSB/3 Board type 3<br>(Resemble the highest values from the measurements) | 5,601              | 1,306              | 467                | 109                |
| Tabulated values [NS-EN-13986/-ISO 10456]                                 | 0,600              | 0,360              | 50                 | 30                 |





**Figure 4** The three different  $s_d$ -values (and corresponding  $\mu$ -values) used in the calculations together with the value of the OSB/3-board used in the calculations of [Vågen et. al. 2011]

**Table 3** *Input parameters for the wall element*

| Material layer      | Thickness [m] | Density [kg/m <sup>3</sup> ] | Thermal conductivity [W/mK] | Built-in moisture [kg/m <sup>3</sup> ] | $\mu$ -value [-]* |
|---------------------|---------------|------------------------------|-----------------------------|--|-------------------|
| Aluminium cladding  | 0,005         | 2700                         | 200                         | 0                                      |                   |
| Ventilation gap **  | 0,139         | 1,3                          | 0,79                        | 0,01                                   | 0,1               |
| (Vempro) PP-foil*** | 0,001         | 130                          | 3                           | 0                                      | 14                |
| Gypsum board        | 0,009         | 675                          | 0,2                         | 20                                     | 8,33              |
| Mineral wool        | 0,25          | 60                           | 0,04                        | 0                                      | 1,3               |
| OSB/3-board ****    | 0,012         | 600                          | 0,13                        | 85,2                                   |                   |
| Mineral wool        | 0,098         | 60                           | 0,04                        | 0                                      | 1,3               |
| Gypsum board        | 0,013         | 625                          | 0,2                         | 20                                     | 8,33              |
| Gypsum board        | 0,013         | 625                          | 0,2                         | 20                                     | 8,33              |

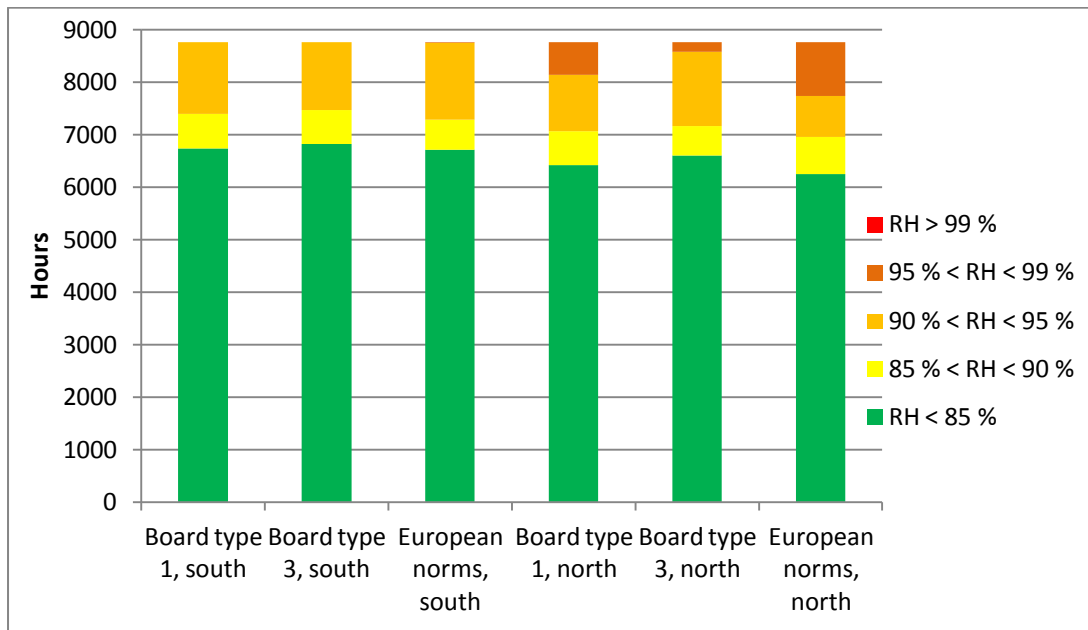
\* Water Vapour Diffusion Resistance Factor

\*\* The layer has an air change rate of 1 air change per hour

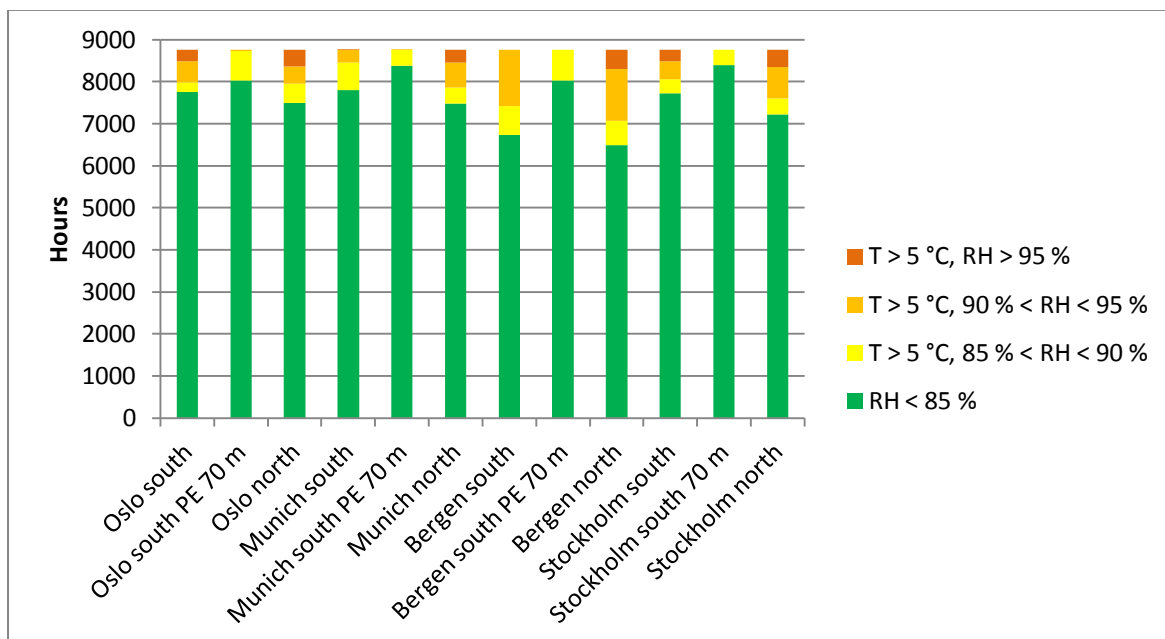
\*\*\* The minimum thickness that WUFI can simulate is 0,001 m. In reality the thickness of the foil is much less. This is corrected by adjusting the properties of the foil so that the actual properties are corresponding to 1 mm.

\*\*\*\* The OSB/3-boards have varying water vapor resistance according to figure 4

## Results and discussion



**Figure 5** Cumulative number of hours fulfilling different criteria for relative humidity and temperature at the inside of the wind barrier for the wall element with a ventilation rate of 1 air change per hour for the air gap behind the cladding. The values for the location of Bergen and 3 different OSB/3-boards, board type 1, board type 3 and values according to the norms [NS-EN-13986/-ISO 10456], see figure 4, has been simulated.



**Figure 6** Cumulative number of hours fulfilling different criteria for relative humidity and temperature at the inside of the wind barrier for a wall element with a ventilation rate of 1 air change per hour for the air gap behind the cladding. The values are for different locations and the vapour resistance of the OSB/3-board is according to figure 4. The columns are representing the first year of simulation.

This work started out with simulations for a wall element in a pilot building with a specified OSB/3-board with a vapour resistance according to figure 4 for different locations [Vågen et. al. 2012]. Since then measurements on the vapour resistance for 4 different OSB/3-boards available on the Norwegian and European market have been performed. Additional simulations have been performed for the most unfavorable climate for the wall element with different measured values for OSB/3-boards as vapour retarder.

Figure 5 and 6 shows the cumulative numbers of hours for one year for different RH and temperature on the inside of the wind breaking barrier in the wall element calculated for different climates and vapour resistances of the OSB/3-boards. The chosen temperature limit is 5 °C and the limits for RH are 85, 90, 95 and 99 %. The limits were chosen in order to illustrate the mold growth potential at the simulating point of interest in the construction. Since there is no good threshold values for mold growth, we chose a relatively low temperature, but above 0°C, and RH above 85% [Holme 2010]. The mold growth potential increases with higher temperature and relative humidity.

The risk of mold growth is small in the wall element. This is independent of climate, vapour resistance of the OSB/3-board, or geographical direction. Mould growth experiments in our laboratories show that the lower humidity limit for growth on gypsum lies in the interval 86 % to 95 % relative humidity when the temperature is 15 °C [Holme 2010]. At these condition visible growth appeared after 1848 hours (11 weeks). At 5 °C as in these simulations, the time until growth will most likely be even longer. None of the simulations for the four cities, nor the different values of OSB/3- boards in this study reached a total number of hours with temperature and relative humidity favorable for mold growth.

Attempts to measure the air tightness of the OSB/3-boards have been carried out unsuccessfully. Due to the high airtightness and a rough surface of the 4 boards the inaccuracy of the measurements made the results not trustworthy. But by saying so this indicates that the airtightness of the boards probably is quite high and will most likely fulfill the requirements for a wind barrier.

Our results are dependent on that the joints between boards and adjacent constructions are airtight.

## Conclusions

There is an increasing interest in using OSB/3-boards (Oriented Strand Board) as water vapour retarders and/or wind barriers in prefabricated wooden wall elements both in new and renovated buildings and in passive houses.

The results from this work show that it is of real significance for assessing the potential moisture performance of a well insulated wall to have knowledge about the actual vapour resistance of the OSB/3-boards (measured data). The tabulated values from [NS-EN- 13986/-ISO 10456] and also tabulated values from the Norwegian handbook; Moisture in buildings [Geving and Thue 2002] is misleading.

Still, numerical calculations show the risk of mold growth is small in the wall element. This is independent of climate, vapour resistance of the OSB/3-board, or geographical direction. Previous Mould growth experiments in our laboratories show that the lower humidity limit for growth on gypsum lies in the interval 86 % to 95 % relative humidity when the temperature is 15 °C [Holme 2010].

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