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MAGNESIUM-OXIDE BOARDS CAUSE MOISTURE DAMAGE INSIDE FACADES IN NEW DANISH BUILDINGS

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Abstract
Magnesium oxide board, "MgO-board", is a factory-made sheathing board product, which has been widely used in the last 5 years in ventilated facades on new or renovated buildings in Denmark. In winter 2014/15, a number of problems began to appear with these boards since the boards and adjoining building elements seemed to suffer from some sort of disease, which manifested itself by damages such as significant moisture, boards leaking salty water ('tears'), corrosion of fittings and anchors and mould growth.
The damages were caused by the fact that MgO-boards absorb moisture from outside air in periods with high outdoor humidity (90-100% RH) and form water drops on the surfaces. The drops contain a high amount of soluble chloride ions and appear on the surfaces of the boards and may often run down the boards and to adjacent structures. Metal fixtures for the MgO- and siding boards may corrode heavily within a few years. The binder in MgO-boards is formed by chemical reaction between MgO and $MgCl_2$, known as magnesium oxychloride cement or Sorel cement. Also organic matter can be found in the material. The paper presents results of investigations of properties for moisture ab- and desorption curves and transport of MgO-boards.

1. Introduction

In winter 2014/15, many moisture damages were observed inside ventilated facades of new or newly renovated Danish buildings. The moisture damaged facades were constructed with sheathing made of magnesium oxide boards (MgO-boards) facing the air gap behind the material used for exterior siding. MgO-boards have often been used as sheathing behind a ventilated air gap as shown in Figure 1 and Figure 3. A photo of a MgO-board is shown in Figure 2.

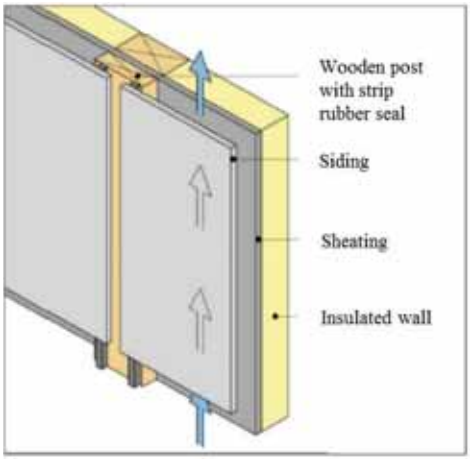

Figure 1: Sketch of a typical façade construction where a sheathing board is used as wind barrier. Adapted from [1].

Figure 2: Photo of 8 mm thick MgO-board with a glass fibre mesh on both surfaces.

The observed damages were caused by the fact that MgO-boards absorb moisture from outside air. Water drops containing chloride ions appear on the outside of the boards – often so many that they run down the vertical boards and out via the air gap behind the siding boards (see Figures 4 and 5). The metal mountings for the MgO-boards can corrode heavily within a few years, cf. Figure 6.

Figure 3: The MgO-board is placed facing the air gap, which is behind the siding boards made of natural slates.

Figure 4: Salty water drops on a vertical MgO-board on the side that faces the insulation filled cavity inside the wall.

Figure 5: The water drops containing chloride ions run down the vertical MgO-boards and drain out of the wall from behind the wall's siding boards.

Figure 6: The zink covering of the steel profile is corroded as a result of direct contact with salty sweat or 'tear' drops from the adjacent MgO-board.

2. Chemical structure of MgO-boards

The binder in MgO-boards is formed by a chemical reaction between MgO and $MgCl_2$, which is known as magnesium oxychloride cement, or Sorel cement, and which is a non-hydraulic cement first produced by Stanislas Sorel in 1867 [2] mainly to be used as a flooring material. The cement is a mixture of magnesium oxide and magnesium chloride – typically with a weight ratio of 2.5-3.5 parts MgO to one part $MgCl_2$. The magnesium oxychloride cement is formed by mixing a magnesium chloride ($MgCl_2$) brine solution with a magnesium oxide (MgO) composition in a selected stoichiometric ratio of $MgCl_2$, MgO, and H_2O. Various explanations about the product and its possible use and qualities can be found in literature [3-10]. The literature tells that the chemical reaction can proceed in different ways dependent on the surrounding conditions. A possible chemical reaction forms the 5 phase magnesium oxychloride cement composition [10]:

$$5\ MgO + MgCl_2 + 13\ H_2O \rightarrow 5\ Mg(OH)_2 \cdot MgCl_2 \cdot 8\ H_2O$$

The hydrated product is hard and strong but the product decomposes over time by contact with water or air at high relative humidity (RH). The durability problems with this material are reason that the material has so to speak been forgotten in the following years. However, within the last 10 years a relatively high number of so-called MgO products (MgO-boards) have been put on the market within the building industry. MgO-boards have a composition, which is very similar to hydrated Sorel cement but has both organic additions, such as sawdust (wood flour), and inorganic filler additions such as sand, lime or volcanic ash – even though it may not be stated in the data sheets for MgO-boards. Figure 7 shows a cut of an MgO-board analysed in a stereo microscope at 10 times magnification. The analysis shows that the investigated MgO-board contains a high amount of organic material such as wood fibres or sawdust, and a high number of fine spherical air pores. Figure 8 is a micro analysis of a thin section of a specimen at 50 times magnification that verified both the considerable

amount of very porous organic material and the many fine spherical air pores. All investigated MgO-boards have some type of fibrous reinforcement (glass fibre mesh) on the faces.

Figure 7: Cut of a MgO-board investigated in a stereo microscope at 10 times magnification.

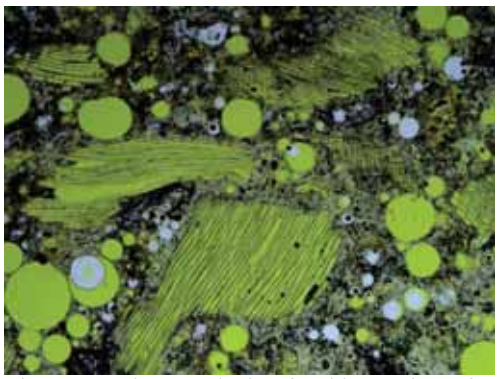

Figure 8: Micro analysis of a thin section of a specimen at 50 times magnification.

3. Materials for measurements

The 8 mm thick MgO-boards used for measurements of the hygroscopic properties, i.e. moisture ab- and desorption curves, have been collected from four different buildings. The different magnesium-to-chloride ratios by mass of the four boards are shown in Table 1. Specimen numbering for ab- and desorption curves is shown in Table 2.

Table 1: Lab specimen number for the four different 8 mm MgO-boards with each product's magnesium-to-chloride content ratio by mass.

Lab specimen number	Mg/Cl
3.1	3.3
3.2	1.7
4.4	2.2
4.7	2.7

Table 2: Specimen numbering for ab- and desorption curves.

35% RH	80% RH	95% RH
3.1A	3.1B	3.1C
3.2A	3.2B	3.2C
4.4A	4.4B	4.4C
4.7A	4.7B	4.7C

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

The initial moisture absorption in MgO-boards from the surrounding air was measured at three different levels of relative humidity at 23 ^{0}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 ^{0}C for 4 days, and cooled to room temperature. MgO-samples with a total weight of about 2 g were placed

in a petri glass dish, which was placed inside a basket made of Teflon. Weighing of the baskets were performed without opening the front doors of the climate chambers, as the baskets were hung up one by one below the balance by means of a steel string. Figure 9 shows the climate chamber where the actual RH is created by mixing flow of dry air with flow of saturated air. Based on a calibrated RH-sensor the connected PID-system regulates the dry airflow and the saturated air flow for obtaining the wanted RH. In this way, the RH is created in wanted steps. Figure 10 shows the specimens in the petri glass dishes placed in the baskets. The measurements were performed after 0, 1, 2, 3, 4, 5, 7 days and after 2 and 4 weeks. The results are presented in Figures 11, 12 and 13. Indication of mould growth on specimen 4.4C was seen after 30 days of exposure to 95% RH, cf. Figure 14.

Figure 9: The climate chamber.

Figure 10: Specimens in the petri glass dishes placed in baskets.

5. Further absorption and desorption measurements

5.1 Subsequent absorption and desorption measurements on MgO-boards

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. The climate chamber used is shown in Figure 9. Desorption was measured for specimens 3.1B, 3.2B, 4.4B and 4.7B, which originally were 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 form drops (i.e. sweating or 'crying') on the surface. We knew from the first part of the tests (at 95% RH) that specimens showed severe sweating starting 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. Desorption points were measured from 92% RH and below.

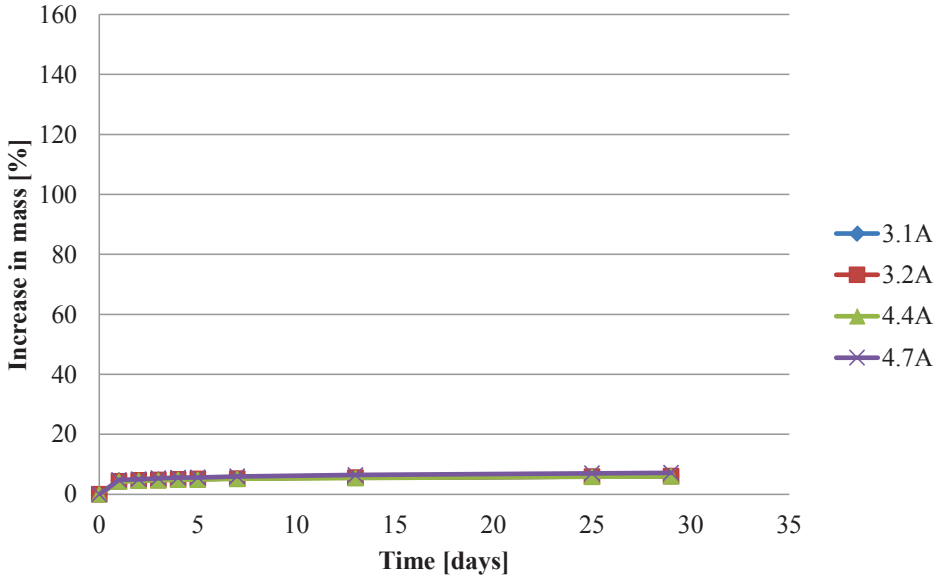

Figure 11: Course of the moisture retention at 35% RH.

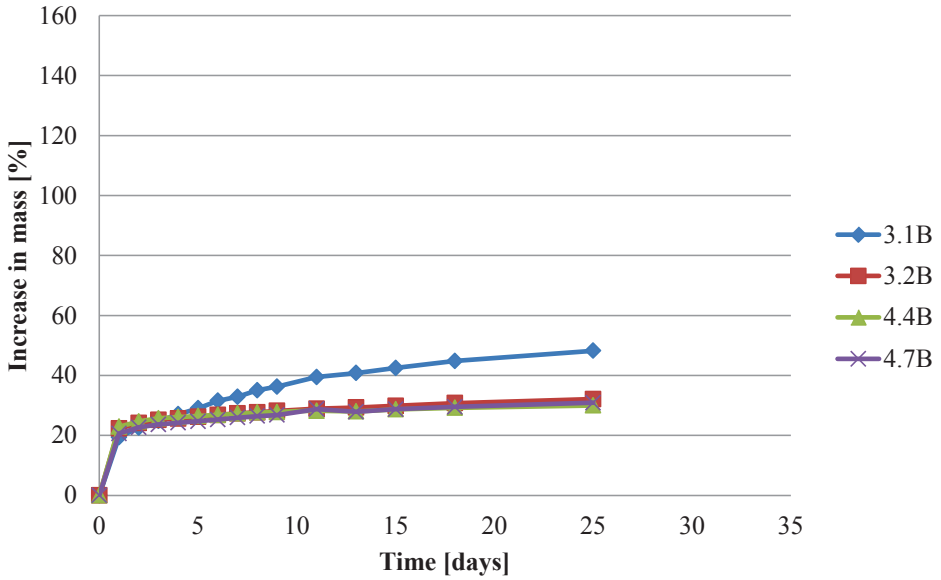

Figure 12: Course of the moisture retention at 80% RH.

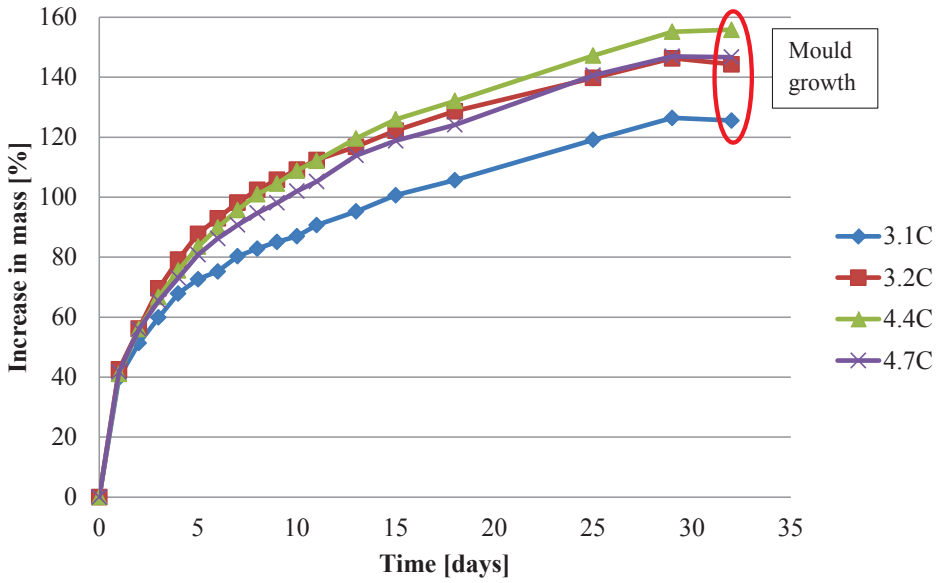

Figure 13: Course of the moisture retention at 95% RH.

Figure 14: Indication of mould growth on specimen 4.4C after 30 days of exposure to 95% RH.

After equilibrium of the specimens had been attained at 30% RH, drying of the specimens 3.1B and 3.2B was performed at 105 ^{0}C, while specimens 4.4B and 4.7B were dried over magnesium perchlorate at room temperature. The purpose of using the two different drying methods was partly to see if a difference in dry mass would occur due to the drying method,

and to see if the initial dry masses were the same as before desorption measurements. The drying results are given in Table 3.

Table 3: Result of difference in dry mass (mass change relative to specimens' mass before desorption measurements) for the two different drying methods: 105 ^{0}C oven drying and magnesium perchlorate drying at room temperature.

Drying method	3.1B	3.2B	4.4B	4.7B
105 ^{0}C	- 15 %	- 0.3 %	-	-
Magnesium perchlorate	-	-	- 12 %	- 12 %

Only specimen 3.2B has nearly the same dry mass as the initial dry mass as before ab- and desorption measurements while the three other specimens have lost 12-15 % in mass independent of drying method. Specimen 3.2B has the lowest Mg/Cl-ratio, cf. Table 1.

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 15.

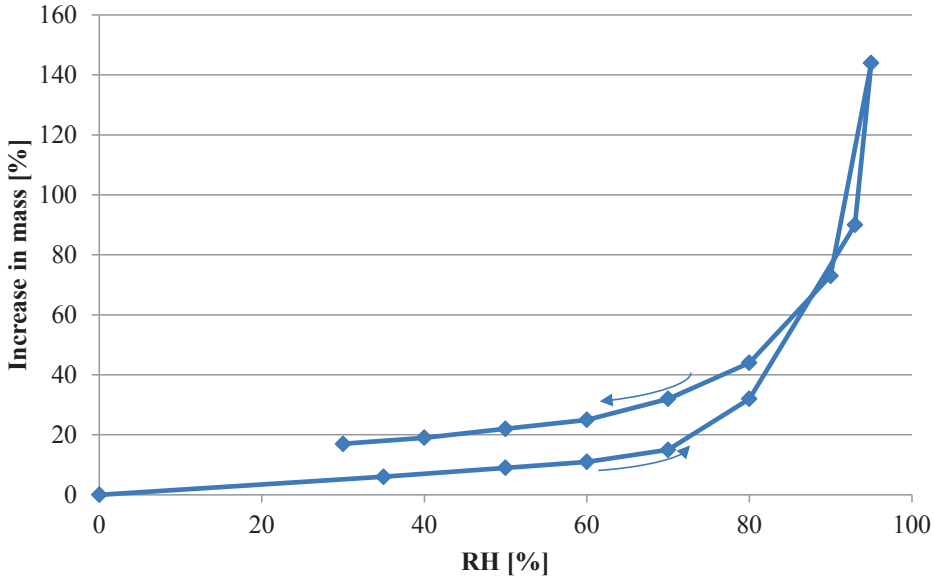

Figure 15: The results of the absorption and desorption measurements for specimen 3.2.

5.2 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.

5.3 Absorption measurements on wood infected by 'tear' drops

The pine wood posts supporting the adjacent MgO-boards inside the façade construction absorb the water drops ('tear' drops) from the MgO-boards. The 'tear' drops contain relatively high amounts of chloride ions. Infected wood from a post from a house, as well as non-infected wood, have been used for absorption measurements as follows: First, the infected wood and the non-infected wood pieces were conditioned to attain equilibrium at 50% RH. They were then conditioned to equilibrium at 80% RH, and finally to equilibrium at 90% RH. The absorption curves for the infected wood and the non-infected wood are shown in Figure 16.

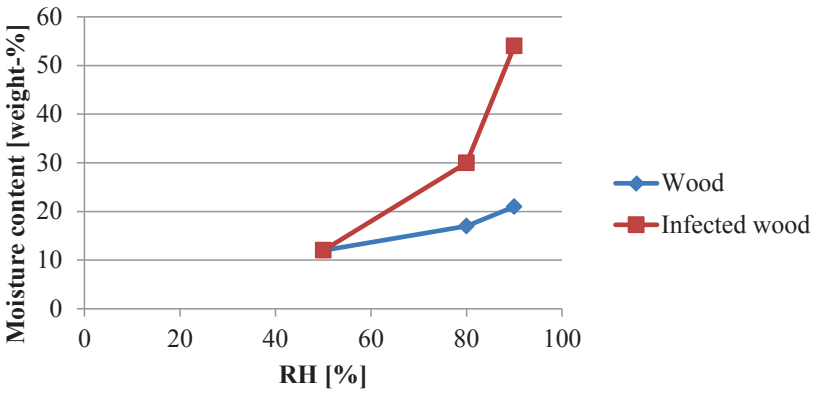

Figure 16: The absorption curves for the infected wood and the non-infected wood.

6. Water vapour resistance for MgO-board

The water vapour resistance of 8 mm thick MgO-board has been measured according to EN 12572 [11], i.e. by using the so-called 'cup method'. Three parallel cups were used in each series: 1) The dry cup series 0/50% RH performed by use of silica gel inside the cups, 2) the wet cup series 50/85% RH by use of saturated potassium chloride solution inside the cups, and 3) the wet cup series 50/93% RH by use of saturated potassium nitrate solution inside the cups. During testing, the climate chamber was 50±2% RH at 23.0±0.1 ^{0}C. The cross sectional area of the specimen was 5000 mm^2. The air velocity above the specimens was 0.8 m/s. 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 4.

The measured water vapour resistances are relatively low, and similar to the water vapour resistance of gypsum board.

Table 4: Water vapour resistance Z_p with respect to relative humidity RH, and water vapour permeability δ_p with respect to relative humidity RH.

Condition ^{0}C - % RH	Water vapour resistance, Z_p [GPa·m^2·s/kg]	Water vapour permeability, δ_p $\times 10^{-12}$ [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 piece of MgO-board of size 50 x 100 x 8 mm^3 was stored horizontally inside a desiccator above water at room temperature. The relative humidity inside the desiccator was 95-100% RH. After about a week, the first 'tear' drops were formed on the upper surface of the MgO-board. After 2½ weeks, the drops were collected and analysed using ICP (Inductively Coupled Plasma Optical Emission Spectrometry) and IC (Ion Chromatograph) equipment at Technical University of Denmark for among other K^+, Na^+, Mg^{++} and Cl^- ions. The results are shown in Table 5.

Table 5: Amount of K^+, Na^+, Mg^{++} and Cl^- ions in 'tear' drops from a MgO-board.

K^+ [mg/liter]	Na^+ [mg/liter]	Mg^{++} [mg/liter]	Cl^- [mg/liter]
12237	4165	13733	40133

8. Discussion

The experiments described in the paper seem to indicate a relative humidity level of 84% RH as a limit above which the MgO-boards that have been tested begin to absorb excessive amounts of moisture from the 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.

9. Conclusions

For this reason, 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.

References

[1] Brandt, E. et al., SBi-instruction 224: Moisture in buildings. In Danish. Danish Building Research Institute, Aalborg University Copenhagen (2009).
[2] Bryson, H.C. Non-compliant products concrete cancer. *Sands, Clays and Minerals* — Vol. 3, Issue 2, pp. 137-140 (1937)
[3] Herholdt, A. et al., The Concrete Book. In Danish. Aalborg Portland (1985)
[4] Thomas, R., What Is MgO Board? *Wall & Ceiling Magazine, USA (2007)*
[5] ICC EVALUATION SERVICE, INC. (2007) Acceptance criteria for fiber-reinforced magnesium-oxide-based sheets. AC386 (2007)
[6] ICC EVALUATION SERVICE, INC., Magnum board. ICC-ES Evaluation Report, ESR-2880, Revised June 2015 (2015)
[7] MBP MAGNUM BUILDING PRODUCTS, Helping The World Building Green. General. MBP Edition -IP, LLC (2015)
[8] Exova, Evaluation of insulated panels with MgO boards facings for water vapor permance in accordance with ASTM E 96/E 96 M – 05 (2010)
[9] JamesHardie (2010): Information on Magnesium Oxide (MgO) and Magnesium Chloride (MgCl) building products. Technical Advisory #23 (2010)
[10] Maya Magstone Inc., Magnesium oxychloride cement. Patent WO2008063904A2 (2008)
[11] EN 12572 Hygrothermal performance of building materials and products – Determination of water vapour transmission properties. European Committee for Standardization, Brussels, Belgium (2001)
[12] Dincel & Associates, Non-compliant products concrete cancer of concrete walls having permanent formwork with fibre cement (FC) sheets and magnesium oxide (MgO) boards
[13] BYG-ERFA. Fugtsugende vindspærreplader. Experience sheet (21) 150505.