Tech Solutions 518.3

Industry Research and Standards for Magnesium Oxide (MgO) Sheathing in the U.S. Construction Market

Summary

Magnesium Oxide (MgO) sheathing is growing in popularity as a high-performance exterior sheathing and composite element for commercial and multifamily buildings. Yet, designers and contractors are often hearing about or experiencing MgO sheathing for the first time on their projects. MgO sheathing is based on magnesia cement (also known as Sorel cement), which has a long and extensive history of being used for building bridges and stadiums or in industrial insulating materials.[1] A more recent application of magnesia cement is as a fire-resistive structural sheathing that provides many of the structural advantages of wood sheathing but with superior resistance to mold and mildew, weather resistance, and more.

As with all construction materials, customer experiences can vary based on how the material is manufactured, designed, installed, and warrantied. Here, DuPont Performance Building Solutions provides recommendations for specifying an MgO-based sheathing in high performance building enclosures.

MgO Sheathing in U.S. Construction

The use of MgO in construction and industrial materials is not new. Refer to Tech Solutions 518.0 for more information. What is new is the manufacturing of MgO as sheathing in ways that realize advanced fire-resistive, structural attachment, and water-resistive properties, along with other unique benefits for use as a replacement for common products like gypsum, oriented strand board (OSB), and plywood.

Why is this needed? Over the past 20 years, the pace of construction has increased as manufacturers and builders have sought to introduce efficiency throughout their projects, including in building enclosure materials. Many sheathing products now incorporate air and water barriers, providing both structural and weather resistance benefits. Others provide fire-resistance using gypsum or fire treated wood-base sheathing.

Additional types, mainly Structural Insulated Sheathing (SIS), include insulation and sometimes water-resistive barriers as well. Importantly, common wall systems using exterior gypsum sheathing in combination with at least one layer of interior 5/8" Type X gypsum satisfies the building code fire requirements, but do not offer any cladding attachment benefits. On the other hand, wall systems using fire-resistive plywood provide structural benefit but are too combustible to meet stringent building code requirements in Types I and II construction under the IBC.

MgO Standards Development in the U.S.

Since 2014, organizations including the **Magnesium Oxide Cement Association (MOCA)**, the global industry association for companies involved in magnesium oxide-based ceramic cement building products, have been actively working to develop industry standards based on scientific research from across the world. These standards are needed to support MgO sheathing's predicted exponential growth in the U.S and beyond.

A multitude of efforts are underway to develop MgO sheathing standards in the U.S. with a goal of being the most rigorous globally. Currently available standards and ongoing development efforts include:

- **MOCA** is working with U.S. and international manufacturers and allies to develop a series of standards specific to North American markets. Currently, MOCA maintains a draft standard for a grading classification for MgO sheathing that manufacturers and suppliers can voluntarily follow.

DuPont™ ArmorWall™ Plus FR SIS undergoes rigourous third-party testing to ensure a high-quality MgO sheathing product.

- The **China Magnesite Materials Association (CMMA)** maintains a comprehensive suite of manufacturing and use standards for MgO sheathing that is used as a benchmark in other countries developing their own standards.

- The **International Code Council Evaluation Service (ICC-ES)** is an organization which aims to help design professionals feel confident that products will meet code requirements. It is actively involved in establishing MgO sheathing acceptance criteria to maintain a high quality of product being used in the U.S. market. ICC-ES has issued Acceptance Criteria AC386 which references ASTM standards for gypsum and calcium (Portland) cement boards. Additionally, AC530 was published for MgO combined with an air and water-resistive membrane. Development is currently underway on acceptance criteria for a composite SIS material using MgO sheathing in combination with insulation and an integrated air and water-resistant barrier.

- **ASTM International**, formerly known as American Society for Testing and Materials, is another international standards organization that is actively developing voluntary consensus technical standards for the MgO sheathing industry. Industry stakeholders including MOCA and DuPont are members of the ASTM E06 Committee on Performance of Buildings which is actively working to develop and publish international consensus standards for MgO. First in line is likely a "Purity Standard" that sets the minimum material composition for MgO used in sheathing supplied to or manufactured in the U.S and Canada.

What the Research Shows

Research by MOCA, universities, and independent third parties yield impressive results for MgO sheathing, particularly when compared to traditional materials that it replaces, such as gypsum, OSB, and plywood.

Like with any construction material, some projects have run into bad experiences with MgO sheathing. This was particularly true with early adopters of MgO boards who imported material that was ill-suited for their application. One such example is a study from Denmark highlighting an application as a windbreak where poor quality MgO boards not designed for exterior applications were used, resulting in significant problems.[2] Similar errors were repeated to a lesser extent in other countries such as the United Kingdom and Australia. It is essential to understand the many preventable causes of these problems and the measures taken by responsible industry stakeholders who are following proven specifications to prevent these issues in the future. With these measures in place, MgO sheathing remains a reliable and highly beneficial product.

Many years of extensive research and testing on MgO sheathing have affirmed a variety of industry best practices to follow. Early in its use as an exterior sheathing material, it was assumed that any MgO board would perform well when encountering bulk water, moisture, or vapor as part of an exterior sheathing assembly. Unfortunately, many suppliers in China produced MgO boards as gypsum replacement for interior wall board applications, which means that they were not designed to meet application requirements as exterior sheathing. It has since been clarified that MgO sheathing should not be expected to perform in all exterior conditions and climates due to its moisture absorption properties. Today, a water-resistant barrier (WRB) integrated with the MgO sheathing or applied to the MgO sheathing itself has become the standard best practice to protect the MgO sheathing from bulk water, wind driven rain and surface condensation. The sheathing is still able to manage moisture vapor through its permeable matrix, which it does better than traditional materials such as gypsum, OSB, and plywood.

Dr. Steven Doggett, a Prinipal Scientist specializing in moisture issues in building enclosure products including MgO recently completed a study on MgO sheathing that affirmed the product's beneficial properties and causes of past failures:

> *"Further benefit is gained by its (MgO) ability to safely store and release moisture without adverse effects such as weeping, a phenomenon observed in MgO panels having flawed magnesium-to-chloride ratios. In such scenarios, moisture adsorption leads to leaching of mineral salts – a condition implicated in metal corrosion and MgO degradation. With proper chloride ratios, this defect of weeping is entirely avoided. Ongoing studies of the ArmorWall™ MgO board support this conclusion. My work also shows a board having consistently favorable free chlorides and an absence of weeping under moisture extremes."*[3]

Research has also determined that the molecular ratios used to make a board, specifically the respective amounts of water, magnesium chloride and magnesium oxide, is critical to the long-term performance of MgO sheathing. Using wrong ratios or failing to properly cure the boards to complete the chemical reactions have been proven to be the cause of halogenation and other problems experienced on projects.

As recently as ten years ago, a lack of standards and regulations internationally led to the use of poor quality MgO sheathing, contributing to issues on projects in Europe and elsewhere. Continued learning through lab and field research has led manufacturers and U.S suppliers to develop better quality control procedures for the MgO sheathing itself. With firm standards now in place in China and more in development, credible suppliers have many ways to ensure they produce high quality MgO sheathing consistently.

What to Look for in Good vs. Bad MgO Sheathing and Products That Use It

When considering which type and brand of MgO sheathing to use in a U.S. project, MOCA recommends that stakeholders "Always purchase boards from reputable suppliers who can provide current test reports for leachable ion content and that have passed the appropriate material property tests." These material property tests should include density and water absorption measurements, mechanical strength and dimensional stability testing. Ensuring that the product manufacturer(s) or raw materials supplier(s) you choose use robust quality control

processes will help prevent problems on your project.

MOCA and industry stakeholders recommend close consideration of the following criteria:

- ***Country of Origin and Manufacturer:*** MgO sheathing used on projects in the U.S. is most commonly sourced from manufacturers in China, with North American manufacturing expected in the next few years. The type, ingredients, quality, and performance of MgO sheathing vary based on the country of origin and the manufacturer. Take steps to ensure that the MgO sheathing you are considering is sourced from a supplier that follows and documents conformance to industry accepted standards.

- ***Type:*** There are many ways to grade the quality and performance of MgO sheathing. First, it is important to recognize the type of MgO sheathing. The two primary types used in the U.S. are based on Magnesium OxiChloride cement (Sorel cement, or MOC) and Magnesium OxiSulfate (MOS). MOC is the more prominent of the two with a more extensive history of usage in the U.S. construction market. Newer to the market is MOS-based sheathing that generally offers strong fire-resistance but lower structural strength, with studies needed on long-term stability. While MOS may seem like an obvious answer to eliminate any risk of chloride leaching, it suffers from high water absorption, similar to low-quality MOC boards used in Denmark. See for instance ***Figure 3*** below, included in the Danish study by Nielsen et al.[4] showing boards with 50% water uptake in humid conditions, leading to both "crying". Such materials would not pass current requirements for exterior sheathing applications.

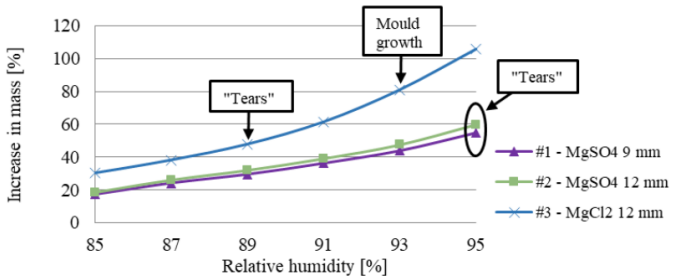


Fig. 3. Moisture retention curve from 85% RH to 95% RH measured over the course of seven weeks. The increase in mass includes the weight of "tears".

- ***Standards Listings and Test Reports:*** As with many other construction materials, one of the best ways to ensure the MgO sheathing product you're considering is of acceptable quality is to verify that it meets minimum industry standards. Easy ways to do this include looking up publicly available ICC-ES, Dr. J Engineering, and other product listings from credible third parties based on published industry standards, such as those from ASTM. Reputable MgO sheathing suppliers voluntarily obtain these certifications, listings, and third-party test reports to demonstrate their products meet rigorous code, life safety, and performance standards.

- ***Technical Criteria:*** Close consideration of technical criteria is also recommended. Project teams should seek expert guidance and only select MgO sheathing that meets rigorous standards to ensure low water absorption, stability regarding chloride leaching (for MOC-based sheathing), mechanical strength, and more. Specific criteria to look for includes:

    - *Water Content:* It is critical that the manufacturing process uses the correct molar-ratio of water, magnesium oxide and magnesium chloride or sulfate to achieve durable properties of the final product. Project teams should seek an MgO supplier with a rigorous chloride leaching testing program.

    - *Density:* Board with densities lower than 1000 kg/m3 are often too porous to qualify for exterior sheathing applications. The density of each sample should vary by no more than 0.5%.

    - *Shrinkage:* The shrinkage of each sample should be less than 0.3% by volume.

    - *Simple Flexural Breakage Test:* Well-made sheathing will pass this stress test while poorly made sheathing will break due to brittleness.

    - *Visual Appearance:* Well-made sheathing will have a uniform appearance with few, if any, surface pinholes and/or voids.

    - *Color:* The color of the sheathing should be uniform with no blotchiness, sheathing without colorants added should be a uniform off-white color.

    - *Reinforcing Mesh:* The wrap and weft of the woven fiberglass mesh should be aligned parallel to the edges of the sheathing.

    - *Voids:* Looking at the edges of the sheathing while stacked in the lift you should see few to no large voids in the sheathing core cement matrix.

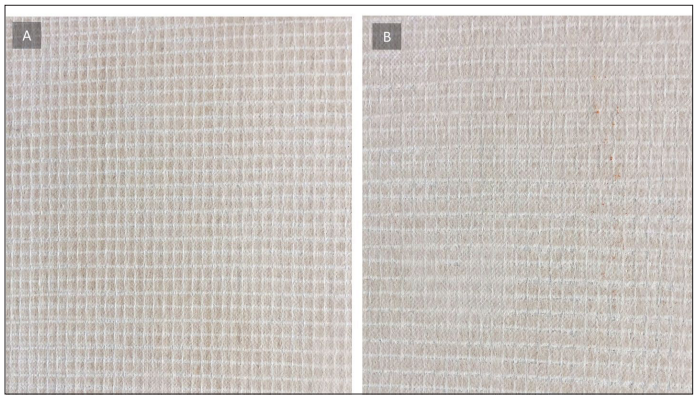
    - *Wet and Dry Bending Tests:* The saturated and conditioned bending strength test results should be within 20% of each other.

    - *Halogenation:* Sheathing should not develop "salty tears" on the bottom surface when kept at 30 to 35° C with 90 to 95% humidity for 72 hours at a minimum. No halogenation during longer duration testing, such as 90 days, is achieved by top MgO sheathing products.

The Most Critical Component to MgO Sheathing: The Weather Barrier

Extensive research and in-field analysis of MgO sheathing has identified one area that cannot be overlooked: an approved water-resistant barrier solution must be integrated into the product or added on top of the product when it is used as an exterior sheathing solution on any building. The building code requires the use of a WRB in all buildings and MgO sheathing is not able to perform that function on its own. When the MgO sheathing does not include an integrated WRB, it is important to account for MgO sheathing having different surface characteristics than many common construction materials such as gypsum, OSB, and plywood. Ideally, the WRB should be tested and approved in conjunction with the MgO sheathing to ensure long-term performance.

When a compatible WRB is not provided, issues with water absorption and WRB delamination may occur, posing a substantial risk to the building enclosure. Determining the suitability of use of a WRB with MgO should include testing such as adhesion of the WRB before and after stressors like water exposure, QUV aging, etc. Water exposure could consist of hydrostatic head per AATCC 127, full water submersion or via the test method developed by Dr. Steven Doggett, applying a 21.6" face column directly onto the coated sheathing of two panels.[3]



A pair of test specimens together (above) with their back sides (below) after 30 days of Dr. Doggett's 21.6" face column testing.

The permeability of the WRB should also be considered when determining how the system will perform long term: lower permeability membranes will need to be installed such that the MgO panel is able to dry any residual moisture (such as construction moisture) to the inside and not be trapped within the panel, which could cause premature delamination of the WRB.

DuPont offers a variety of building enclosure products with high quality MgO sheathing for multifamily and commercial markets.

DuPont™ ArmorWall™ Plus Fire-Rated (FR) Structural Insulated Sheathing (SIS) and ArmorWall™ SP Plus FR SIS are ICC-ES listed, high strength, fire-resistant exterior wall sheathing products that incorporate DuPont™ ArmorBoard, an MgO sheathing, as a core componentalong with a factory-applied, high quality air and water-resistive barrier and a fused polyurethane insulation layer. Both products incorporate five traditional building enclosure elements into a single panel product: structural sheathing, fire-resistance, air barrier, water-resistive barrier, and a high-performance continuous insulation layer.

DuPont™ ArmorWall™ SP Plus FR SIS has an additional layer of MgO sheathing on the interior side, making it a 2-hour fire-rated product. Seen here on the 1525 N Elston multifamily building in Chicago, IL.

The five-in-one system can replace several traditional individual components that, on their own, add cost, labor and complexity to a project. With ArmorWall™ Plus FR SIS and ArmorWall™ SP Plus FR SIS, there are fewer components and materials to install, which has the ability to reduce the number of installation revolutions to one. One installation revolution enables both products to help reduce the time needed to weather-in a building by weeks, not days, further reducing labor, material, and other project costs.

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