Feature

Emerging Materials: Benefits and Limitations of MgO-Based Sheathing Products

By Adam Broderick, PhD; Michelle Hudack, PhD; Michal Porter-McCarthy, PhD; Gregory Stewart; and Mark Rickard, PhD

This paper was presented at the 2025 IIBEC/OBEC BES.

CHEMISTRY OF CEMENTITIOUS MATERIALS

Cement is a generic term for a binding material commonly used in construction, composed primarily of inorganic crystals. These crystals are formed in two general steps. First is hydration, during which activated cement compounds (e.g., calcium silicates in portland cement, calcium sulfate in gypsum, or magnesium oxide [MgO]) dissolve and then react with water. This is followed by solidification, where the ingredients, which include hydrated cement, additional water, and other salts present in the admixture, arrange themselves via a complex series of steps into a regular lattice of alternating components.[1]

The shape, size, composition, and structural pattern of crystals that form in these processes depend on many factors, including concentration of different components, temperature and water content during cure, surface area of the activated cement, and the presence of catalyst-like compounds that promote or inhibit certain crystal forms. The nature of the crystals that form can vary substantially in their properties, even in cases where the initial mixtures are identical but curing conditions favor formation of one type of crystal or packing density over another.

Generally, practitioners in the space of building enclosures are likely to be familiar with concrete (calcium silicate or portland cement with aggregate) and gypsum (recrystallized calcium sulfate) and the conditions under which one or the other can be used without risk of compromising the function of the materials. In contrast, cements based on MgO, which differ in key ways from both cement and gypsum, are less widely understood and may be unnecessarily avoided or used incorrectly.

MGO CEMENT AND BOARDS

Calcined MgO readily converts to magnesium hydroxide, a soft mineral similar in consistency to gypsum, when hydrated as a single component. When hydrated in the presence of magnesium salts such as magnesium chloride ($MgCl_2$), magnesium sulphate ($MgSO_4$), or magnesium phosphate ($MgPO_4$), a much harder and more durable microscopic structure is formed. To date, commercially viable construction panels have been produced using cements based on $MgCl_2$ and $MgSO_4$, colloquially referred to as *chloride* or *magnesium oxychloride (MOC) boards* and *sulfate* or *magnesium oxysulfate (MOS) boards,* respectively.

For both types of boards, a particular crystalline phase has been identified that provides maximum strength and resistance to water damage (**Table 1**). Unlike cement or gypsum, which form via the hydration of a single primary component, MgO involves synergistic effects of two different components in addition to water, and manufacturers must take care to ensure that raw material ratios and curing conditions allow the formation of the correct crystalline phase.

The manufacturing process involves precise mixing of dry and wet components, casting, and curing under controlled conditions to ensure consistency and quality. A typical board formulation is shown in **Table 2.** Quality control is critical, focusing on the homogeneity, purity, and reactivity of MgO; ratio control with the components of the cement; as well as proper curing processes. Poorly manufactured boards may contain improperly formed cement crystal phase or excess salts that can leach out of the cement, both which can lead to reduced strength and increased corrosion risk.

EARLY USE AND STANDARDIZATION OF ACCEPTANCE CRITERIA

Early applications of MgO panels in the construction industry in Scandinavia as part

TABLE 1. Comparison of magnesium oxide (MgO) with other types of cement materials.

Type of inorganic cement	Crystalline structure	Typical compressive strength	Hydrolytic/temperature stability
MgO-based	$5Mg(OH)_2 \cdot MgCl_2 \cdot 8H_2O$ $5Mg(OH)_2 \cdot MgSO_4 \cdot 7H_2O$	50–200 MPa 40–100 MPa	Variable stability when soaked; Stable to 90°C/194°F (dry)*
Gypsum	$CaSO_4 \cdot 2H_2O$	2–3 MPa	Soluble in water; stable to 150°C/302°F (dry)
Portland cement	$(3CaO \cdot SiO_2) + (2CaO \cdot SiO_2) + (3CaO \cdot Al_2O_3) + (4CaO \cdot Al_2O_3 \cdot Fe_2O_3)$	30–55 MPa†	Stable to water saturation, temperatures >200°C/392°F

** Walling and Provis (2016), † Zhang (2011)*

TABLE 2. List of common raw materials used in manufacturing a typical magnesium oxychloride board.

Raw material	Approx. percentage of board	Purpose
Magnesium oxide	30–45%	Cement formation
Magnesium chloride	30–45%	Cement formation
Water	10–25%	Cement formation and filler hydration
Perlite	0–20%	Reduces density
Wood flour	0–15%	Reduces density, increases toughness
Additives	<2%	Defoaming or foaming, water stability additives, processing aids

Data from Doggett and Davis (2024).

of the exterior building enclosure led to a significant failure. Boards were not designed specifically for exterior use and lacked the protection of a weather-resistive barrier, making them even more susceptible to moisture condensation in the cold humid climate. Even so, while quality boards may have resisted degradation, there was a large variability in the quality of manufacturing likely due to poor control of compositions, resulting in variability in the water stability of those boards. Because of this, many boards suffered from degradation of the MOC cement, leading to issues with leaching, corrosion of adjacent metals, mold growth in wood structure, and loss of panel strength.[5] In response to these issues and due to the lack of existing MgO standards or guidance in model building codes, industry groups and code officials in China, Europe, and the US worked to establish minimum performance acceptance criteria to provide an alternate compliance pathway for MgO-based boards used in construction projects, including interior walls and ceilings, exterior sheathing, sub-roofing, and underlayment. ICC-ES AC386 was the first ICC acceptance criteria for this product type, and covers a broad range of considerations, including physical properties, installation requirements, and ongoing quality control. There are ongoing efforts to update AC386 and convert the acceptance criteria to a standard in mandatory language to allow direct reference by model codes; "ICC 1125 Standard Specification for Classification of Magnesium Oxide Board and Construction" is on track to be published in early 2026.

Acceptance criteria serve as an alternative compliance pathway designed to identify products that align with the intent of the building code, which is developed through an industry consensus process representing the best available expertise for maintaining effective building operation throughout its lifespan. These criteria typically concentrate on properties of the manufactured board that, based on correlation or accelerated testing, most reliably predict whether a product will meet its intended, code-mandated function. Since model building codes primarily emphasize critical life safety, they often do not provide explicit guidance regarding durability and long-term performance. More rigorous testing protocols, incorporating extended durations and more severe conditions, can further mitigate risk and demonstrate differences in long-term performance among products, even when all may meet baseline acceptance criteria.

Monitoring the performance of MgO products under both real-time and accelerated conditions offers valuable insights into their long-term behavior within buildings. Exterior sheathing materials are subjected to fluctuating environmental factors, such as changes in temperature and humidity, which are often challenging to replicate accurately in laboratory settings—specially when aiming to accelerate testing. By integrating laboratory evaluations with systematic real-world exposure, it is possible to more effectively assess potential failure mechanisms and bridge gaps in understanding product performance.

Ongoing work within the industry continues to push the boundary on what is known about the long-term performance of MgO boards in response to various external conditions. This report will consider several studies evaluating the extension of accelerated lab testing with real-time monitoring of the same or similar properties.

Experimental Methods: Exposure Conditions

Samples selected for evaluation in all of the studies were chloride-based MgO boards rated for use as exterior sheathing boards with direct cladding attachment. All samples, unless indicated otherwise, were initially equilibrated in a controlled environment held at 75°F (24°C) and 50% relative humidity (RH) for a minimum of 24 hours prior to any measurements or change in conditions. From there, they were either placed in a controlled environmental chamber at a specified condition or in a small open air test box (**Fig. 1**). The temperature and RH of the environmental chamber were validated using a calibrated digital thermometer and humidity

Figure 1. *Small test hut used to house various panel configurations containing magnesium oxide boards and expose them to local ambient conditions without direct exposure to rain, such as might be experienced in a vented air gap behind typical claddings. The bottom and top of the enclosure are open to allow airflow through the enclosure (left image), with a hinged roof assembly allowing access to the samples evenly spaced within the enclosure (right image).*

sensor and were maintained constant for the indicated duration of the test.

A more dynamic, real-world exposure regime was provided by the open-air test boxes, or "test huts" (Fig. 1). Samples include boards predrilled with fasteners for fastener withdrawal measurements or steel coupons for tracking corrosion over time. Test huts were placed in four locations intended to represent different medium to very high humidity conditions, including Midland, MI; Tacoma, WA; Miami, FL; and Jyllinge, Denmark.

Internal conditions within the open-air enclosure were monitored continuously for temperature and relative humidity. Data for two of the locations are shown in **Figure 2.** The Michigan location is IECC climate zone 5A, and the Denmark location 5C. While they are in the same climate zone number based on heating degree days, the marine climate of Jyllinge, Denmark creates a higher relative humidity for much of the year, with relative humidity rarely dropping below 60% and staying above 70% RH for the majority of the wintertime.

Experimental Methods: Property Evaluation

Moisture uptake was measured by weighing the sample before and after complete drying at 108°F (42°C) for a minimum 1 week and until weight change dropped to less than 0.5%, and assuming all mass loss is excess water. Corrosion testing followed AWPA E12-20 methodology using G60 and carbon steel coupons sandwiched on both sides with uncoated MgO boards and held in place with nylon bolts. Fastener withdrawal was evaluated using ASTM D1761-20 using #10-9 ultra-low-profile head screws.

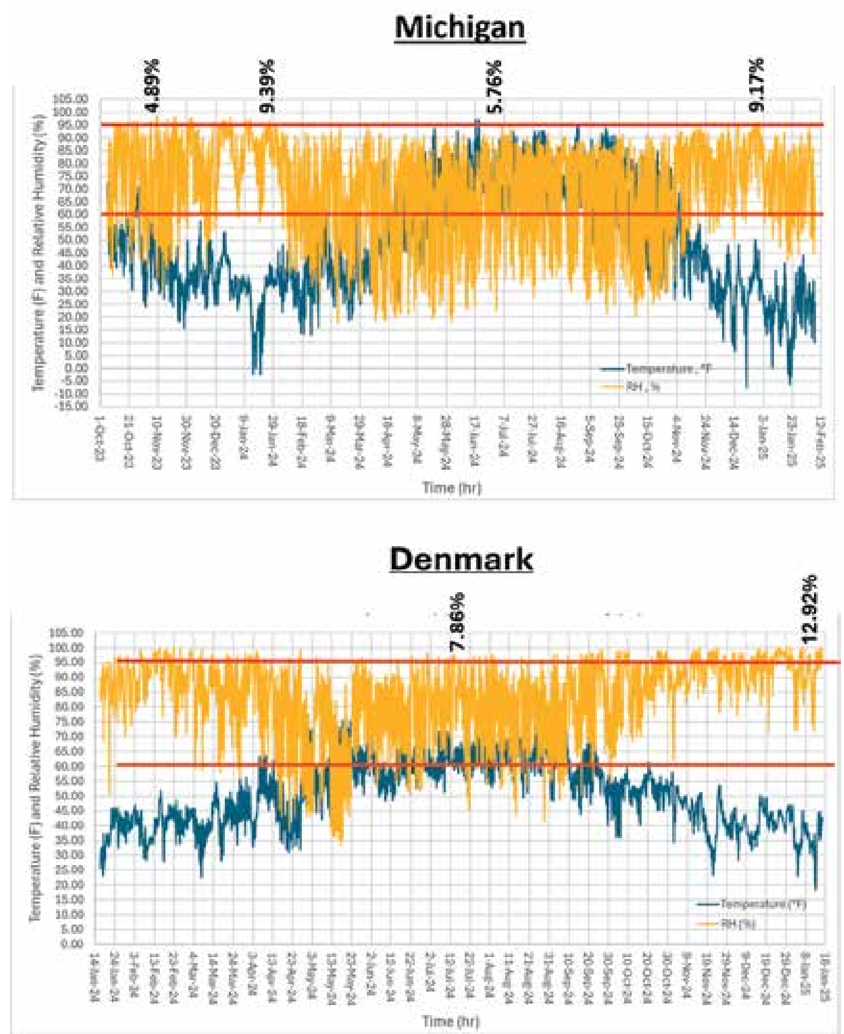

Figure 2. *Plots of temperature (blue) and relative humidity (orange) recorded within the small test huts at two locations: Midland, Michigan (top), and Jyllinge, Denmark (bottom), over the course of 12–16 months. At several points, magnesium oxide board samples with water resistive barrier were removed from the test hut to measure moisture content, which is reported above the plot. The red lines indicate 60% and 95% relative humidity.*

FASTENER ATTACHMENT STRENGTH

One of the key advantages of some MgO boards rated for use as structural exterior sheathing (typically, 1.3 cm or thicker and density >1.0 gm/cm^3) is the ability to fasten cladding attachments directly to the sheathing, rather than ensuring fasteners extend through the sheathing (and other building envelope layers) and attach directly into structural framing members. This provides numerous benefits towards installation and building performance, including: flexibility and speed in placement of attachment brackets independent of framing pattern; minimizing thermal bridging through insulation panels behind sheathing; decreasing the length (and cost) of fasteners; eliminating risk of missing a stud and having to address errant holes in the water, air, and thermal control layers; and, in some cases, a reduction in the number of fasteners required due to more equal distribution. To be used in this way, boards should have appropriate measurements and engineering calculations by a reputable third party to validate the "as-manufactured" cladding attachment requirements and fastening patterns.

Pushing beyond testing the boards as manufactured, AC386 includes a component of short-time exposure to water spray, followed by repeating the fastener testing, and establishes the requirement that fastener strength does not drop after such exposure. This test is intended to confirm that a board does not suffer from short-term water instability of the cement crystal in the event of a single severe wetting event. Two other weakening mechanisms not captured here that could degrade fastener holding power over time include load cycling that slowly causes local damage to the cement surrounding the fasteners, and moisture-driven degradation of the cement crystal structure over time.

As with many product data measurements, the minimum performance value reported for a product is often lower than what would be typically measured to ensure the ability to consistently hit that minimum target. For the following data set, the fastener pull-out strength is considered both from the perspective of the minimum value reported in the literature for the boards tested in this study ("minimum specification") before application of any safety factors, and from the historical quality control measurement averages ("historical average").

To evaluate the risk of the first mechanism, fasteners were screwed into an MgO board, cycled up to 4,500 times through a load (either in tensile pull-out or shear) ranging from 45%–100% of the minimum and then pulled to failure.

The relationship between the number of cycles and the cycle load follows a nearly exponential relationship, as shown in the blue line in **Figure 3** (plotted on a logarithmic x axis). The plot starts with pre-stressing the fastener with a single pull-out or shear stress cycle at 100% of the minimum specification and then stepping down to eventually hitting 45% of the minimum specification with 4,500 load cycles. The values of the final stress-to-failure data point are normalized to the historical average, not the minimum specification, to better illustrate changes to performance as a result of the cycling.

In most cases, the peak force stayed within a standard deviation of the historical average, indicating no statistical change in performance. For those that did drop, the historical average is sufficiently higher than the minimum specification load that all samples had a final peak force average above the minimum specification. The highest drop, ~7%, came for the highest number of cycles for fastener tensile pull-out, and while the value is still above the minimum specification, follow-up studies will be needed to push the total number of cycles at that and even lower load cycles to ensure that low load stresses do not accumulate over time.

The other potential long-term failure mechanism considered for fastener holding power was longer-term exposure to atmospheric moisture. As noted in Figure 2, simply exposing these MgO boards to the environment led to peak moisture loads of 9%–13%, depending on the duration of high-humidity conditions without periods of drying. The samples left in the test huts provided an opportunity to look at fastener withdrawal after exposure to 6 and 12 months of ambient environment. **Figure 4** shows the fastener pull-out data for two boards from different manufacturers without any exposure or after 6 or 12 months of exposure.

All of the boards show no loss in strength through one year of continuous exposure to ambient humidity (board B did not have data for the Midland, MI, location). Locations with higher humidity in general (Denmark and Florida) did not behave differently from those in lower humidity. Additional samples continue to be exposed in these test huts and will be evaluated at later time points to confirm the strength retention over time.

CORROSION RESISTANCE

One of the signs of poor board manufacturing practices in early MgO board use was corrosion of fasteners and steel profiles from the façade.[5] Due to poor ratio control and/or degradation mechanisms that liberated salt from cement

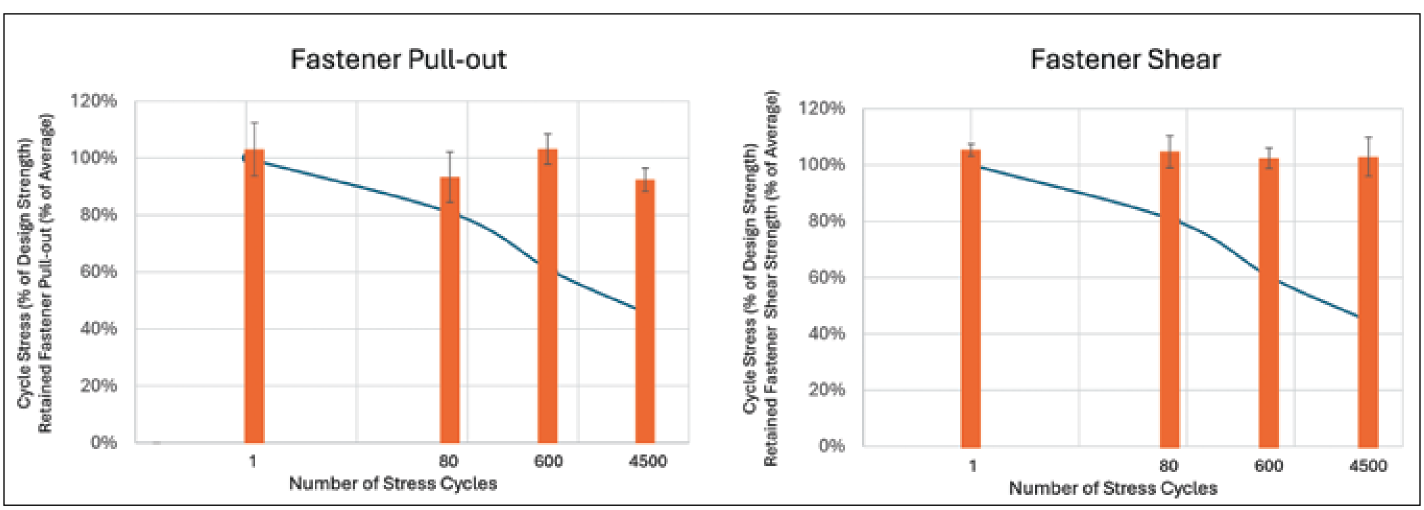

Figure 3. *Graphs of fastener pullout (left) and fastener shear (right) as a function of the number of load cycles, shown as orange bars and reported as a percentage of the average control prior to cycling. Also shown on the graph is an x-y plot of the cycling load value (calculated as a percentage of the minimum spec value) versus the number of cycles. Read together, each orange bar represents the relative peak pullout strength when tested to failure after cycling the indicated number of times, at the percent load indicated by the blue line.*

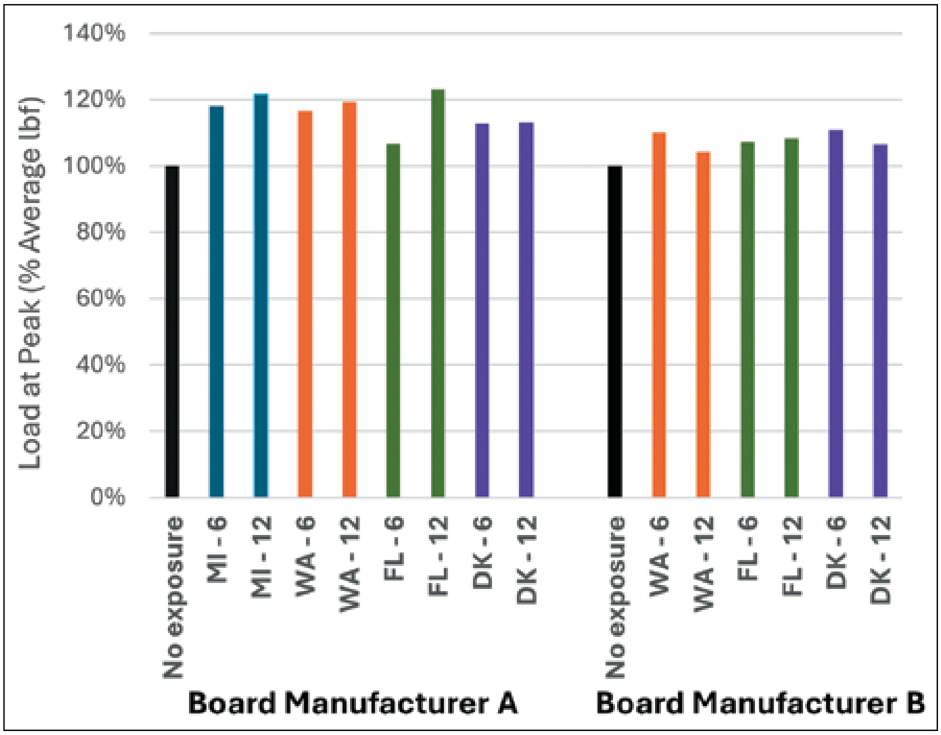

Figure 4. *Graph of peak load measurements from ASTM fastener pull-out testing for two board manufacturers. Samples of each board were evaluated after 6 and 12 months in each of the tested locations, as indicated (Michigan [MI], Washington [WA], Florida [FL], and Denmark [DK]); the "no exposure" data points reflect the long-term average test measurement for boards as received from the respective manufacturer.*

crystals, enough excess magnesium chloride salt was present in the boards to cause deliquescence, a process in which a substance (such as $MgCl_2$) absorbs moisture from the atmosphere until it dissolves in the absorbed water and forms a solution. This evidences itself as the spontaneous formation of water droplets on an MgO board surface, often referred to as "tears" or "sweating." Any MgO board used in a location where exposure to high humidity is a possibility must be tested to ensure it will not deliquesce.

AC386 Appendix A takes this a step further by requiring testing the corrosion potential of MgO boards in direct contact with metal (but not sweating) using AWPA E12-20 with grades of steel expected to come in contact with the MgO boards. This test, as written in the acceptance criteria, combines evaluating the potential for MgO board sweating as part of the sample conditioning pre-step, as well as measuring the accelerated corrosion rate at moisture loads above ambient humidity.

One approach to expand understanding of corrosion risk is to "super-accelerate" and test materials in a scenario that exceeds the minimum requirements for the accelerated corrosion tests. While results are likely to be worse, it provides a better understanding of the actual performance boundary. For the test data shown in **Figure 5,** two factors of the testing were made more aggressive: test temperature and metal coupon material. Higher temperatures both increase the kinetics of corrosion and increase the moisture present to accelerate corrosion. In this study, increasing the temperature from 86°F to 122°F (30°C to 50°C) while maintaining relative humidity (90%) increases the total water content in the air by over a factor of three. Additionally, using a carbon steel metal coupon without any galvanization treatment instead of the more common materials such as G60 allows corrosion to progress without the generation of a zinc passivation layer.

There is a fair amount of variability between different boards, which primarily indicates the variability of the test method itself but does suggest there are small differences in the boards themselves. All fall below the standard requirement of 20 mil/year corrosion rate established as the limit for chromated copper arsenate (CCA) wood to be used with steel fasteners.

Corrosion data in real time is generally difficult to accomplish due to the very long time scales involved; hence the need for the accelerated test above. However, real-time data, such as that coming from the outdoor exposure test hut, eliminates the assumptions associated with the accelerated test and helps benchmark real-world performance.

Unaccelerated corrosion rates are reported in **Figure 6** for the four locations of test huts described earlier. Samples placed in the test hut were assembled using the process outlined in AWPA E12-20, and post-exposure corrosion rate measurements were completed in the same way, such that the only modification to the method was the variable, real-world exposure conditions. Compared with the accelerated data in Figure 5, corrosion-rate values are over an order of magnitude lower for steel even at the most aggressive climates (highlighting acceleration due to the high temp/RH for samples in Figure 5), and as much as another order of magnitude lower for G60, showing the effectiveness of standard galvanization protection, in NA climates.

To put these numbers in perspective, ISO 9223-12 "Corrosion of metals and alloys" lists a range of expected corrosion rates for some metals, including carbon steel, in various atmospheric environments. With the exception of the Florida sample, all of the data points for carbon steel in contact with the MgO boards tested fall well within the expected corrosion rate for a "Low" or "Very Low" corrosive environment. Florida, on the other hand, falls just outside of that range, in the "Medium" corrosive environment. At this point, it is not clear whether this is truly representative of effects from the MgO sample, or simply reflects the more challenging environment in Florida (or some combination of the two).

One particular point of interest is the similarity between the G60 and carbon steel corrosion data from the Denmark samples. While this is still a limited number of data points, the trend (if continued) warrants additional study to understand the particular effect of long-term exposure to cold, moist climates and potential differences in the corrosion mechanisms there compared to other climates.

For most of the G60 samples, the decrease in corrosion rate at 12 months (and 18 months, for Midland) data compared with the initial 6 months is expected. Early in the exposure process, passivation of the surface is technically a corrosion-related process and due to the way the test is run becomes part of the measured corrosion. Once that initial passivation is complete, the overall corrosion rate drops due to the passivation. Florida is an interesting outlier in that regard, and while samples conditioned there do not show the highest corrosion rate, it does increase between 6 and 12 months. Data collection on samples in these test huts is ongoing and measurements at 18 months and later will show how these trends continue, but up to this point real-time corrosion of G60 in contact with MgO boards does not cause a concerning amount of corrosion.

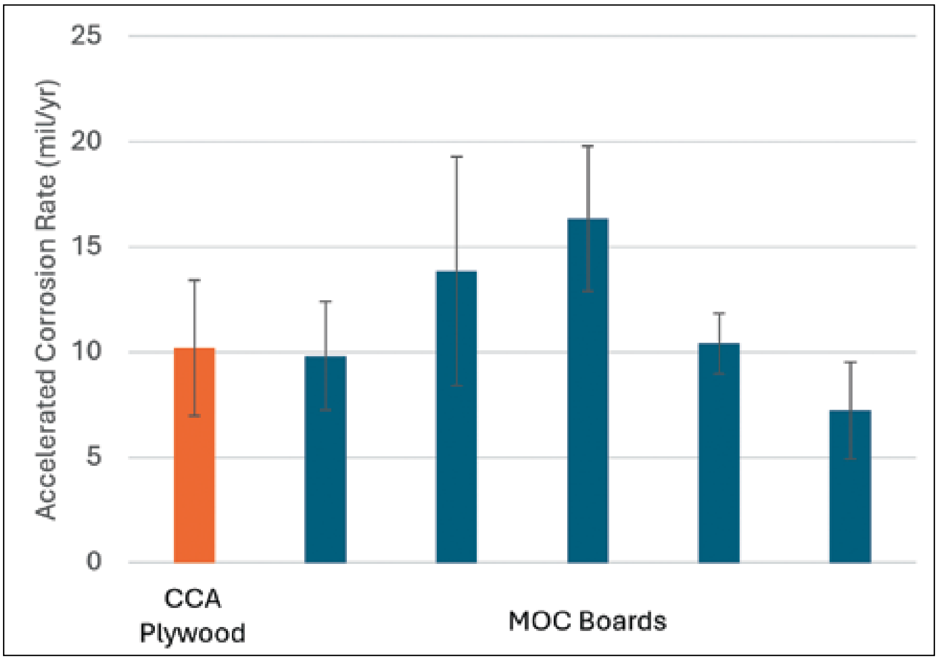

Figure 5. *Plot of annualized corrosion rate for chromated copper arsenate (CCA)-treated plywood (orange) and magnesium oxide (MgO) boards (blue) in contact with low-carbon steel for five different lots of boards from two manufacturers. The corrosion test was run at 50°C and 90% relative humidity.*

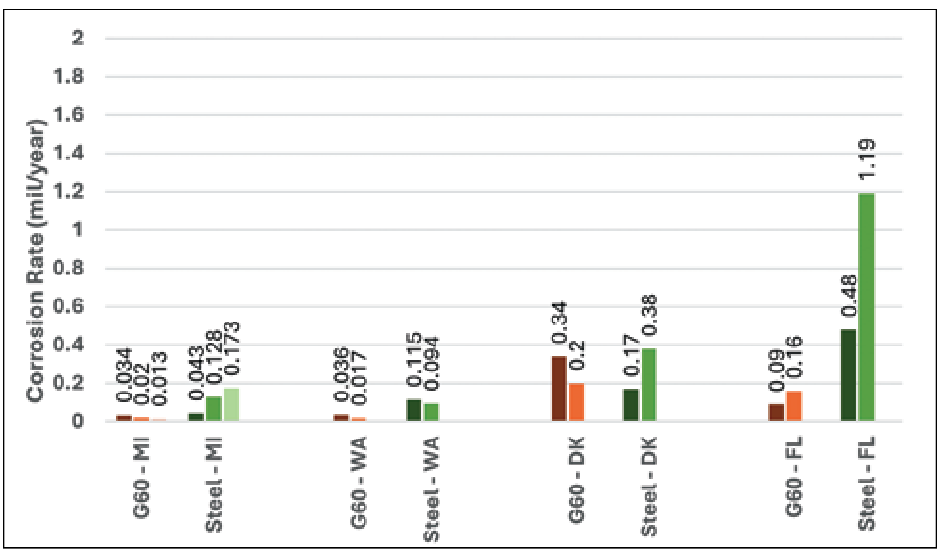

Figure 6. *Measured annualized corrosion rate for G60 galvanized steel (orange) or carbon steel (green) coupons exposed for 6 months (dark), 12 months (medium), or 18 months (light, Michigan [MI] only) to ambient conditions in small test huts at all locations (Washington [WA], Denmark [DK], and Florida [FL]), as indicated.*

CONCLUSION

As with all cementitious materials, MgO-based cement boards need to be prepared with appropriate formulation and curing control to ensure that the crystalline structure is stable, with minimal excess salts present in the cement matrix. High quality boards, such as those evaluated in this study, retain their strength as a cladding attachment base during extended exposure to ambient moisture, as well as during stress cycling of fasteners. In addition, corrosion potential is within acceptable limits both during highly accelerated corrosion testing, and over a long period of exposure to ambient moisture.

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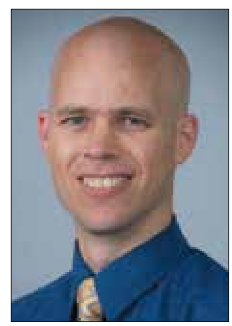
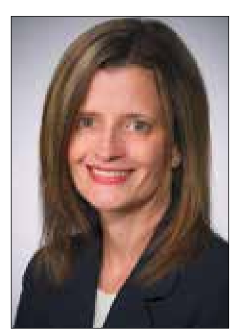
ABOUT THE AUTHORS



ADAM BRODERICK, PHD

Adam Broderick *is a research and design scientist with DuPont Performance Building Solutions focused on applying material science and building science fundamentals to drive innovative building enclosure products and applications. He is on the front lines of developing and testing the newest technologies available to enable easier construction of higher-performing, more resilient buildings. Despite having a background in formulating and evaluating products in the lab, he's happiest when on a building site, collecting feedback on new products and application methods under development, and learning about the most challenging unsolved problems facing builders today as they give rise to the innovations of tomorrow.*



MICHELLE HUDACK, PHD

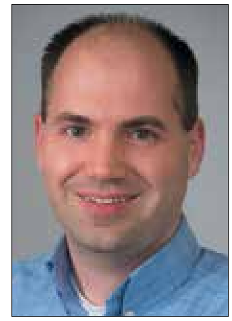
Michelle Hudack *is a senior lead scientist at DuPont with expertise in polymer chemistry and building science. She earned her doctorate from the University of Rochester, NY, and has led field evaluations of MgO-based sheathing products across diverse climates to assess durability and corrosion resistance. Her work bridges* laboratory research with real-world performance, focusing on how emerging materials impact long-term building integrity. Michelle is driven by the rewarding challenge of ensuring buildings maintain fire safety and insulation performance, contributing to the advancement of resilient, high-performing structures.*

MICHAL PORTER-MCCARTHY, PHD

Michal Porter-McCarthy *is a senior lead scientist at DuPont with a PhD in chemical engineering. She is currently focused on MgO-based panel products, where she has played a key role in defining lab testing procedures to evaluate corrosion risks linked to low-quality MgO sheathing materials under accelerated conditions. Her work includes ensuring robust quality control methods to identify potential product issues. She has a passion for driving innovation informed by sound science and life-cycle thinking and for understanding the role of new materials like MgO-based sheathing panel products in the decarbonization of the built environment.*

GREGORY STEWART

Greg Stewart *serves as the roofing applications development leader in shelter solutions at DuPont, bringing over 25 years of expertise in product, process, and applications development. He actively represents DuPont in key roofing industry groups and is known for his inventive approach to solving complex technical challenges. Stewart's leadership has energized innovation across shelter solutions, contributing to multiple successful development initiatives. He holds eight granted patents and was part of the DuPont team honored with the prestigious ACS Heroes of Chemistry award in 2024 for groundbreaking reduction in embodied carbon.*



MARK RICKARD, PHD

Mark Rickard *started his career in analytical chemistry and materials development at Dow Chemical in 2008 and transitioned to DuPont's Shelter Solutions business in 2019. He has developed innovative products that help solve important sustainability problems. Two examples are Low GWP Froth-Pak Spray Foam, which is a more sustainable spray polyurethane foam that uses carbon dioxide (CO_2) to reduce its global warming potential by more than 99%, and Low-GWP Styrofoam Brand XPS Insulation, which delivers a 94% reduction in embodied carbon.*

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