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Moisture damage with magnesium oxide boards in Danish facade structures

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Abstract

Magnesium oxide boards have been widely used on facades in Denmark during 2010-2015. However, the magnesium salts absorb humidity from the ambient, and they begin to leak salty water, which is highly corrosive, and leads to moisture and mould problems in wooden members of the structures. MgO-boards were not tested for their hygrothermal function before being used on exterior wall structures, which has had detrimental consequences, such as an expected cost of repair of around 2 billion DKK. Properties for moisture transport and retention properties have been determined and will be shown together with some examples of damaged structures.

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Keywords: Moisture, sheathing board, magnesium oxide, salt, damage, mould, corrosion

1. Main text

Many moisture damages were observed in winter 2014/15 in ventilated facades of new or newly renovated Danish buildings. The damaged facades had magnesium oxide-boards (MgO-boards) as sheathing facing the ventilated air gap behind the exterior siding. MgO-boards have often been used as sheathing behind a ventilated air gap as shown in Figure 1a and Figure 2a. A photo of an MgO-board is shown in Figure 1b. Examples of saltwater leaks and subsequent damage are shown in Figure 2b, 3a and 3b.

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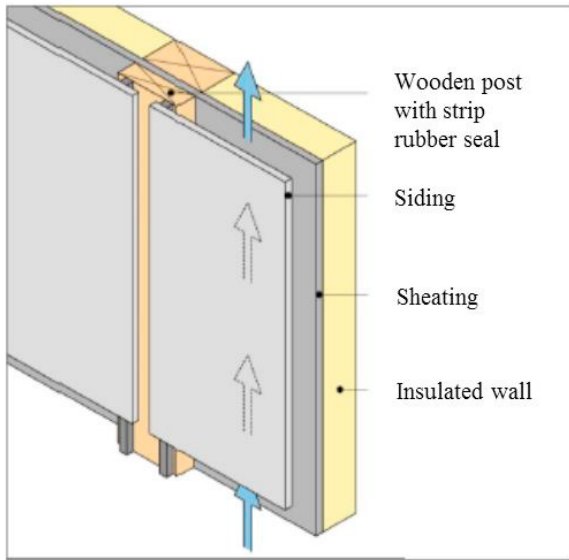


Fig. 1. (a) Sketch of a typical façade construction where a sheathing board is used as wind barrier. Adapted from [1];
(b) Photo of 8 mm thick MgO-board with a glass fibre mesh on both surfaces.



Fig. 2. (a) The MgO-board is placed facing the air gap, which is behind the siding boards made of natural slates;
(b) Salty water drops on a vertical MgO-board on the side that faces the insulation filled cavity inside the wall.

2. Chemical structure of MgO-boards

The binder in MgO-boards is formed by a chemical reaction between MgO and $MgCl_2$, typically in a weight ratio of 2.5-3.5 parts MgO to one part $MgCl_2$. The product is quite similar to Sorel cement, which was first produced by Stanislas Sorel in 1867 [2] and used as a flooring material. Various explanations about the product and its possible use and qualities can be found in literature [3-10]. The hydrated product is hard and strong but the product decomposes over time by contact with water or air at high relative humidity (RH). MgO-boards often have organic additions, such as sawdust, and inorganic fillers such as sand, lime or volcanic ash. Figure 4a shows a picture of an MgO-board from a stereo microscope at 10 times magnification. Figure 4b shows a microanalysis of a thin section of a specimen at 50 times magnification that reveals that the investigated MgO-board contains a high amount of very porous organic material, and a high number of fine spherical air pores. All investigated MgO-boards have glass fibre felt as facer.



Fig. 3. (a) Water drops containing chloride ions run down the vertical MgO-boards and drain out of the wall from behind the wall's siding boards; (b) Zink covering of the steel profile is corroded as a result of direct contact with salty leaked water from the adjacent MgO-board.

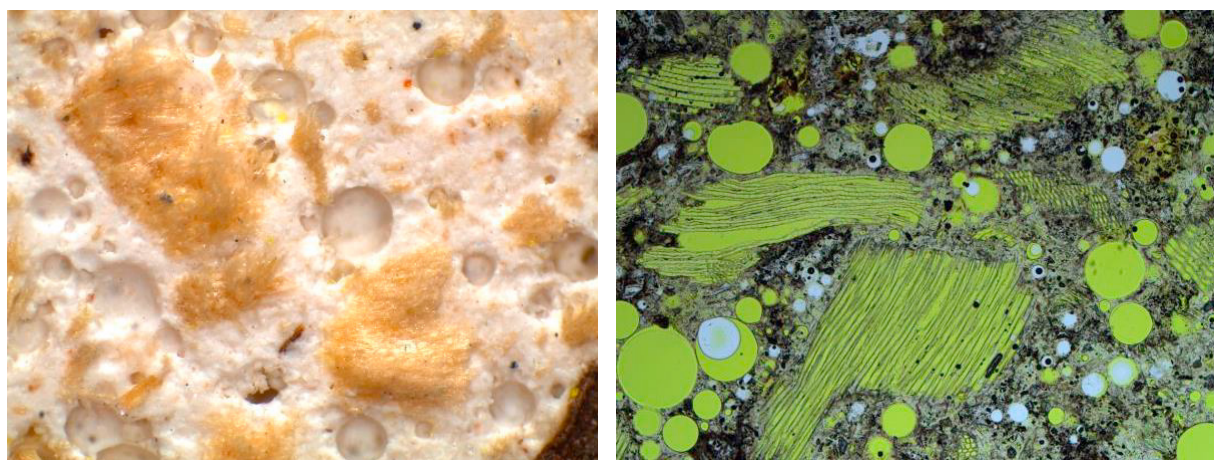


Fig. 4. (a) Cut of a MgO-board investigated in a stereo microscope at 10 times magnification; (b) Micro analysis of a thin section of a specimen at 50 times magnification.

3. Initial tests of moisture absorption in MgO-boards from surrounding air

8 mm thick MgO-boards were collected from four different buildings and used for measurement of moisture absorption and desorption curves. The magnesium-to-chloride ratios by mass of the boards varied from 2.7 to 3.3.

Moisture absorption in MgO-boards from the surrounding air was measured at three different levels of relative humidity at 23 °C: 35% RH, 80% RH and 95% RH. Before start of the moisture exposure, samples of size 5 x 4 x 3 mm were dried at 105 °C for 4 days. MgO-samples with a total weight of about 2 g were put in a petri dish, which was placed in a Teflon basket, and weighed without removal from the climate chambers. The specimens were weighed after 0, 1, 2, 3, 4, 5, 7 days and after 2 and 4 weeks. Specimens exposed to 35 % RH reached 6-7 % moisture content by weight after a week and then remained at that level, while specimens exposed to 80 % RH reached 26 % by weight after a week, and about 30 % after 4 weeks (48 % for one of the specimens). Results are presented in Figure 5 for specimens exposed to 95 % RH. Mould growth was seen after 30 days of exposure to 95% RH.

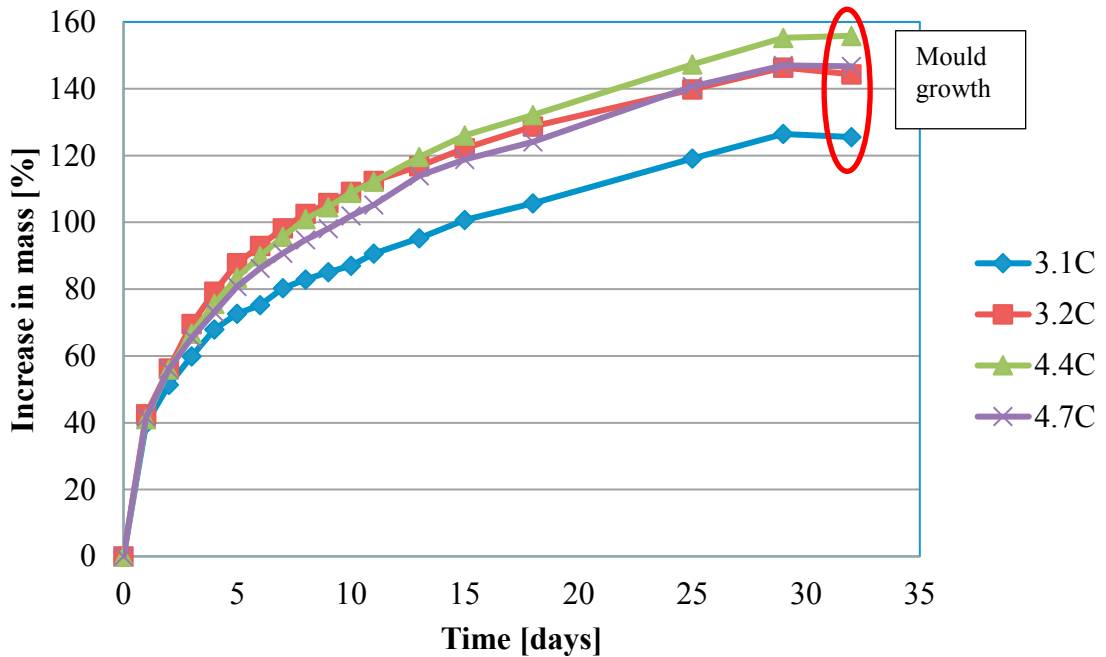


Fig. 5: Course of the moisture retention at 95% RH.

4. Further absorption and desorption measurements

Subsequent measurements of absorption and desorption were performed for the same four specimens that were analysed for initial moisture absorption at 35% RH and 80% RH, i.e. the initial dry masses were known. Desorption was measured for the specimens that were originally used for determination of initial moisture absorption at 80% RH. Before starting the desorption runs, the humidity of the climate chamber was increased from 80% RH to 92% RH in steps of 2% RH with the purpose of finding the level of RH at which the specimens began to leak salty water from the surface (sweating). The first part of the tests (at 95% RH) had revealed that specimens show severe sweating after one week, while boards at 80% RH apparently did not sweat after 80 days of exposure. In view of the risk of mould growth at RH higher than 92% RH, desorption was started at this RH.

After equilibrium had been attained at 30% RH, drying of two of the specimens was performed at 105 °C, while the two other specimens were dried over magnesium perchlorate at room temperature. The purpose of the repeated drying by the end of the sorption tests was to see if the dry masses were the same as before the measurements. The results were that one sample had lost 0.3% in dry weight, while the other three specimens saw dry weight losses of 12-15 %

Absorption was measured for specimens that were originally used for initial moisture absorption at 35% RH. The absorption points were measured from 35% RH and up to 92% RH. An example of the results of the absorption and desorption measurements is shown in Figure 6.

5. RH where sweating starts on the outside of the MgO-boards

As described above, the RH was gradually increased from 80% RH to 92% RH in steps of 2% RH with the purpose to find out at which RH the MgO-board starts sweating. It must be stated that the specimens stayed more than 30 days at 80% RH before the humidity was increased to 82% RH. The results of this gradual increase in RH showed the initially sweating on the specimens' surfaces or in the cup below the specimens at 84% RH.

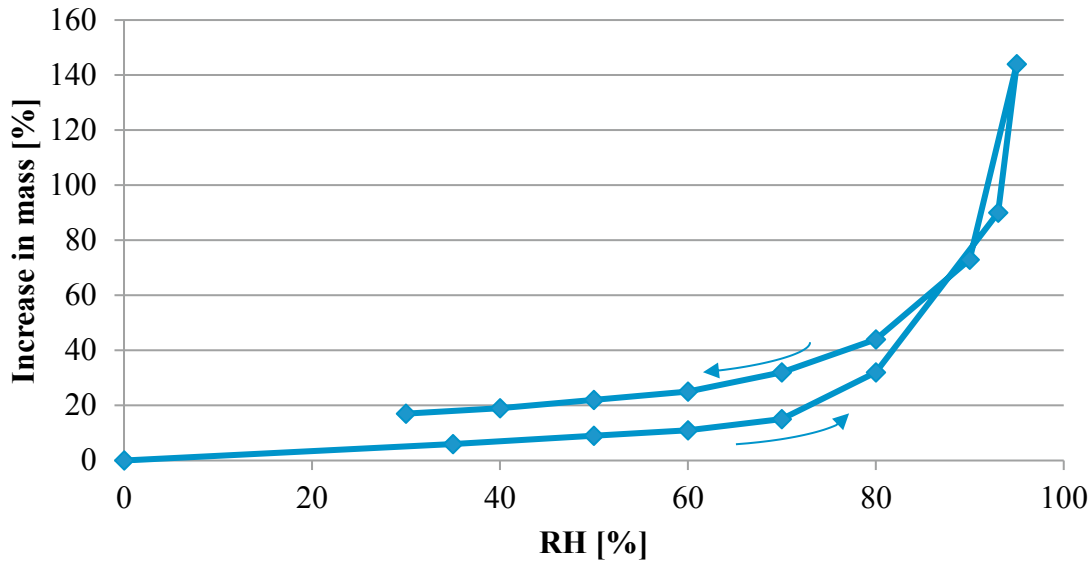


Fig. 6: Results of the absorption and desorption measurements for one of the specimens.

6. Water vapour resistance for MgO-board

The water vapour diffusion resistance of 8 mm thick MgO-board has been measured according to EN 12572 [11]. Three different series were carried out: 1) A dry cup series 0/50% RH performed by use of silica gel inside the cups, 2) a wet cup series 50/85% RH with saturated potassium chloride solution in the cups, and 3) a wet cup series 50/93% RH with saturated potassium nitrate solution in the cups. The climate chamber was operated at $50 \pm 2\%$ RH at 23.0 ± 0.1 °C. The measured results are reported as water vapour resistance Z_p with respect to relative humidity, RH, and water vapour permeability δ_p with respect to relative humidity, RH, in Table 1. The measured water vapour resistances are relatively low, and similar to the water vapour resistance of gypsum board.

Table 1: Water vapour resistance Z_p with respect to relative humidity RH, and water vapour permeability δ_p with respect to relative humidity RH.

Condition °C - % RH	Water vapour resistance, Z_p [GPa·m ² ·s/kg]	Water vapour permeability, δ_p ×10 ⁻¹² [kg/(Pa·m·s)]
23 – 0/50	1.5±0.2	5.3±0.5
23 – 50/85	0.7±0.1	11.4±2.1
23 – 50/93	0.5±0.1	16.0±3.9

7. Analysis of ‘tear’ drops from an MgO-board

A 50 x 100 x 8 mm³ piece of MgO-board was stored horizontally inside a desiccator over water at room temperature. The relative humidity inside the desiccator was 95-100% RH. After about a week, the first drops were formed on the surface of the MgO-board. After 2½ weeks, the drops were collected and analysed using Inductively Coupled Plasma Optical Emission Spectrometry and Ion Chromatograph equipment. The results are shown in Table 2.

Table 2: Amount of K⁺, Na⁺, Mg⁺⁺ and Cl⁻ ions in 'tear' drops from a MgO-board.

K ⁺ [mg/litre]	Na ⁺ [mg/litre]	Mg ⁺⁺ [mg/litre]	Cl ⁻ [mg/litre]
12237	4165	13733	40133

8. Corrosion

Salt from MgO-boards is highly corrosive on metal fasteners and profiles. Zink flashings of 0.8 mm corrode in 1-2 years. Electro galvanized steel profiles, nails and screws will corrode through to the steel in 1-2 years. Aluminum alloys have different resistance against corrosion and the best alloys have been seen undamaged for 2-3 years. Stainless steel of A2 and A4 can be used without problems. When MgO boards have been sitting on a wooden structure, MgCl₂ salt will have been absorbed by the wood, which is then corrosive to metallic fasteners other than stainless steel.

9. Discussion

The experiments described in the paper indicate that a relative humidity level of 84% RH is a limit above which the MgO-boards begin to absorb excessive amounts of moisture from surrounding air. Since this and higher values of relative humidity are typical in locations where exterior sheathing is to be used, it can be stated that MgO-boards cannot be a suitable product for this use. This is supported by the numerous examples of failures, which have been seen in recent years, where such boards leak salty water that cause damage on adjacent construction members of wood or metal, and which even over time lead to disintegration of the MgO-board itself. Information sheets exist both from Australia [12] and Denmark [13] that warn about the use of MgO-boards in humid environments.

10. Conclusions

It can be stated that MgO-boards are not suited as sheathing in exterior facades or any other application where the boards are in contact with a moist climate. At RH above approximately 84% RH the MgO-boards will form drops of salty water on the surfaces, and this water will be absorbed in wooden structures in connection with boards and water absorption will increase and can lead to mould growth on wood. The MgO-board itself is also sensitive to mould growth due to the content of organic material. Furthermore, the MgO board will itself also be disintegrated over time when it is exposed to high humidity due to the dissolution of the salts it consists of. If metal parts, such as galvanized steel, fasteners and flashings are in contact with MgO-boards, they will start to corrode within short time, leading to safety problems in the structure. Sheathing with MgO boards are now being replaced by other types of materials in a great number of buildings in Denmark.

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