

# MgO: No **Sweat**... Sweet!

## Magnesium oxide exterior panels

August 5<sup>th</sup>, 2024

Westford Symposium



# Introductions



## Adam Broderick

### Material Science

(PhD Chemical Engineering, Dow Mat Sci)

+

### Building Science

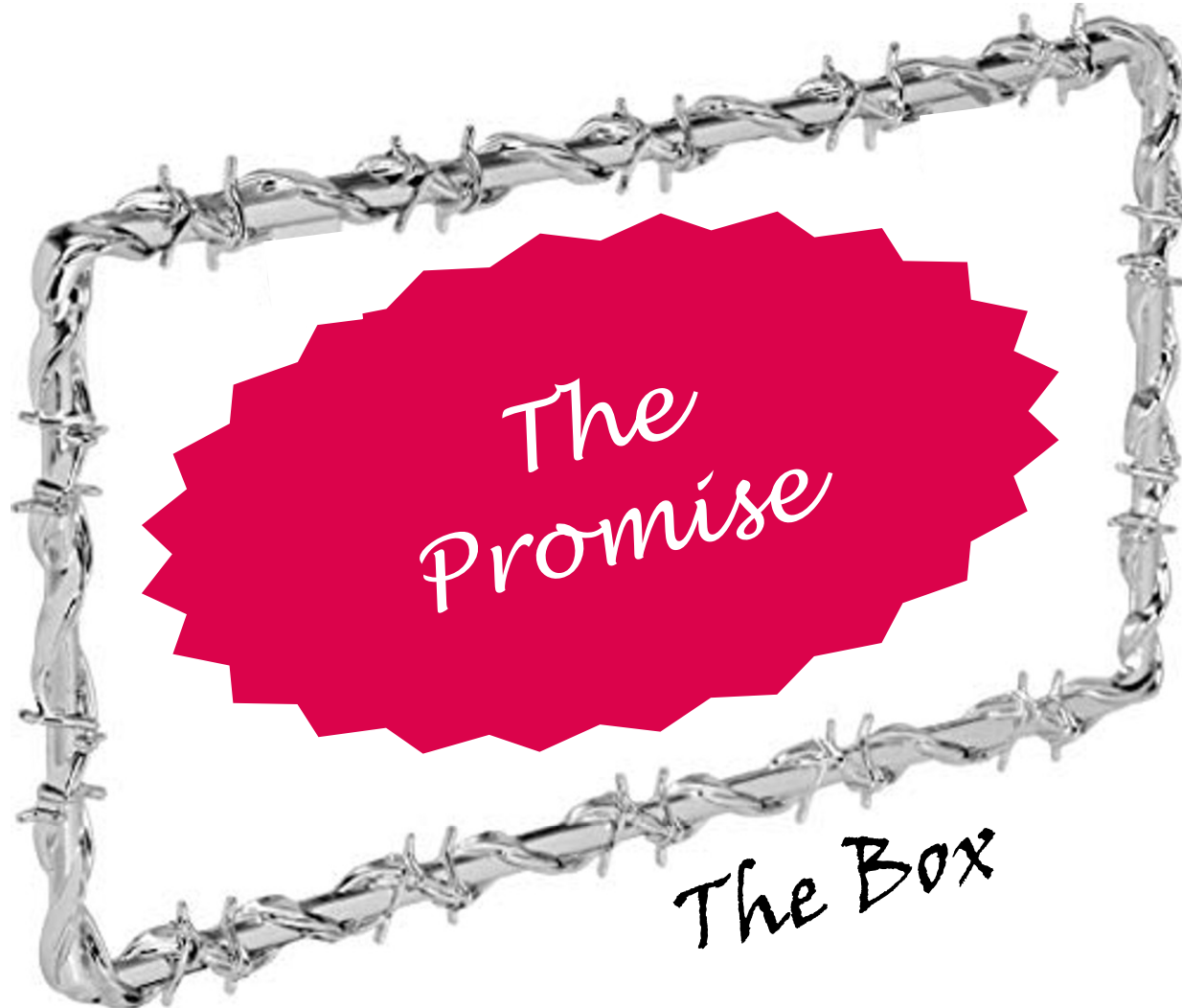
(10 yrs Construction Product R&D, hands-on building, site visits and product trials)



## Aaron Grin M.A.Sc., P.Eng

- Master of Applied Science - University of Waterloo
- Consultant in the field of applied Building Science, Forensics, and R&D
- Special Lecturer at the University of Waterloo School of Architecture
- FGIA/WDMA, SCEE, ASTM E06
- Personal: Three kids, gardening, cooking, smoking meat, and I like to build things - <https://youtu.be/wOrxUQY766U>

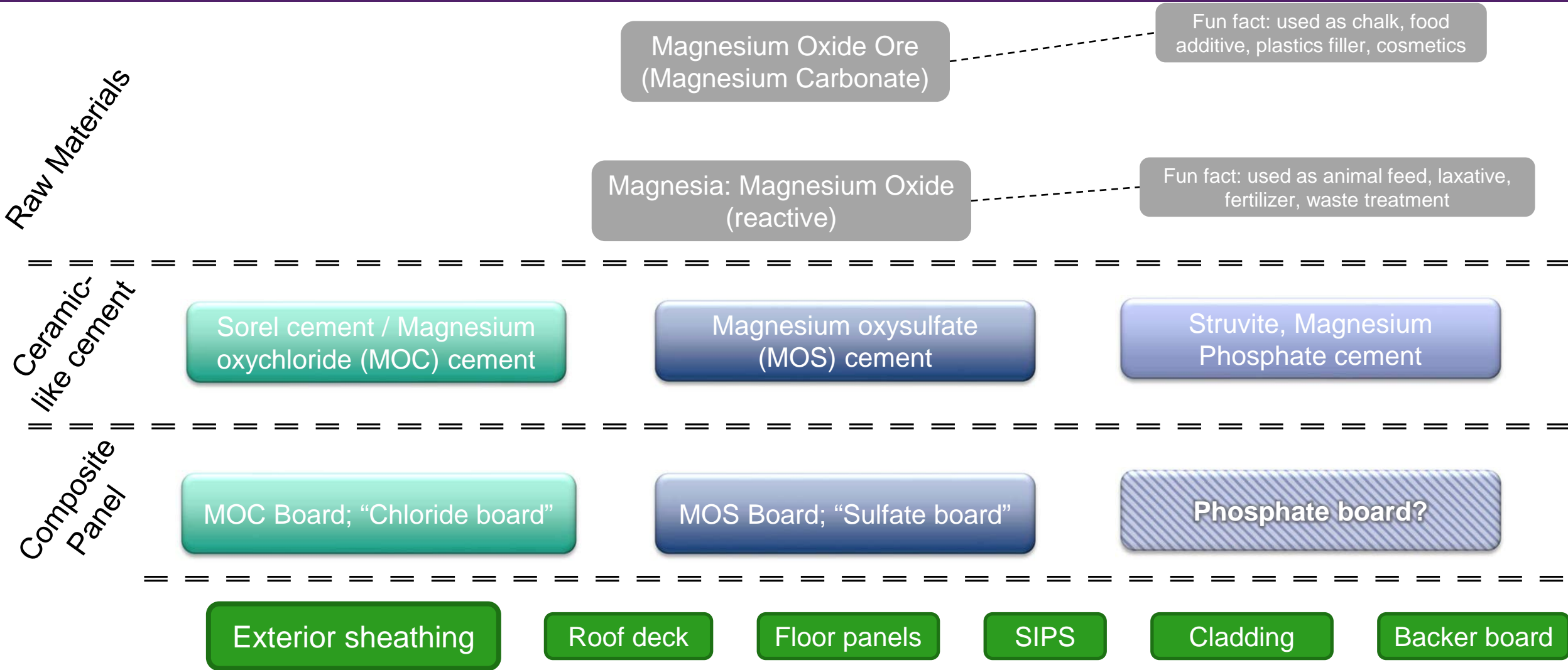
# How to think about new materials like MgO?



# What we'll cover today:

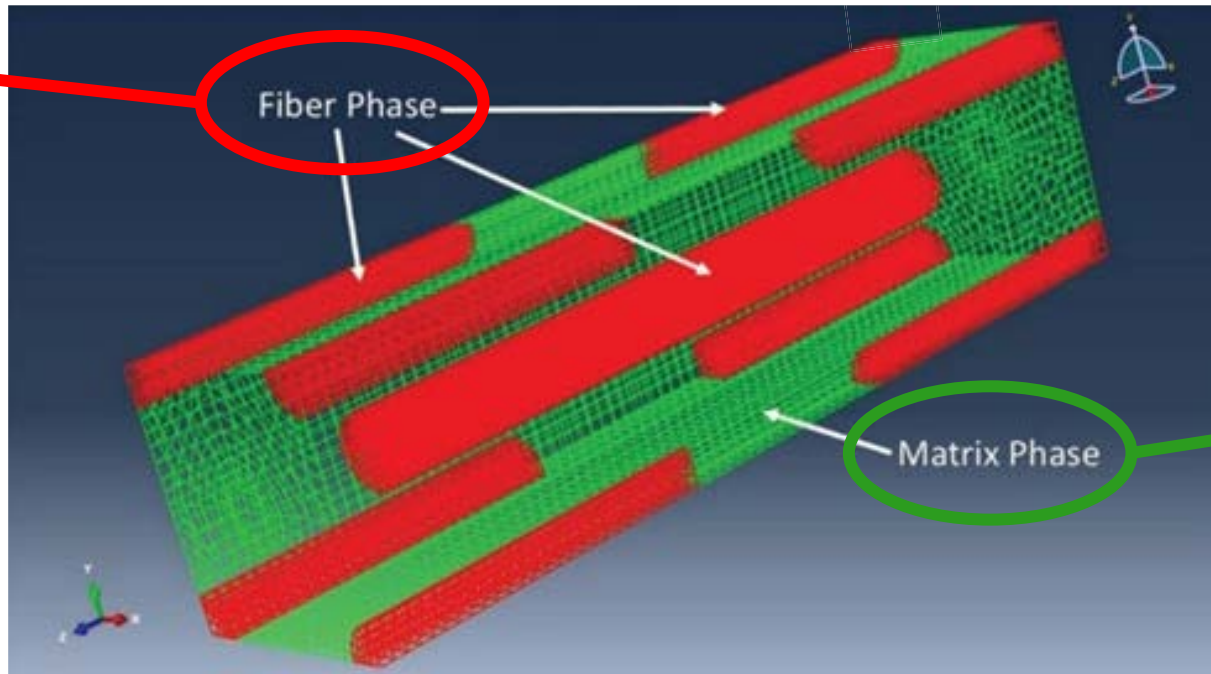
1. What's in an MgO Board?
2. Why is MgO Awesome? "The Promise"
3. Where has MgO gone wrong and how to mitigate risk? "The Box"
4. Quick dive into real world and accelerated testing

# MgO Overview – Talk like an expert



# Background – Composite Assemblies

**Strength**  
**Flexibility**  
**Cohesion**  
**Impact Resistance**  
**Fastener holding**

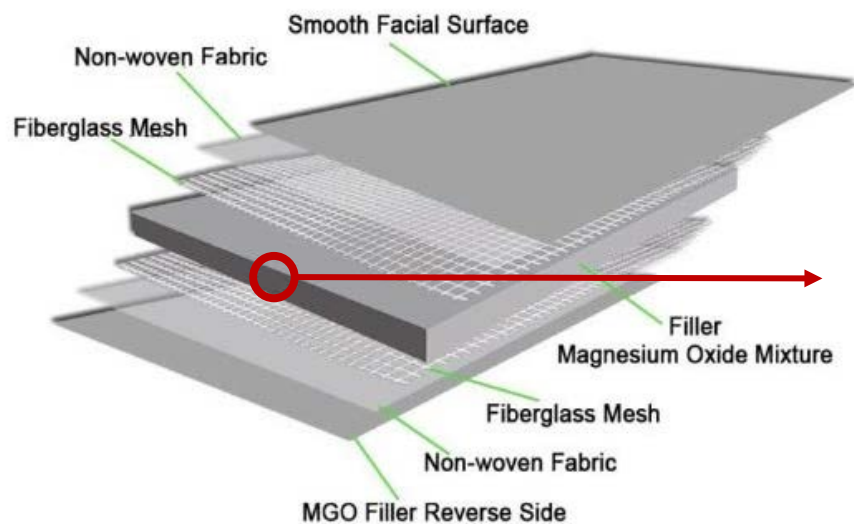


**Durability**  
**Weathering**  
**Dimensional stability**  
**Fire, water, microbial**

*Combine best properties of both... but only with good adhesion and compatibility!*

# MgO Boards at all size scales...

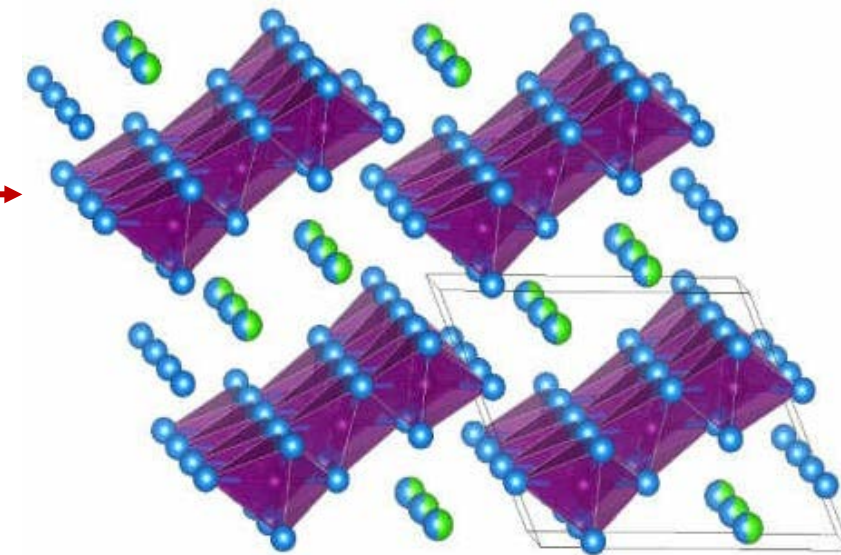
## MgO Cement – Glass Fiber Composite Panel



## Composite Cement



## Inorganic Crystal



Carbon Dioxide Uptake by MOC-Based Materials - Scientific Figure on ResearchGate. Available from: [https://www.researchgate.net/figure/Crystal-structures-of-Phase-3-left-and-Phase-5-right-Mg-atoms-are-located-in-the\\_fig1\\_340240893](https://www.researchgate.net/figure/Crystal-structures-of-Phase-3-left-and-Phase-5-right-Mg-atoms-are-located-in-the_fig1_340240893) [accessed 14 Jun, 2024]

# 1X zoom: Benefits of Glass Fiber Reinforcement

## What makes it work

- Internal pH of 10-11, which won't degrade typical coated glass fibers
- Exhibits excellent binding ability to a variety of reinforcement fibers

## What do we get?

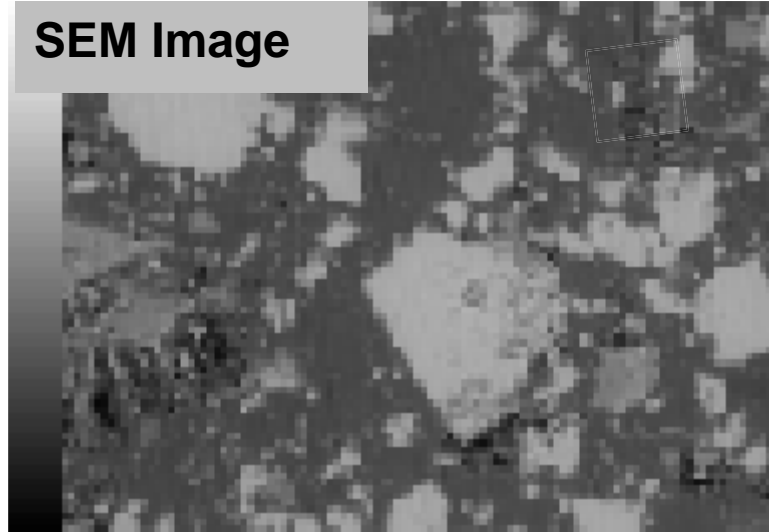
- Flex strength
- Fastener pull-out
- Crack resistance



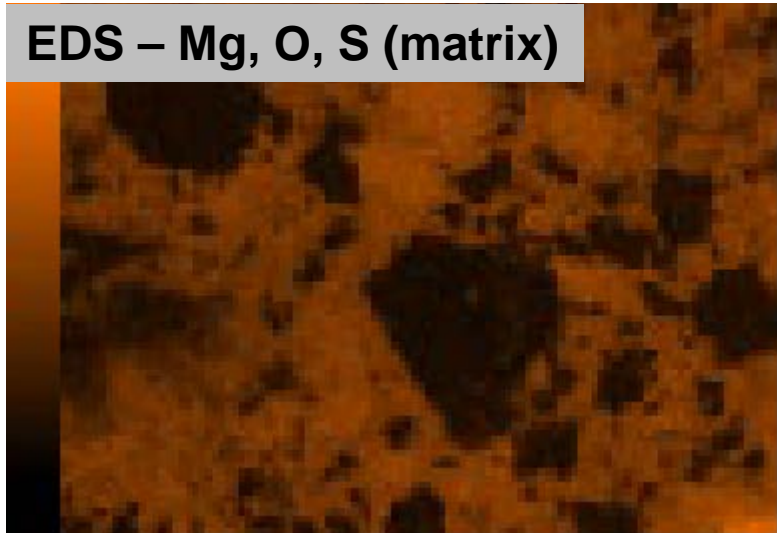


# 10x Zoom: Fillers/Additives

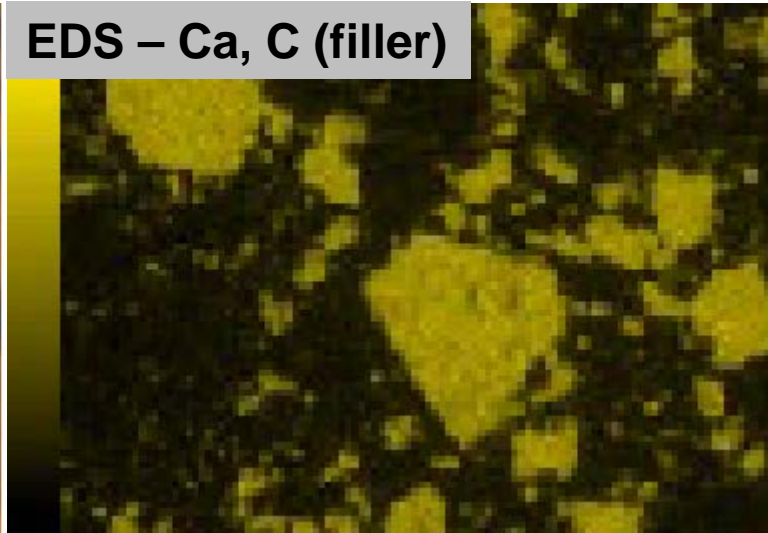
SEM Image



EDS – Mg, O, S (matrix)



EDS – Ca, C (filler)



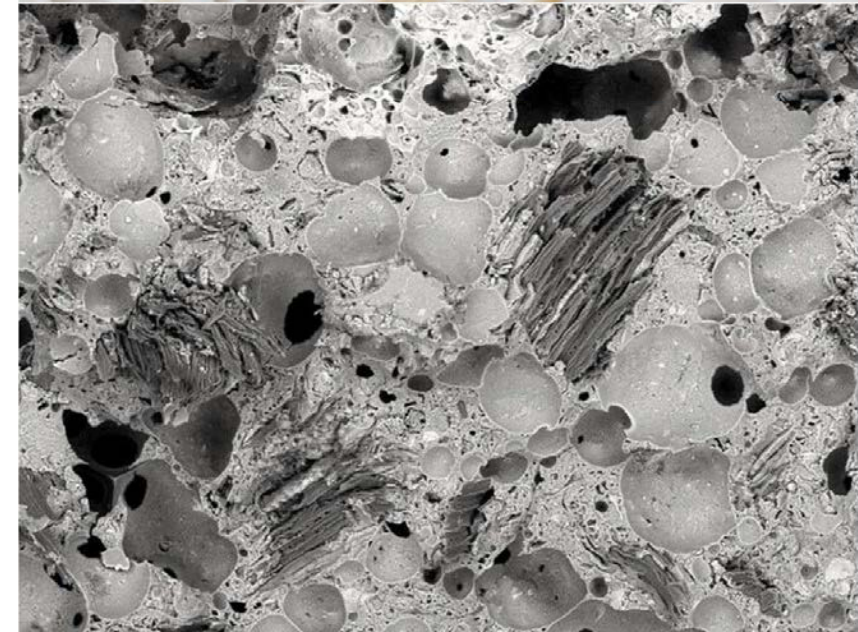
# 10x Zoom: Wood/Perlite with Cement Binder

## What makes it work

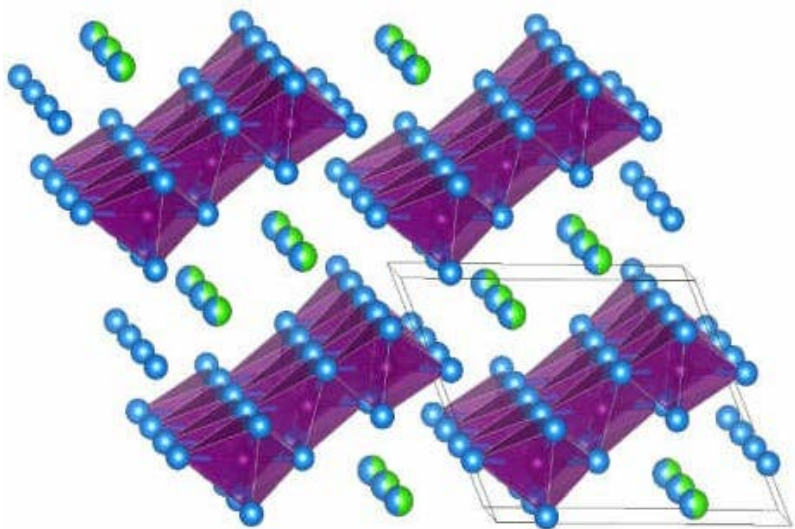
- Good adhesion and compatibility between fillers and matrix
- Toughness (wood), low density (wood and perlite)

## What do we get?

- Easier handling
- Crack resistance
- Fastener holding
- Water permeability

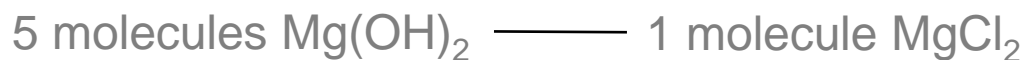


# 1000X Zoom: What is the matrix structure?



Example: Magnesium oxychloride

5-1-8 crystal structure (Phase 5)



Crystal growth **self-assembly process** requires:

- Right **ratio** of ingredients
- Correct **temperature** (not too fast, not too slow)

“Current product performance”	MOC Phase 5	MOS Phase 5-1-7
High Strength	++	+
Strength retention (high temp)	++	+
Water resistance	+	++
No corrosion contribution	+	++

# How the Sausage is Made



Mix



Pour



Stack

Cure (2 stage)



Sand and trim



Store and Ship



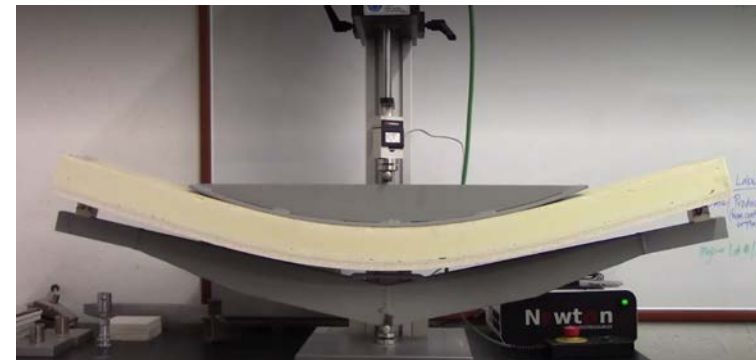
Mgo board machine, Deyi Machinery, video accessed 6/10/24

**Critical to Quality!!**

**Improved Since Early Boards**



# Connect the Dots: Material Science and Panel Performance



# Material Science of MgO under Fire

[ICC-ES ESL 1302 for Hourly Rated Walls](#)

[ICC-ES ESL 1442 for NFPA 285](#)

During fire:

- Wood oxidizes (<5%)
- Water evaporates (~40%)
- Glass/MgO composite left behind



“ArmorWall™ is a trademark of DuPont de Nemours, Inc.

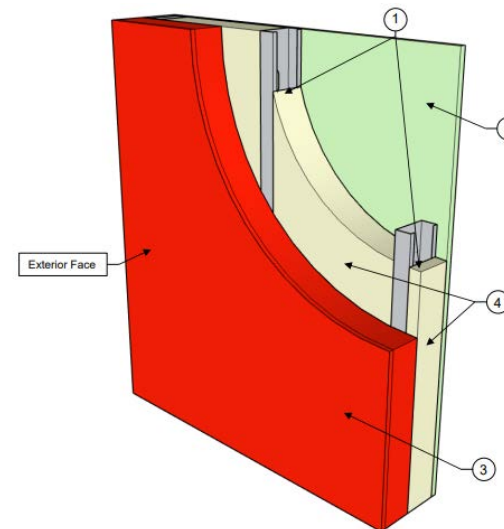
*Example: DuPont ArmorWall™ fire listings:*

**NFPA 285** (4 base walls, 4 insulation types, 21 cladding types, 4 rough opening treatment options)

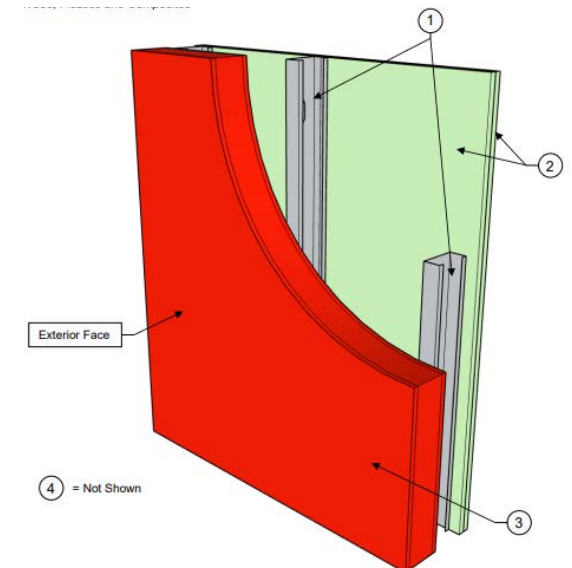
**ASTM E119** (½-, 1-, and 2-hour rates assemblies)

**E84 Class A**

1-hr UL Assembly

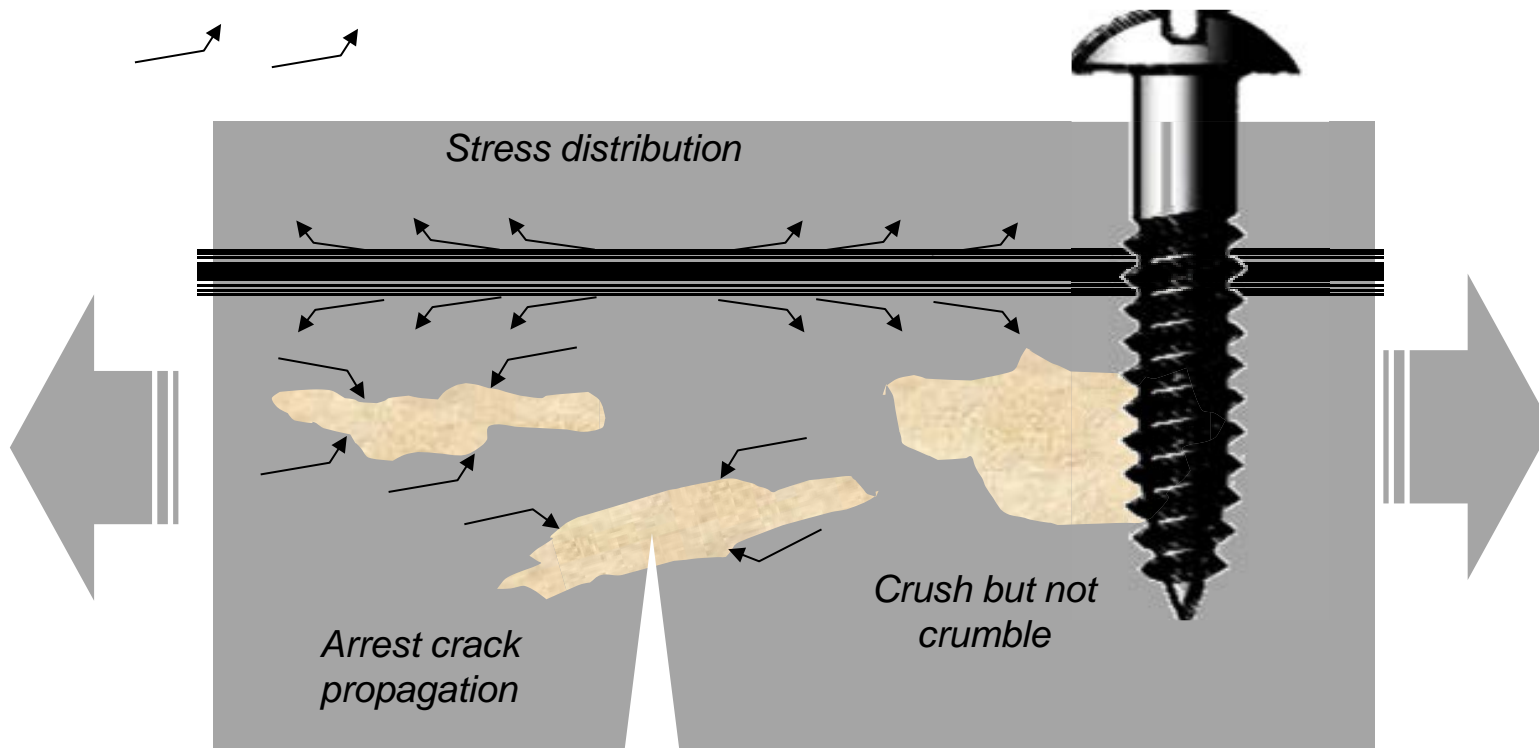


2-hr UL Assembly



2024 Westford Symposium

# Board Performance- Strong but not Brittle



Shear • Impact • Flex • Racking • Fastener

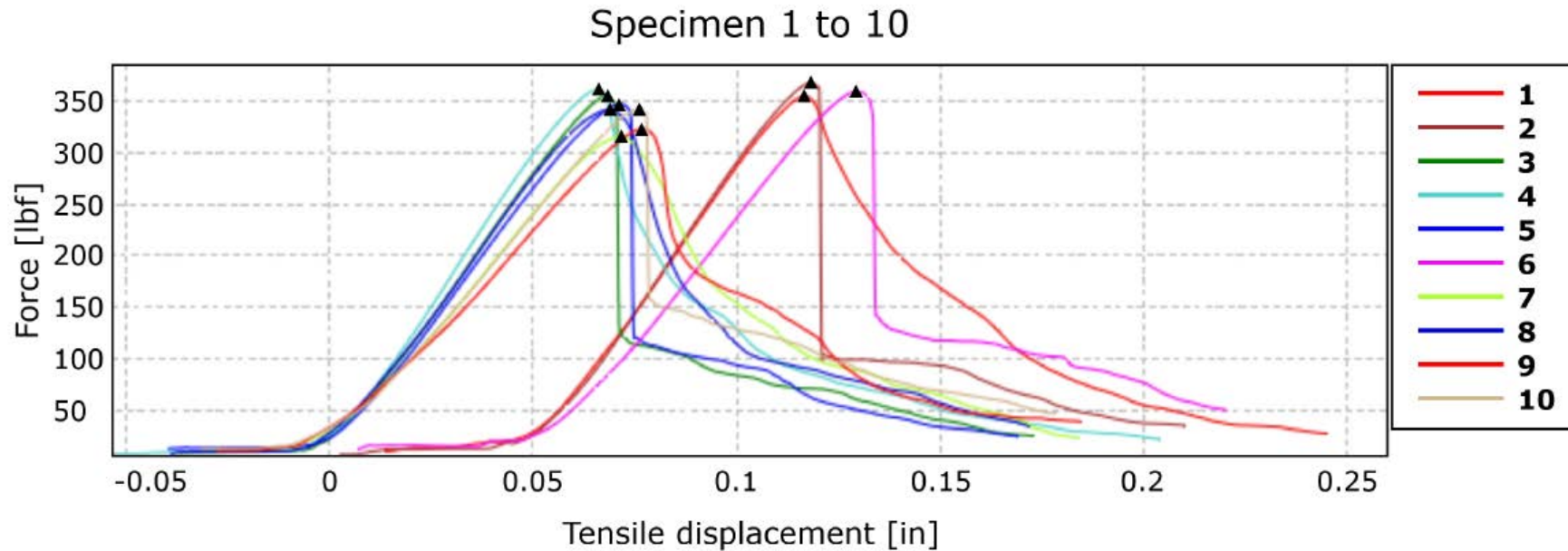
Direct attachment of cladding



MOC cement has a compression strength of over 10,000 psi... ~50% higher than Portland cement!



# Cladding Fastener Withdrawal



Cladding Attachment		
Fastener Shear in Sheathing Only	ASTM D1761	519 lbs
Fastener Pull Through	ASTM D1761	505.2 lbs
Fastener Withdrawal Capacity	ASTM D1761	284 lbs



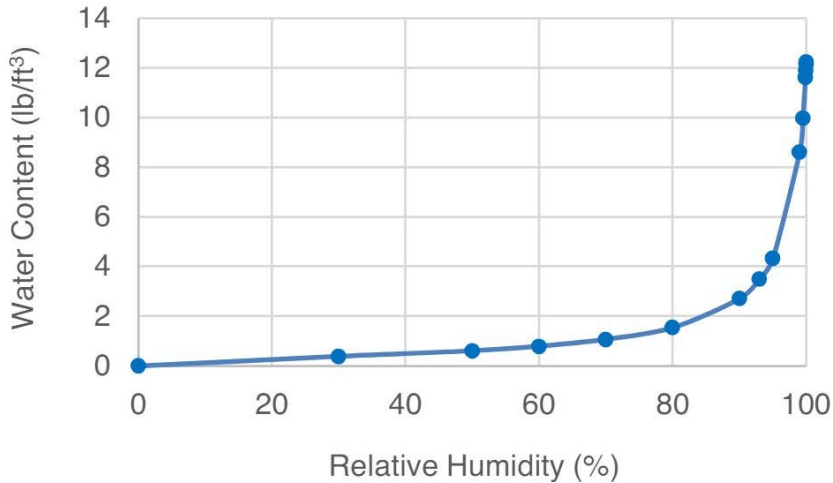
# Board Performance: Water vapor

## Move

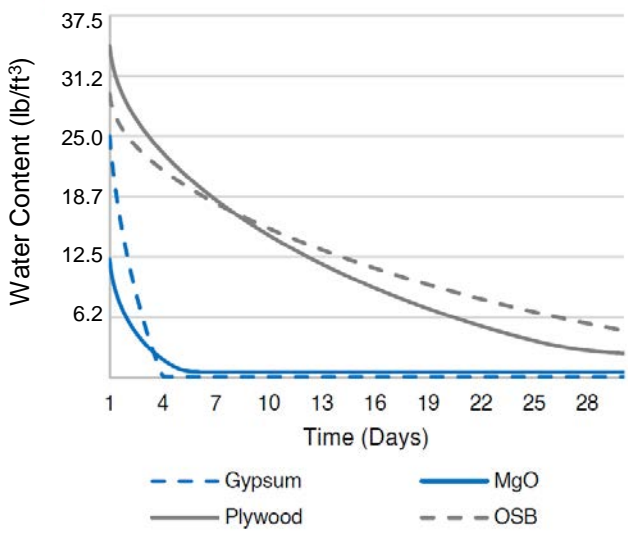
WRB coating: 1-30 perm  
1/2" MgO : 10 Perm



## Store



## Release



Data credit: Built Environments Inc.

### How?

- Randomly oriented wood
- Interconnected pores
- Hygroscopic MgO cement crystals



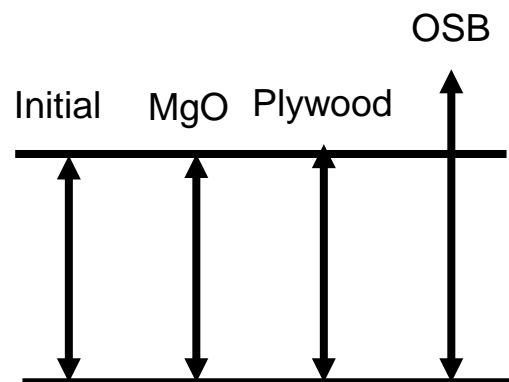
# Board Performance- Bulk Water

Lower water absorption than wood products



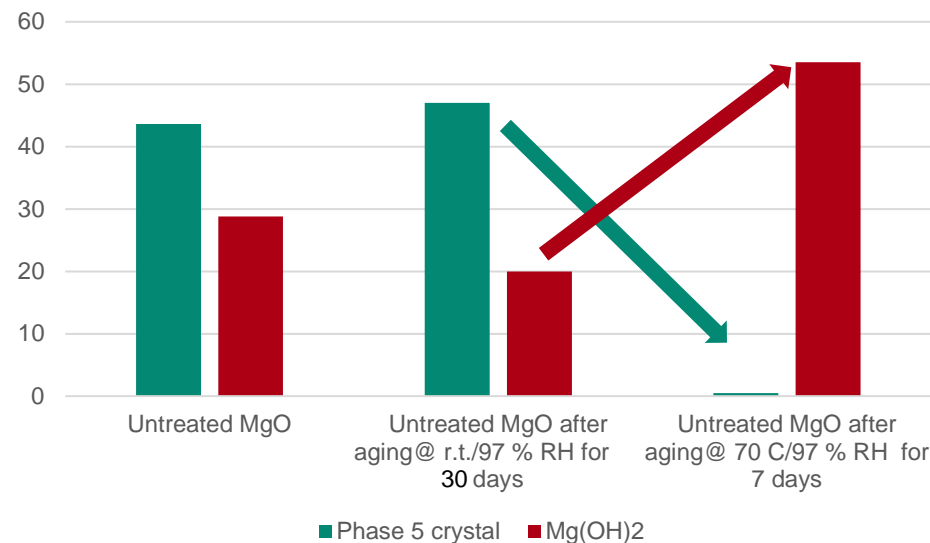
Dries quickly

Dimensionally stable



Relative thickness after 25 wet/dry cycles

\*Disclaimer: stable to bulk water... within limits!!



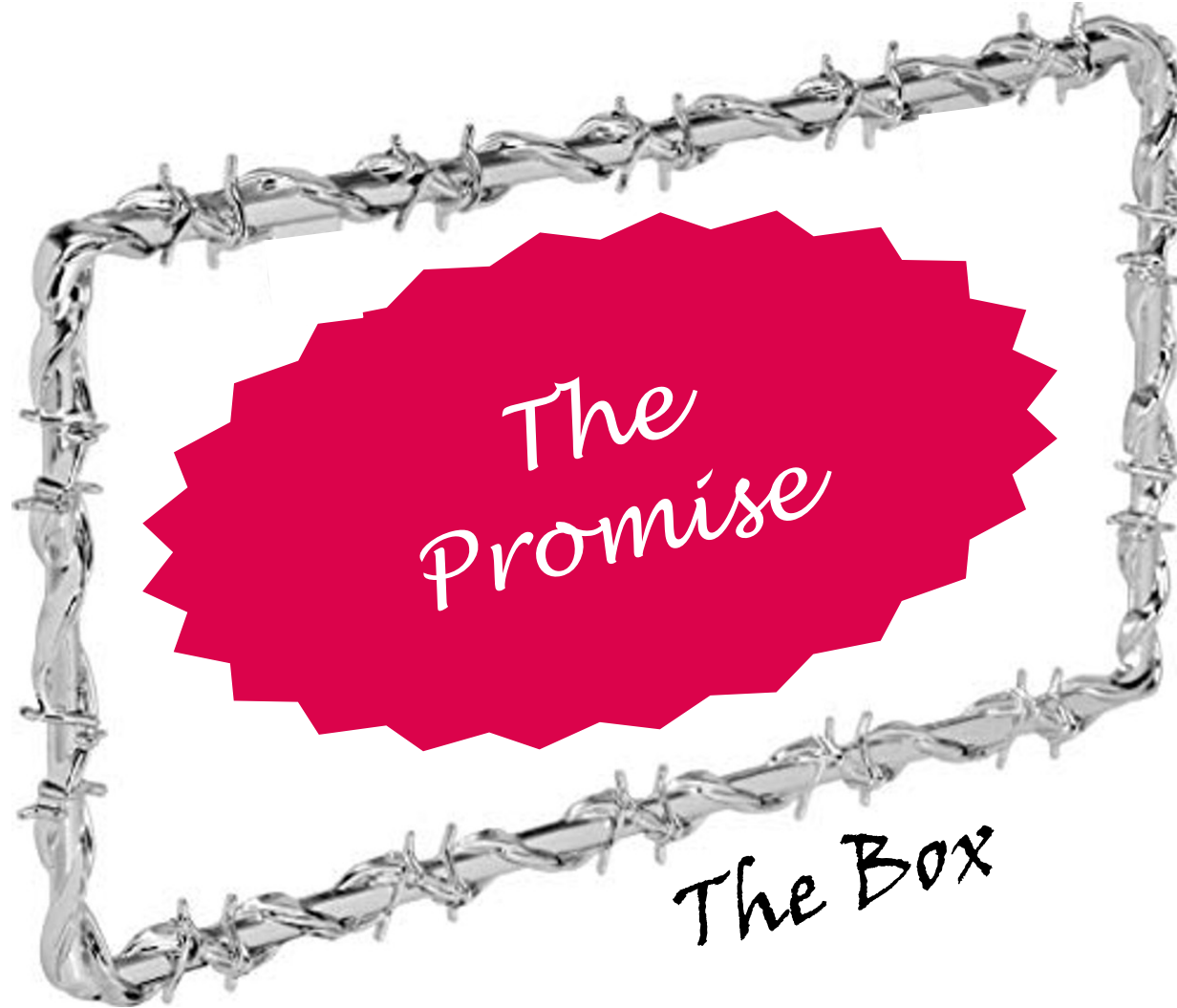
In lab: high temp (70 C / 158 F) + water

=

No cement crystals and all hydrolyzed byproduct



So... what's the box?





# Denmark Façade Failure



“Sweating”

Available online at [www.sciencedirect.com](http://www.sciencedirect.com)

  **ScienceDirect**  
Energy Procedia 132 (2017) 765–770

**Energy Procedia**  
www.elsevier.com/locate/procedia

11th Nordic Symposium on Building Physics, NSB2017, 11-14 June 2017, Trondheim, Norway

**Moisture damage with magnesium oxide boards in Danish facade structures**

Carsten Rode<sup>a,\*</sup>, Tommy Bunch-Nielsen<sup>b</sup>, Kurt Kielsgaard Hansen<sup>a</sup>, Bent Grelk<sup>a</sup>

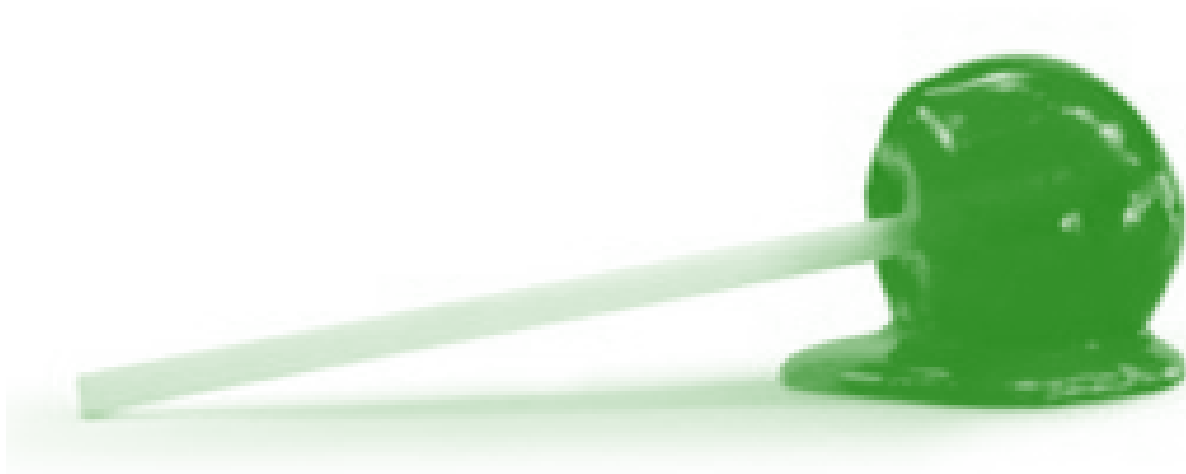
<sup>a</sup>Technical University of Denmark, Dept. of Civil Engineering, Brovej, Building 118, DTU, 2800 Kgs. Lyngby, Denmark  
<sup>b</sup>Bunch Bygningssjænik ApS, Staktoften 224, 2950 Vedbæk, Denmark



Corrosion



# MgO sweating... what in the world?



Concentrated Magnesium chloride solution droplets

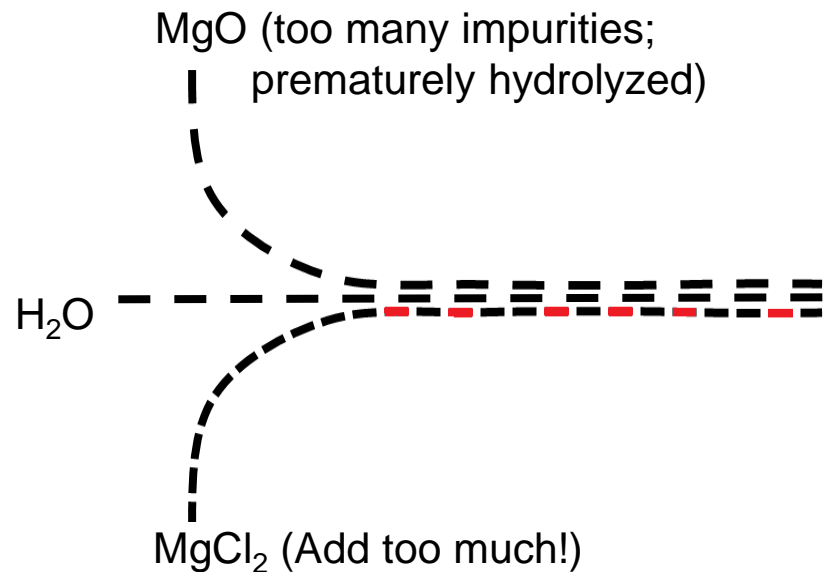


**Deliquescence**: the process by which a substance absorbs moisture from the atmosphere until it dissolves in the absorbed water and forms a solution.

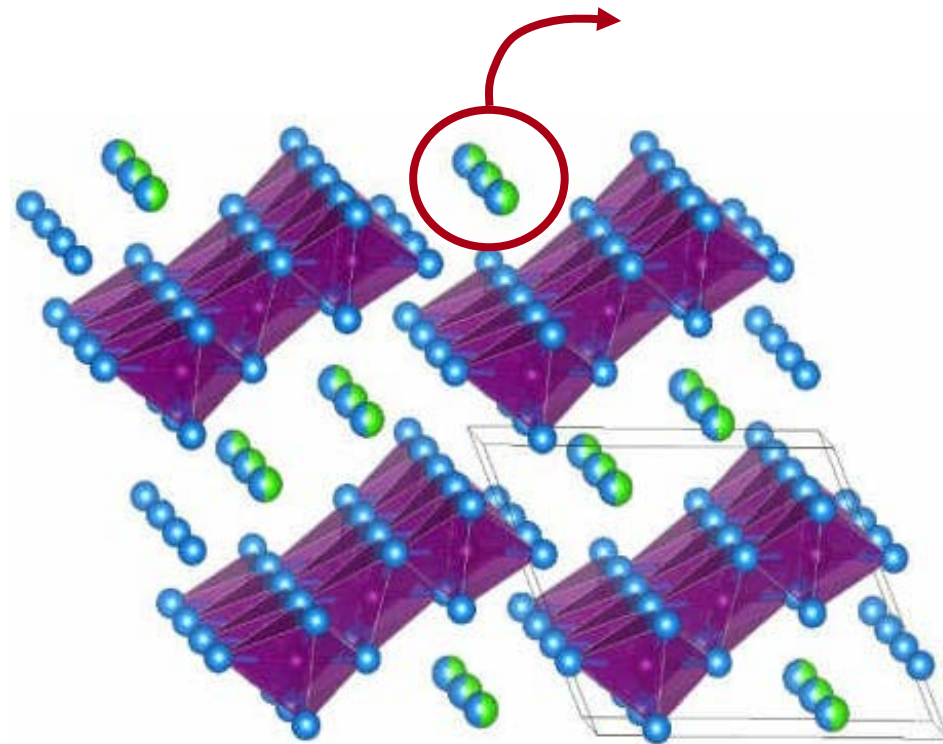
# Chemistry Lesson: Where does extra Chloride come from?

Ingredient ratio

“Stoichiometry”



Poorly formed crystal falls apart



# Outside the box...

Unprotected fasteners

Poor quality boards

High humidity at interior board surface

Air tightness

No supplemental water control layer



# So where are we now?

1. High Quality Board
2. WRB
3. Interior vapor throttle
4. Protected and sealed fasteners



**All need to be compatible!!! Look for composite panel rather than mix and match.**

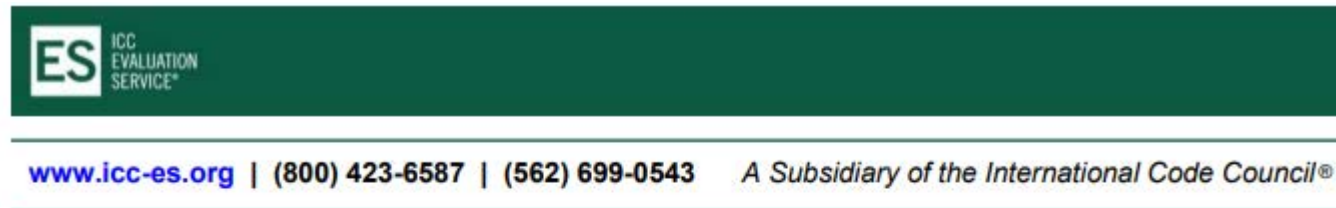


# Don't put lipstick on a Pig – Start with a good MgO board

ASTM (XYZ)

ICC 1125

MgOBPA



## ACCEPTANCE CRITERIA FOR FIBER-REINFORCED MAGNESIUM-OXIDE-BASED SHEETS

AC308

Approved October 2023  
(Compliance Date - October 2025)

AC308 Section 3.1.1 – Flexural Strength	AC308 Section 3.1.7 – Nail-Head Pull Through
AC308 Section 3.1.2 – Freeze-Thaw Cycling	AC308 Section 3.1.8 – Falling Ball Impact
AC308 Section 3.1.3 – Dimensions and Tolerances	AC308 Section 3.1.9 – Shear Bond Strength
AC308 Section 3.1.4 – Moisture Movement	AC308 Section 3.1.10 - Humidified Deflection
AC308 Section 3.1.5 – Water Absorption	AC308 Section 3.1.11 – Flame Spread Characteristics
AC308 Section 3.1.6 – Compression Indentation	AC308 Section 3.1.12 – Corrosion Effects



# Behind the scenes: Elements of good QC

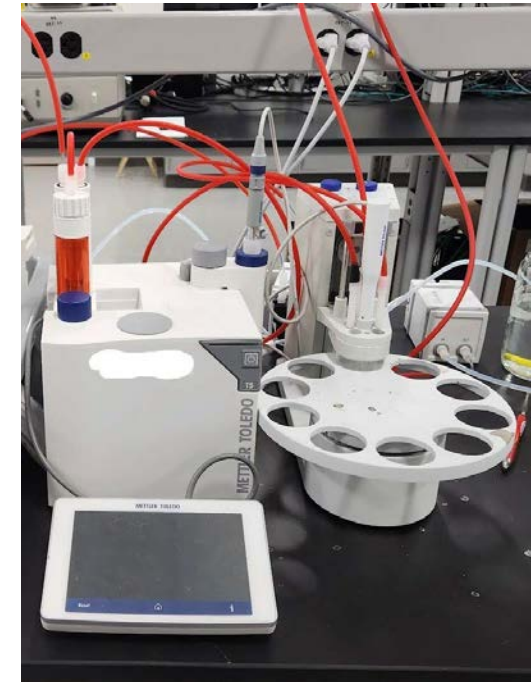
When you specify a board... do you trust their QC?



High Humidity – Does it sweat?



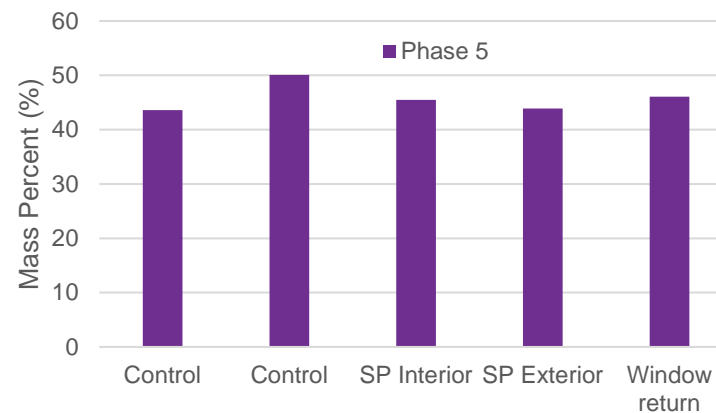
Crush and soak– How much chloride does it release?



# In the field... what are we seeing?

## Site review and analysis (Portland, Maine):

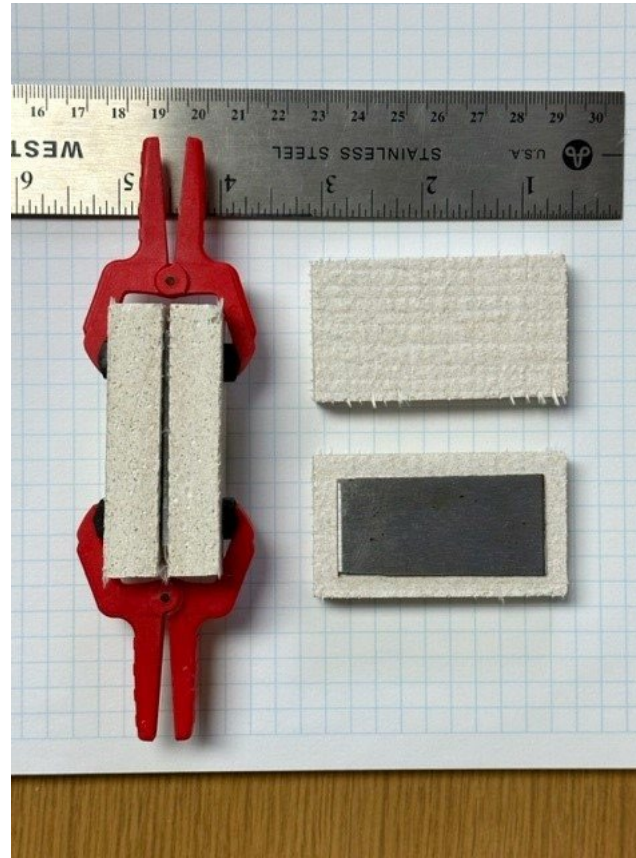
- Exposed returns and SP panels for > 12 months. (Aug '21 - Aug '22)
- No corrosion of fasteners or studs in contact with MgO found during investigation
- Open stairwell, no roof covering – rain can hit interior of boards
- Both SP and ArmorBoard completely exposed on the interior



# Beyond QC... How do we know it works?



Test Huts



Accelerated corrosion tests predict long-term failure risk



Australian research lab tests MgO samples for > 2 years at high RH



# Test Hut Validation Research

August 5, 2024



# Past Projects



DuPont RBETS – Florida (credit RDH)



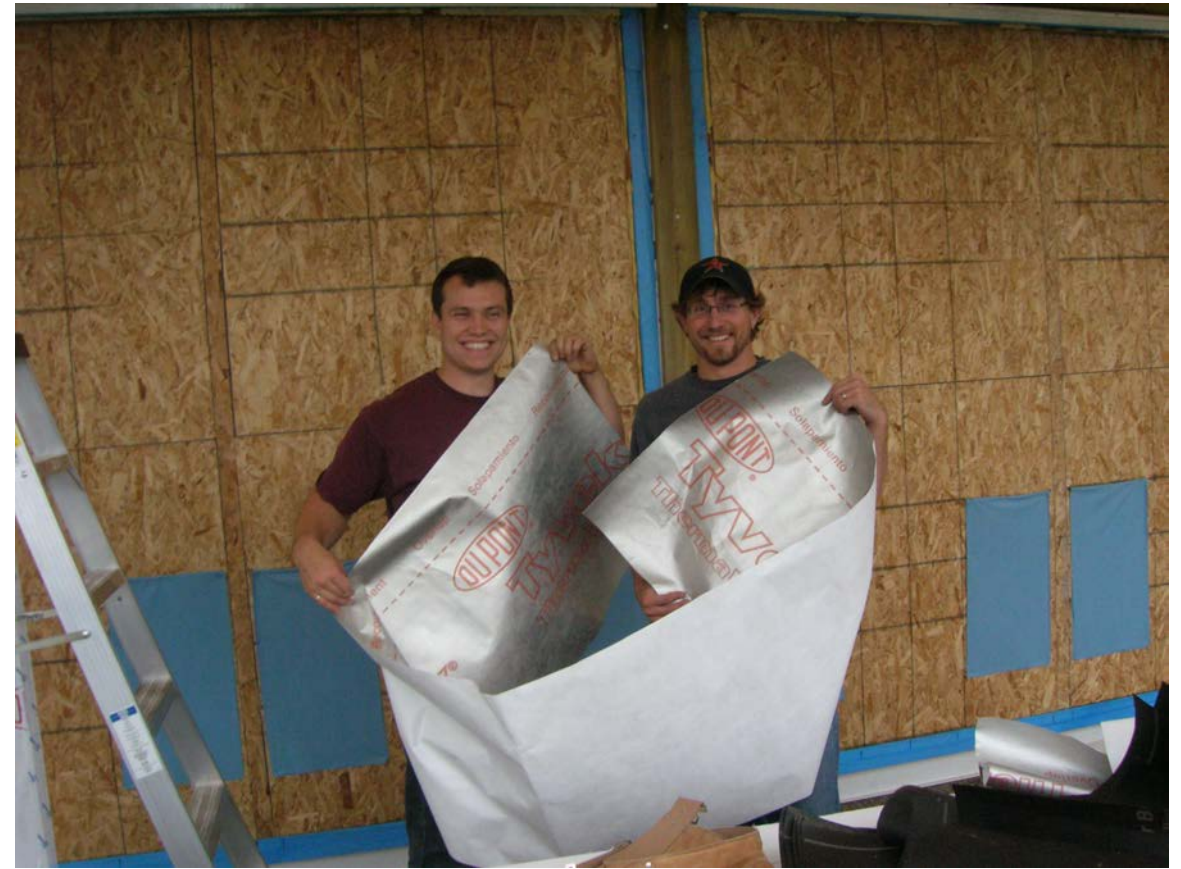
DuPont RBETS – Oregon (credit RDH)



# Past Projects



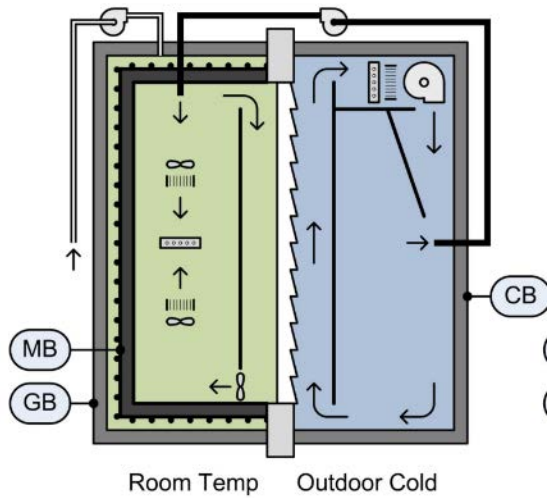
Summer Camp Mockup



DuPont Florida Test Hut



# Past Projects



Building Science Corporation – Thermal Metric (credit RDH)



Toronto Metropolitan University – Building Physics Lab (credit TMU)



Carleton University – CABER Facility – Guarded Hot Box and PSR (credit Carleton)



George Brown College – Climate Chamber (credit RDH)

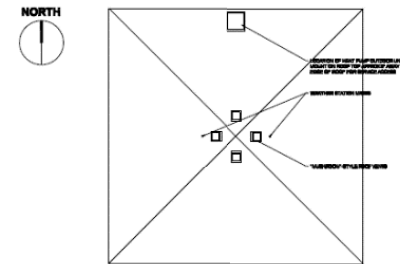
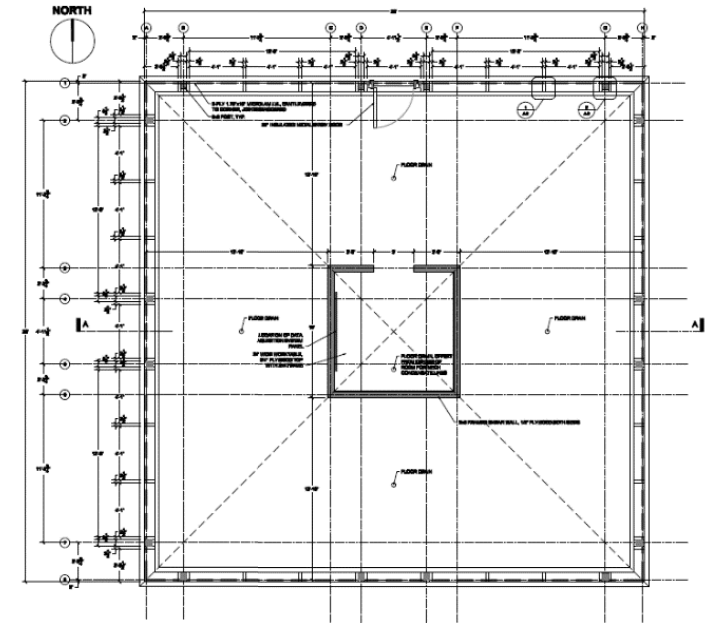
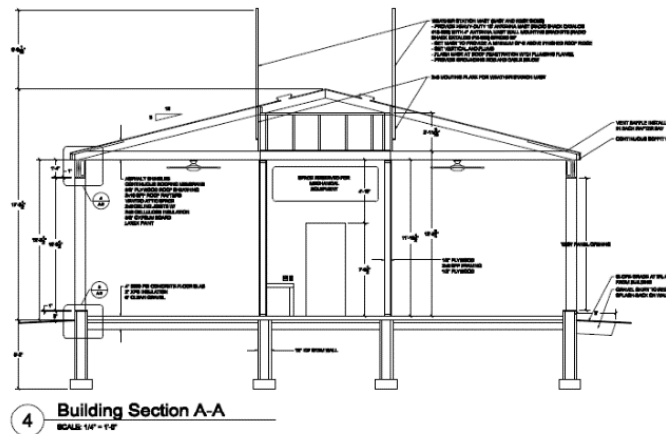
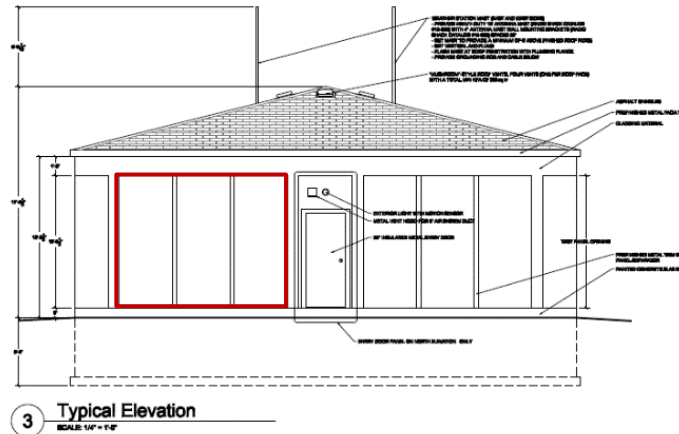




# Midland Outdoor Exposure Facility

“Taj MaHut” – The pinnacle of building enclosure exposure facilities

- 7 walls per orientation\*
- 4'x10' openings (or up to 12'x10')
- Corner instrumentation
- Weather station
- Pressurization/Depressurization
- ~800 sensors (T/RH/MC/Flux)



# Past Projects



Dow – Midland, MI

# Midland Outdoor Exposure Facility



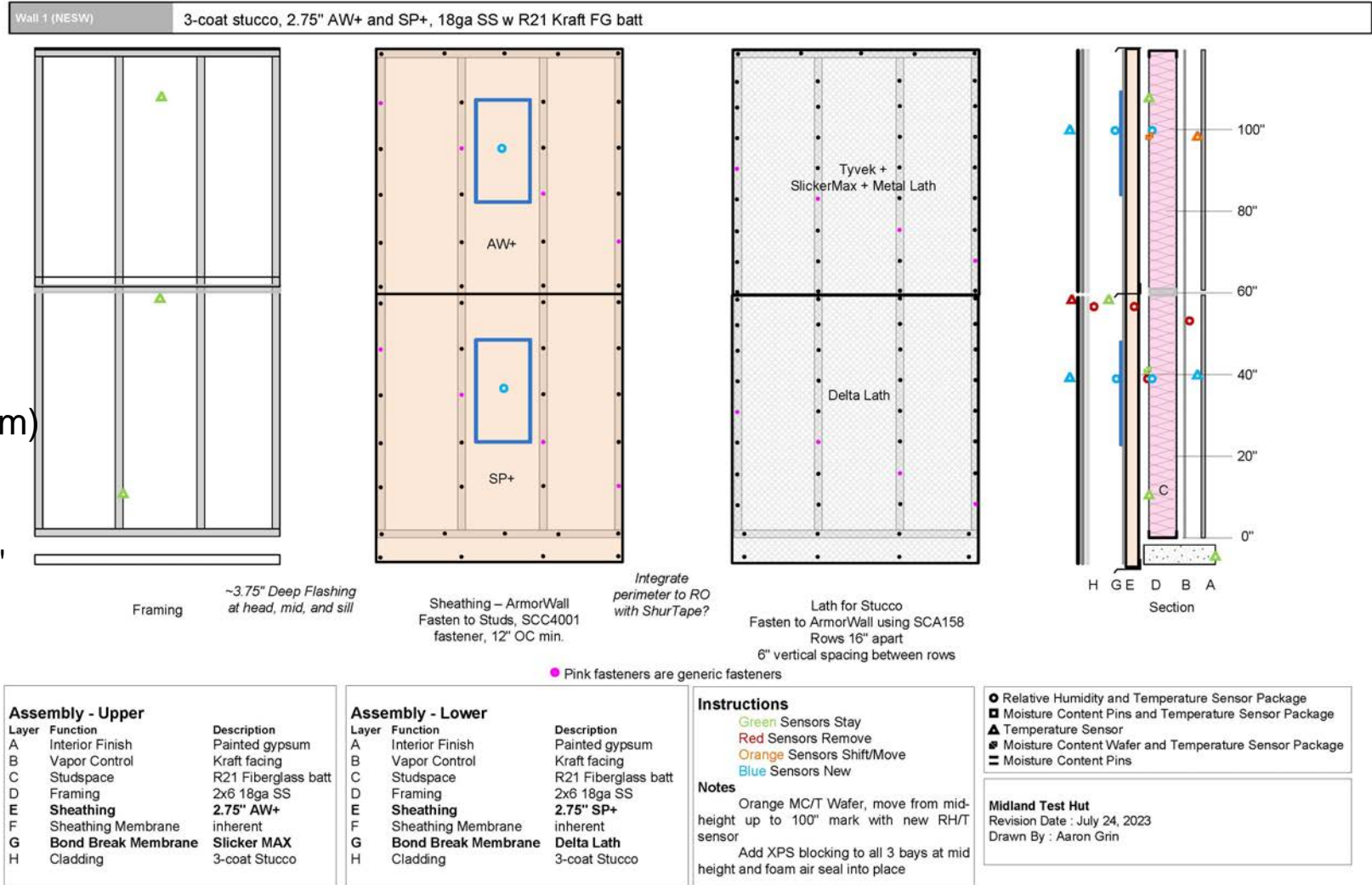
# Finished Walls – Nov 2023



# Wall Assembly 1

## Test Wall – Split Upper/Lower

- 3 Coat stucco
- Slicker (open) and Delta Lath (low perm)
- ArmorWall Plus™ - 2.75" - Upper 5'
- ArmorWall SP Plus™ - 2.75"- Lower 5'
- Insulated 6in Steel Stud Wall
- Added Stressors
  - Intentional wetting at WRB layer



ArmorWall™ is a trademark of DuPont de Nemours, Inc.

# Wall Assembly 2

## Test Wall – Split Upper/Lower

- Metal Panel Cladding
- Gap
- AW+ - 2.75"- on 4in insulated stud
- ArmorBoard™ - 0.5"- on 6in insulated stud
- Added Stressors
  - Intentional wetting at WRB layer
  - Air leakage into stud-bay

Wall 2 (NESW) Steel Panel, 1" furring, 2.75" AW+ and 0.5" ArmorBoard, 18ga SS

**Framing**  
~4" Deep Flashing at head, mid, 2" at Sill

**Sheathing – ArmorWall**  
Fasten to Studs, 12" OC min for SCC4001 for AW+  
SC1121 for ArmorBoard

*Integrate perimeter to RO with ShurTape?*

**Vertical Girts for Cladding**  
Fasten to ArmorWall using SCA 200  
Rows 16" apart, offset from Studs by 1.5"  
Max 12" spacing fasteners vertically

**Section**  
Mid-panel separator – 1" xps + 3/4" ply, wrapped in SAM

● Pink fasteners are generic fasteners

Assembly - Upper			Assembly - Lower		
Layer	Function	Description	Layer	Function	Description
A	Interior Finish	Painted gypsum	A	Interior Finish	Painted gypsum
B	Vapor Control	Kraft facing	B	Vapor Control	Kraft facing
C	Studspace	R14 Fiberglass batt	C	Studspace	R21 Fiberglass batt
D	Framing	2x4 18ga SS	D	Framing	2x6 18ga SS
E	Sheathing	2.75" AW+	E	Sheathing	0.5" ArmorBoard
F	Sheathing Membrane	inherent	F	Sheathing Membrane	inherent
G	Drainage Gap	inherent	G	Drainage Gap	inherent
H	Cladding	Steel Panel	H	Cladding	Steel Panel

Instructions
Green Sensors Stay
Red Sensors Remove
Orange Sensors Shift/Move
Blue Sensors New

Notes
Figure out alignment such that the exterior surfaces line up. Ok for interior drywall to have a jog at the horizontal joint.

Legend
○ Relative Humidity and Temperature Sensor Package
◻ Moisture Content Pins and Temperature Sensor Package
▲ Temperature Sensor
◼ Moisture Content Wafer and Temperature Sensor Package
■ Moisture Content Pins

Midland Test Hut
Revision Date : July 24, 2023
Drawn By : Aaron Grin

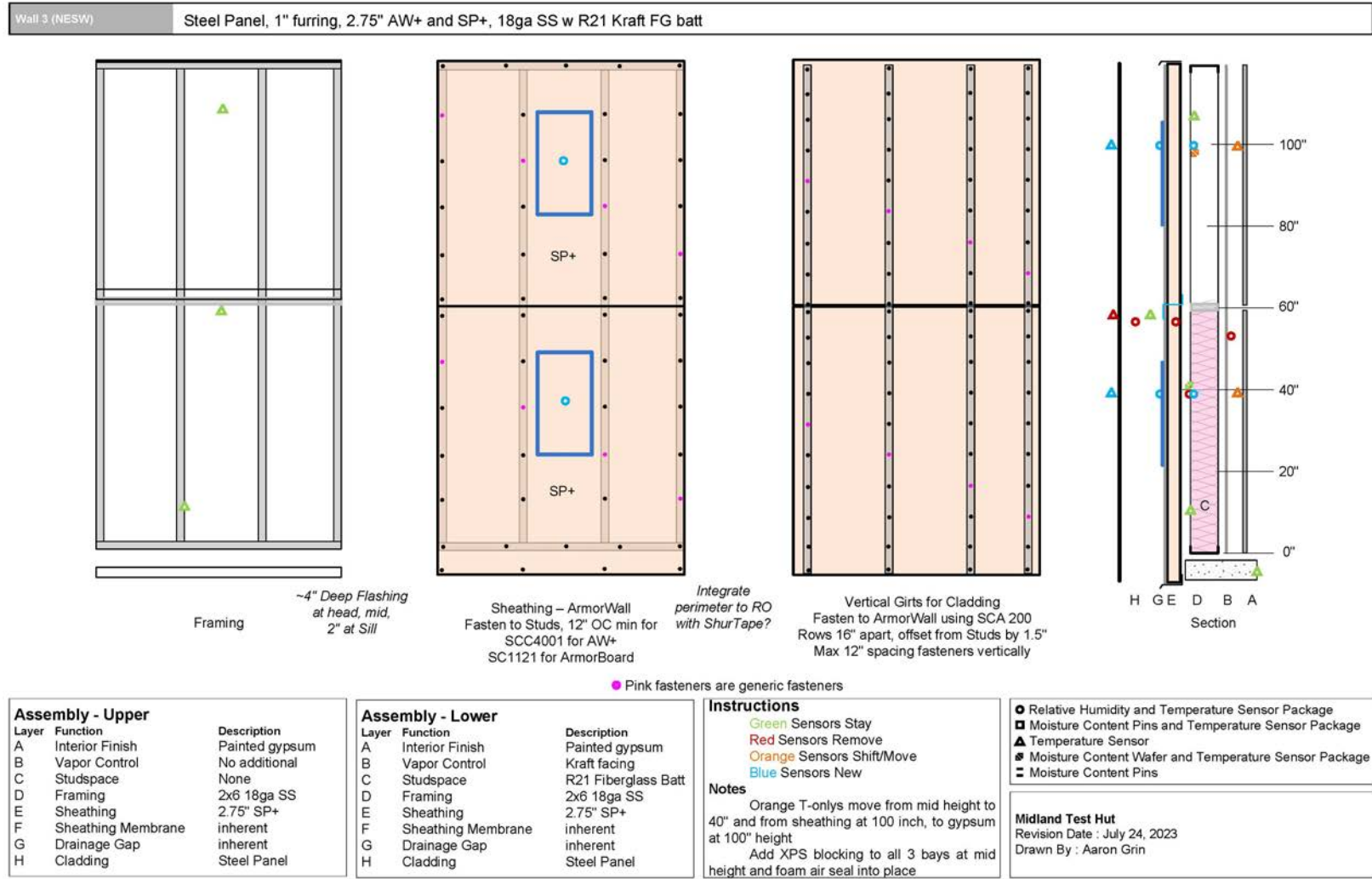


ArmorBoard™ is a trademark of DuPont de Nemours, Inc.

# Wall Assembly 3

## Test Wall – Split Upper/Lower

- Metal Panel Cladding
- Gap
- AW+ - 2.75" – empty 6in steel stud
- AW+ - 2.75" – insulated 6in steel stud
- Added Stressors
  - Intentional air leakage into stud-bay

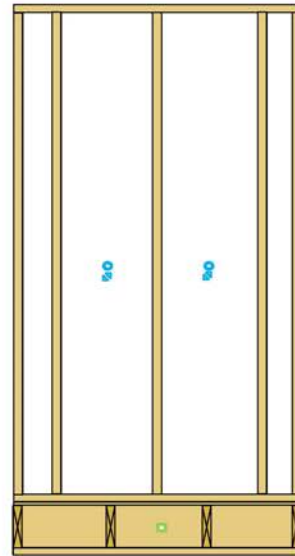


# Wall 4 – Recreate Denmark MgO Wall

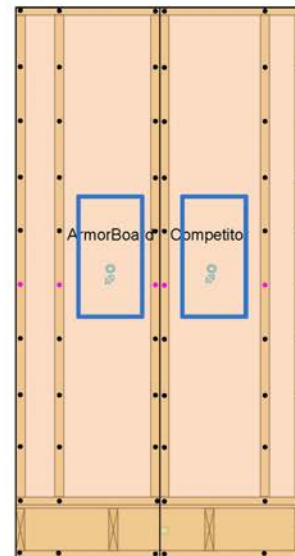
Wall 4 (NESW) Fiber Cement Siding, MgO vs AW+, 2x6, R19-21 Fiberglass Batt w/ Poly

## Test Wall – Split Left-Right

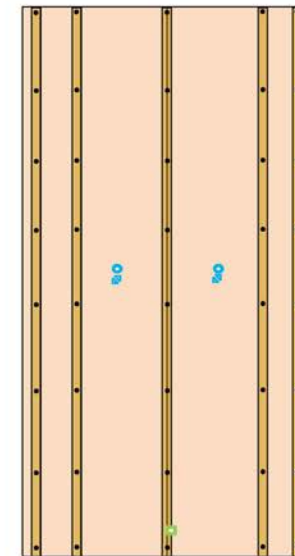
- Fiber Cement Cladding installed as Tiles
- 0.5in Gap
- Bare MgO 0.5"
- AB+ Coated MgO 0.5"
- Insulated 2x6 Cavities



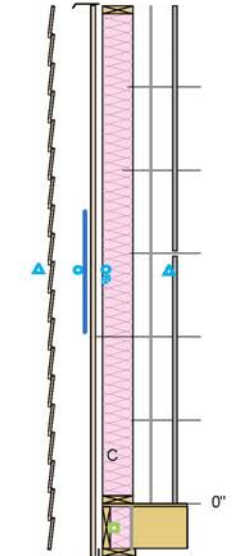
Framing  
~2" Deep Flashing at head and Sill



Sheathing  
ArmorBoard + Competitor  
Fasten to Studs, 12" OC min, SC1121  
Integrate perimeter to RO with ShurTape?



Vertical Girts for Cladding  
Fasten to ArmorWall using SCA158 Rows 16" apart  
16" vertical spacing



H G E D B A  
Section

- Added Stressors
  - Intentional wetting at WRB layer
  - Intentional air leakage into stud-bay

● Pink fasteners are generic fasteners

Assembly (left)		
Layer	Function	Description
A	Interior Finish	Painted gypsum
B	Vapor Control	Kraft facing
C	Studspace	R14 Fiberglass batt
D	Framing	2x4 SPF Studs
E	Sheathing	0.5" AW+
F	Sheathing Membrane	inherent
G	Drainage Gap	0.5" Vertical Strapping
H	Cladding	Fiber Cement Tiles

Assembly (right)		
Layer	Function	Description
A	Interior Finish	Painted gypsum
B	Vapor Control	Kraft facing
C	Studspace	R14 Fiberglass batt
D	Framing	2x4 SPF Studs
E	Sheathing	0.5" MgO (others)
F	Sheathing Membrane	none
G	Drainage Gap	0.5" Vertical Strapping
	Cladding	Fiber Cement Tiles

**Instructions**  
 ● Green Sensors Stay  
 ● Red Sensors Remove  
 ● Orange Sensors Shift/Move  
 ● Blue Sensors New

**Notes**  
 Frame two 16" bays off of center. Frame remainder as required.

● Relative Humidity and Temperature Sensor Package  
 ■ Moisture Content Pins and Temperature Sensor Package  
 ▲ Temperature Sensor  
 ● Moisture Content Wafer and Temperature Sensor Package  
 ■ Moisture Content Pins

**Midland Test Hut**  
 Revision Date : July 24, 2023  
 Drawn By : Aaron Grin





# Test Hut Update



# Test Hut Update

- Test Wall 1
  - *SlickerMax® (vapour open)*
  - *vs Delta Drain® (vapour barrier)*
  - Wetting Apparatus in Drainage Cavity
  - Surface Temperature Sensors
  - Cavity T and RH Sensors

SLICKER® MAX is a registered trademark of Benjamin Obdyke Inc

DELTA® DRAIN is a registered trademark of Ewald Dörken AG



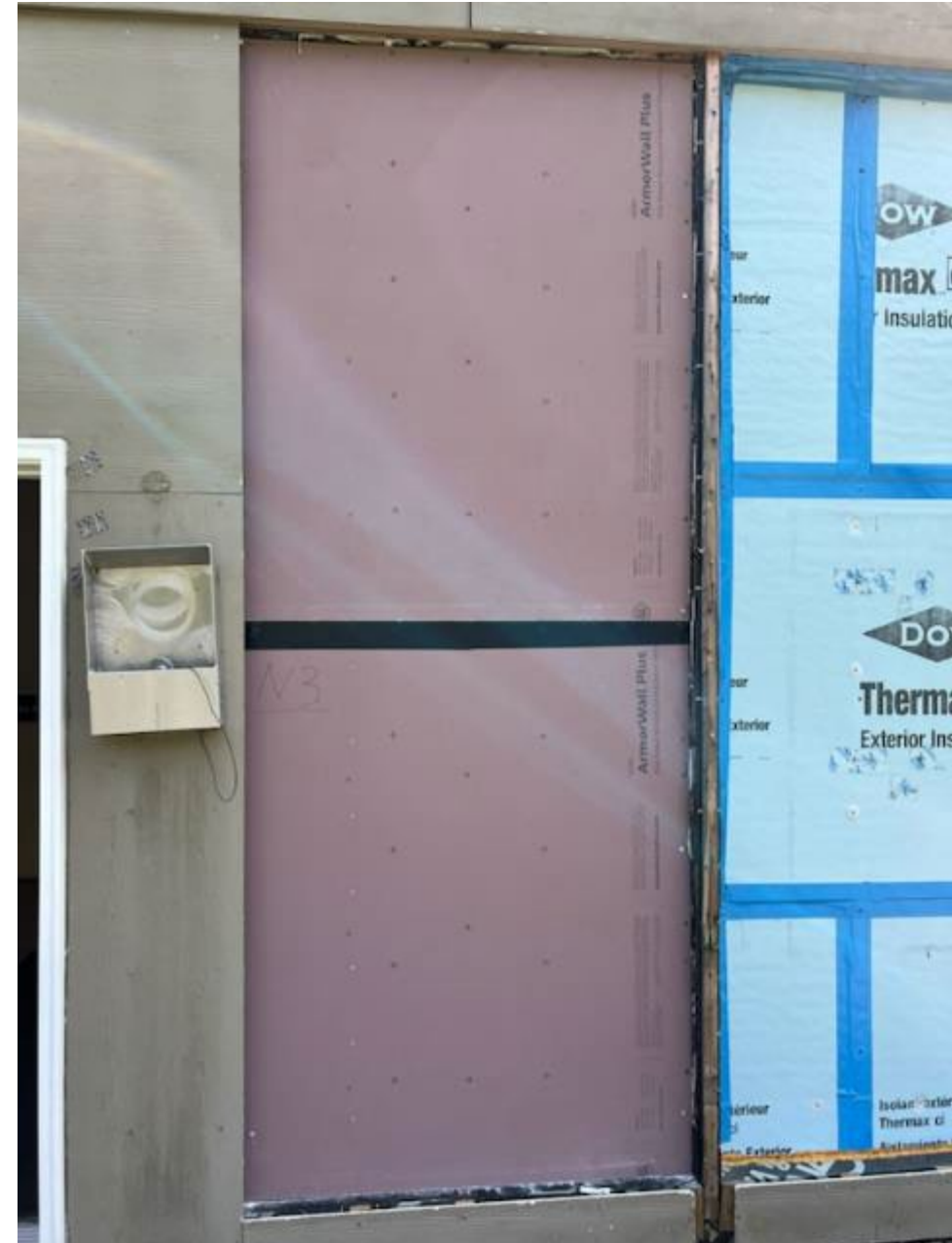
# Test Hut Update

- Test Wall 2
  - $\frac{1}{2}$ " ArmorBoard on 2x6
  - $2\frac{3}{4}$ " AW+ on 2x4
  - Wetting Apparatus in Drainage Cavity
  - Surface Temperature Sensors
  - Cavity T and RH Sensors



# Test Hut Update

- Test Wall 3
  - $2\frac{3}{4}$ " AW+ on 2x6 w and w/o Cavity insulation
  - Wetting Apparatus in Drainage Cavity
  - Surface Temperature Sensors
  - Cavity T and RH Sensors



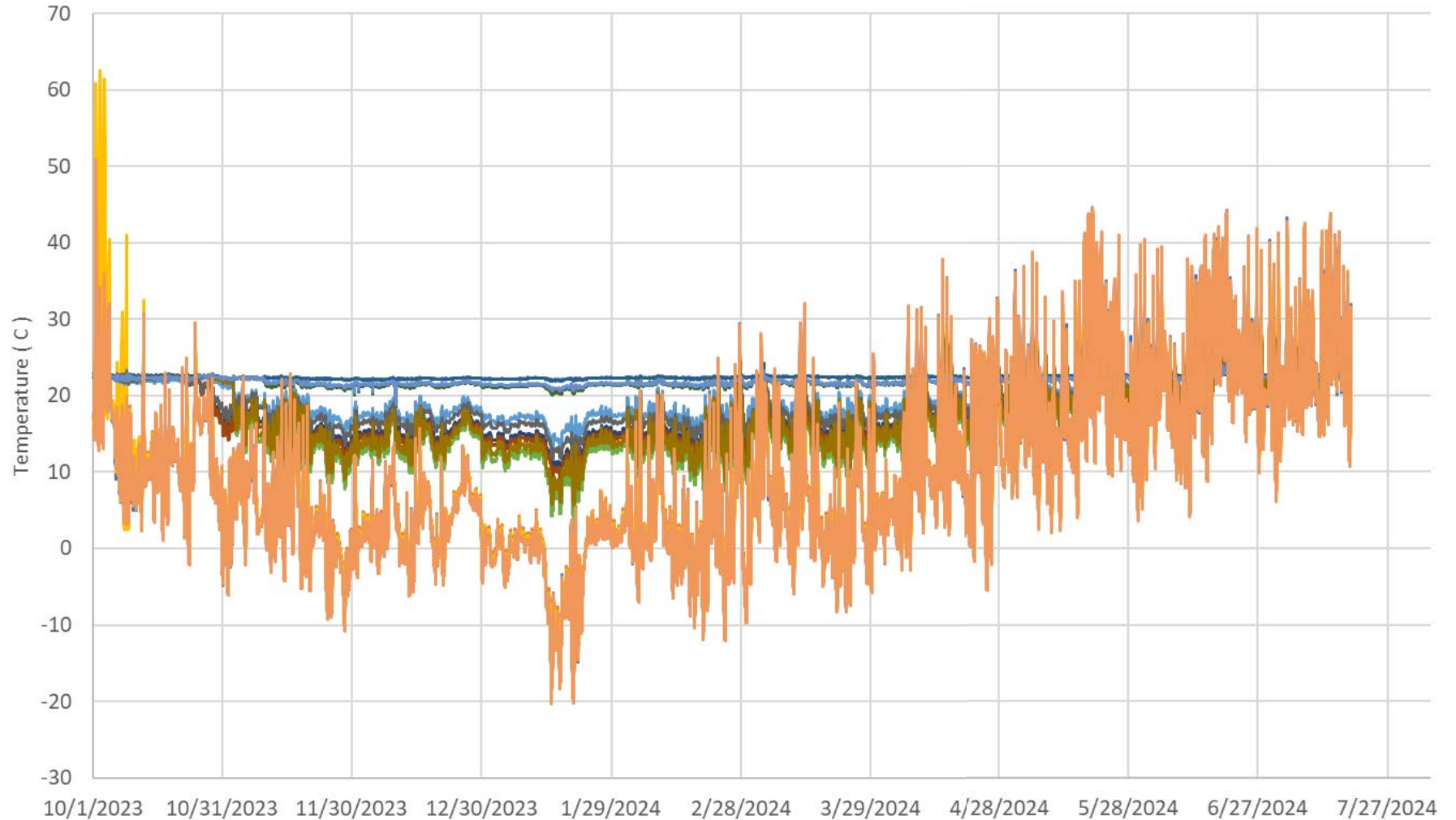
# Test Hut Update

- Test Wall 4
  - *Bare MgO vs Coated on 2x4 wood*
  - Wetting Apparatus in Drainage Cavity
  - Surface Temperature Sensors
  - Cavity T and RH Sensors



# Test Hut Update

West Wall 1

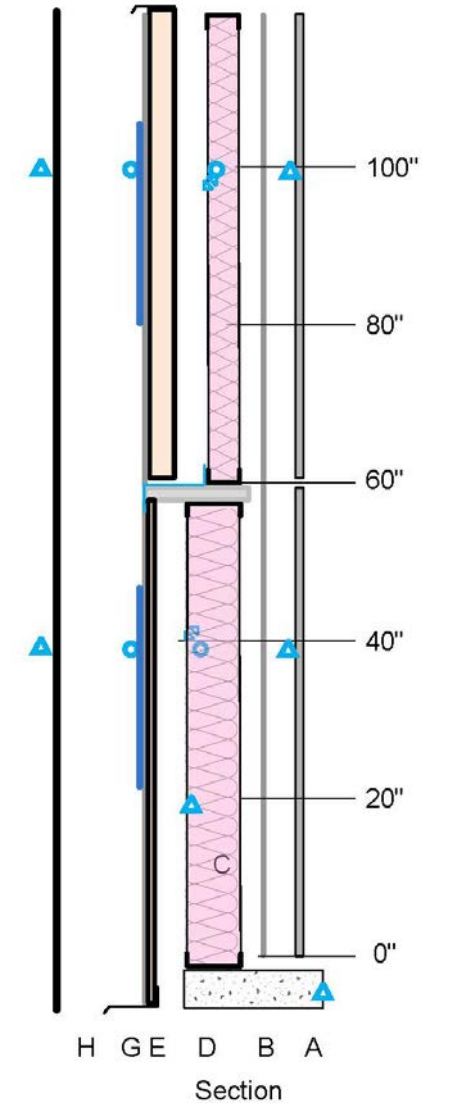
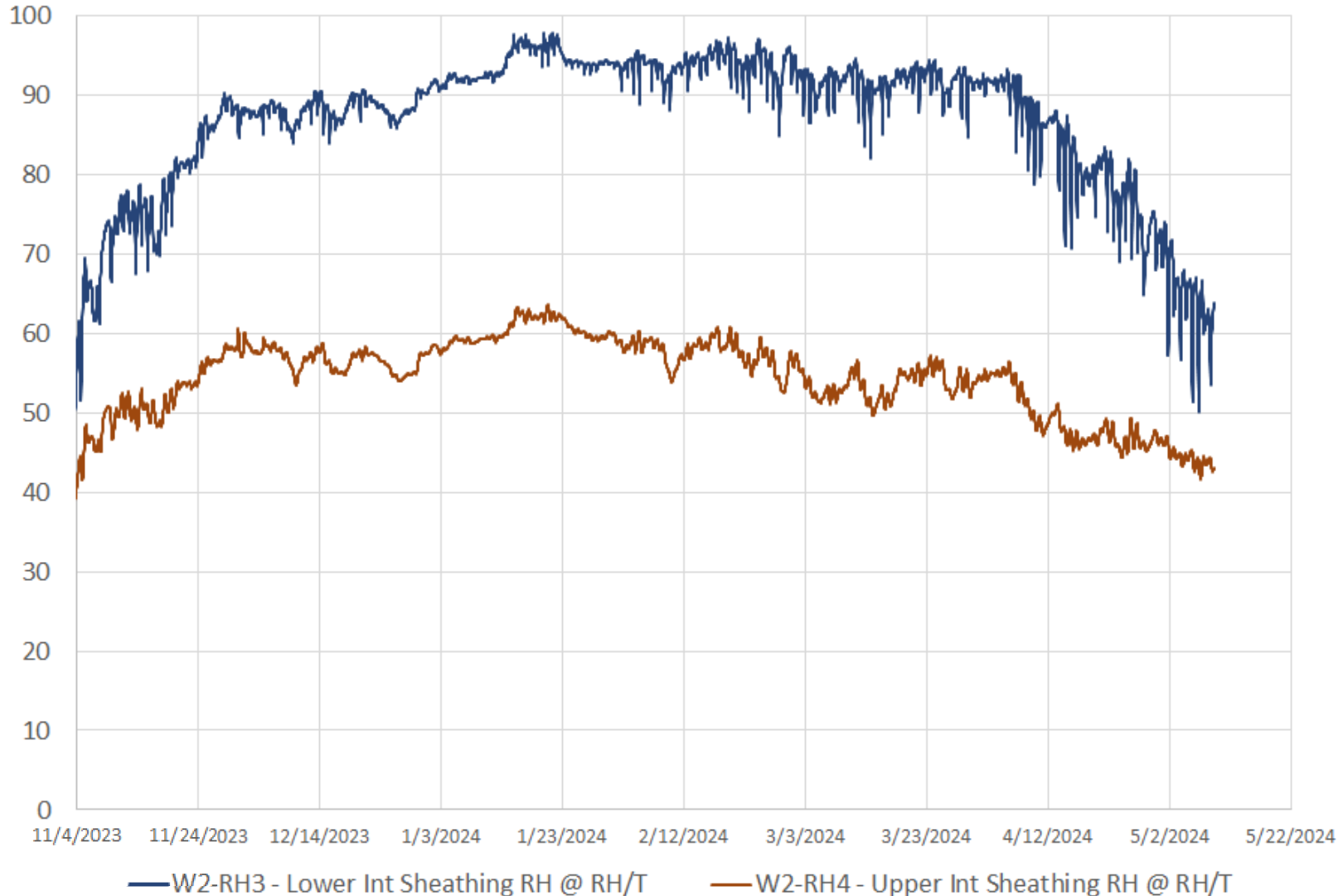


- W1-T1 - Exterior Cladding Surface Lower T
- W1-T2 - Exterior Drainage Lower T at T/RH
- W1-T3 - Exterior Drainage Upper T at T/RH
- W1-T4 - Exterior Drainage Upper T at T/RH
- W1-T5 - Upper Int Sheathing I @ Stud
- W1-T6 - Upper Int Sheathing I @ MC/I
- W1-T7 - Lower Int Sheathing T @ MC/T
- W1-T8 - Lower Int Sheathing T @ RH/T
- W1-T9 - Lower Int Sheathing T @ Stud
- W1-T10 - Upper Int Sheathing T @ RH/T
- W1-T11 - Interior Slab
- W1-T12 - Upper Back of Drywall
- W1-T13 - Lower Back of Drywall
- W1-T14 - Exterior Cladding Surface Upper T



# Wall Assembly 2 – Diffusion Analysis

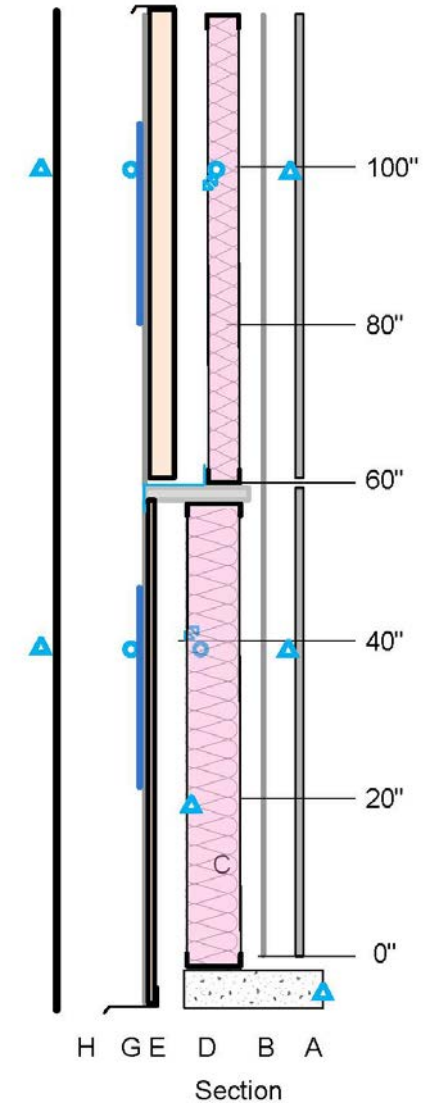
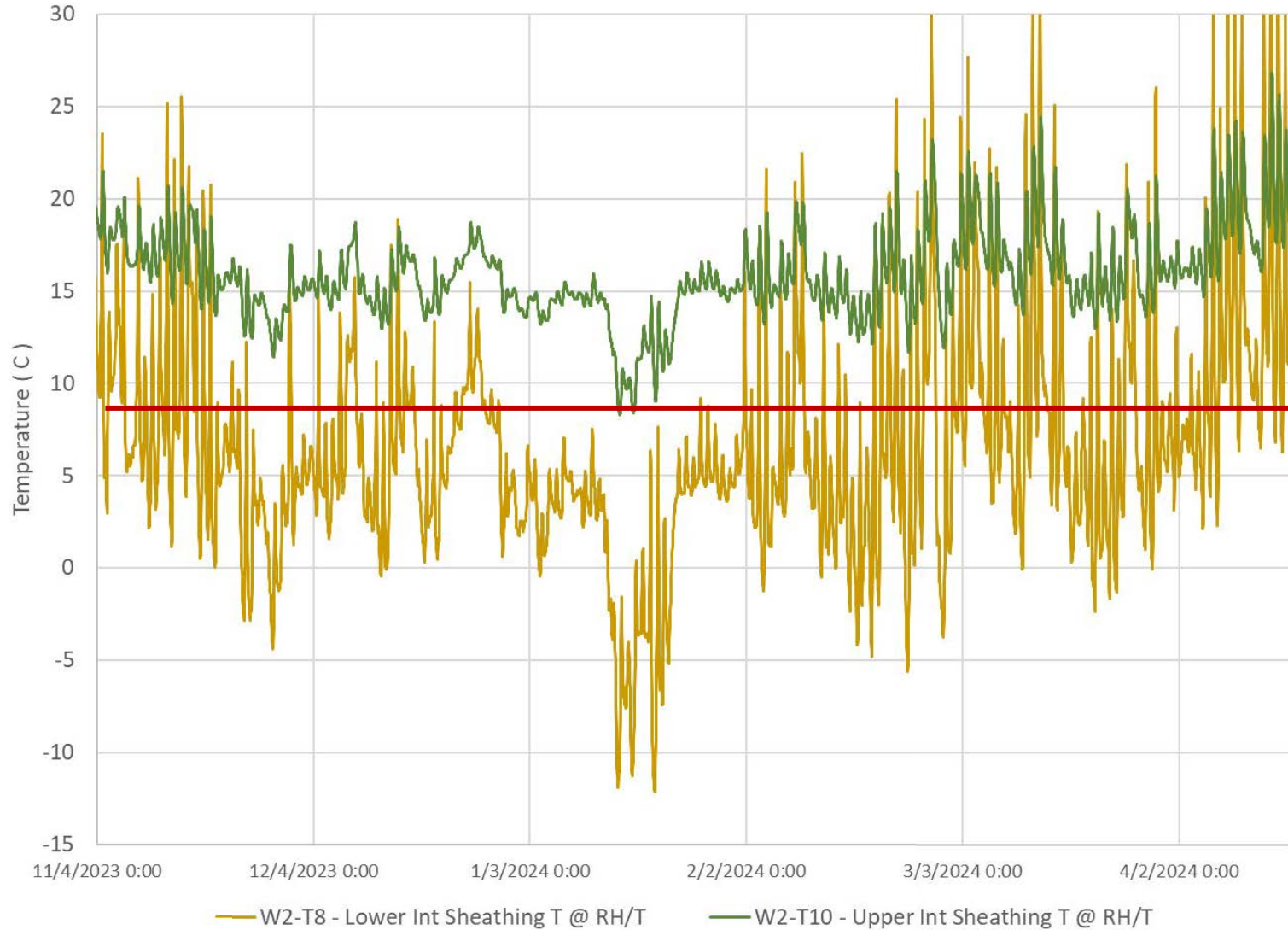
West Walls 2 Relative Humidity - Interior of MgO Sheathing vs 2.75" AW+



- Relative Humidity and Temperature Sensor Package
- Moisture Content Pins and Temperature Sensor Package
- ▲ Temperature Sensor
- ▨ Moisture Content Wafer and Temperature Sensor Package
- Moisture Content Pins

# Wall Assembly 2 – Thermal Analysis

West Wall 2 - Condensation Plane Temperatures

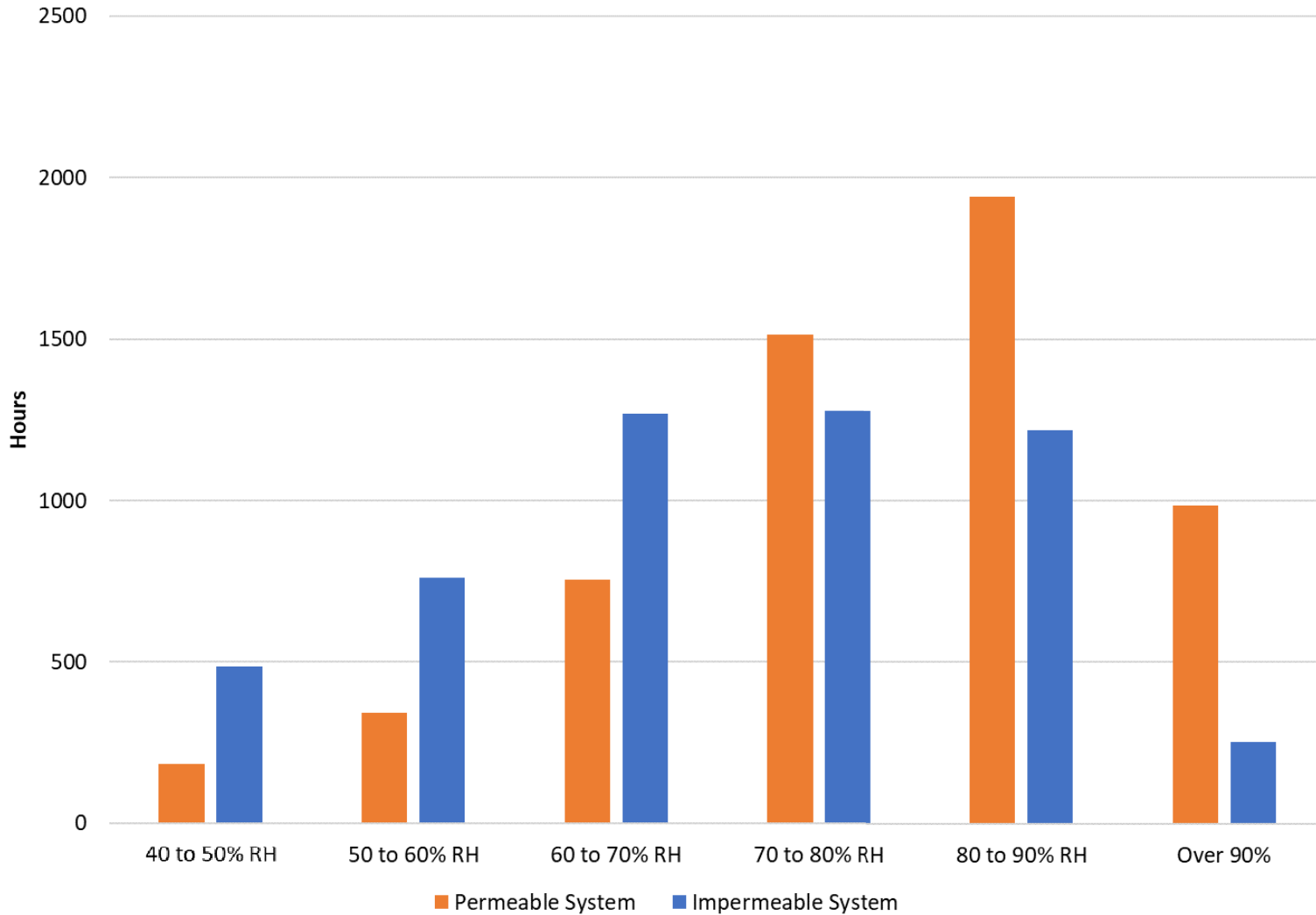


- Relative Humidity and Temperature Sensor Package
- Moisture Content Pins and Temperature Sensor Package
- ▲ Temperature Sensor
- ▨ Moisture Content Wafer and Temperature Sensor Package
- ▬ Moisture Content Pins



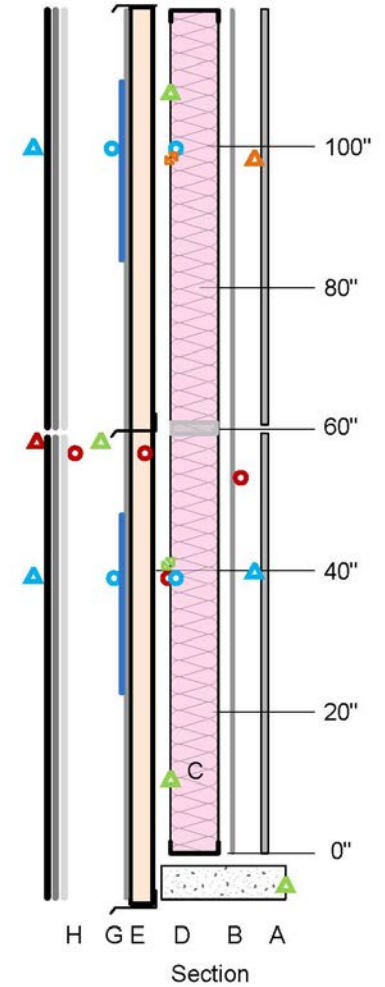
# Wall Assembly 1 – RH Analysis

West Wall 1 - Hours of Exposure - Drainage Cavity RH



Assembly - Upper		
Layer	Function	Description
A	Interior Finish	Painted gypsum
B	Vapor Control	Kraft facing
C	Studspace	R21 Fiberglass batt
D	Framing	2x6 18ga SS
E	<b>Sheathing</b>	<b>2.75" AW+</b>
F	Sheathing Membrane	inherent
G	<b>Bond Break Membrane</b>	<b>Slicker MAX</b>
H	Cladding	3-coat Stucco

Assembly - Lower		
Layer	Function	Description
A	Interior Finish	Painted gypsum
B	Vapor Control	Kraft facing
C	Studspace	R21 Fiberglass batt
D	Framing	2x6 18ga SS
E	<b>Sheathing</b>	<b>2.75" SP+</b>
F	Sheathing Membrane	inherent
G	<b>Bond Break Membrane</b>	<b>Delta Lath</b>
H	Cladding	3-coat Stucco



- Relative Humidity and Temperature Sensor Package
- Moisture Content Pins and Temperature Sensor Package
- ▲ Temperature Sensor
- Moisture Content Wafer and Temperature Sensor Package
- Moisture Content Pins

# 2024-2026 Test Hut Plans

- Data Analysis
  - Lots to do
  - Extrapolation of WUFI® vs real-time data
  - Real-time data vs Carleton test hut data
- Late 2024 or early 2025
  - Adding air leakage
  - Adding water leakage
- 2026 Wall Change Out and Destructive Analysis

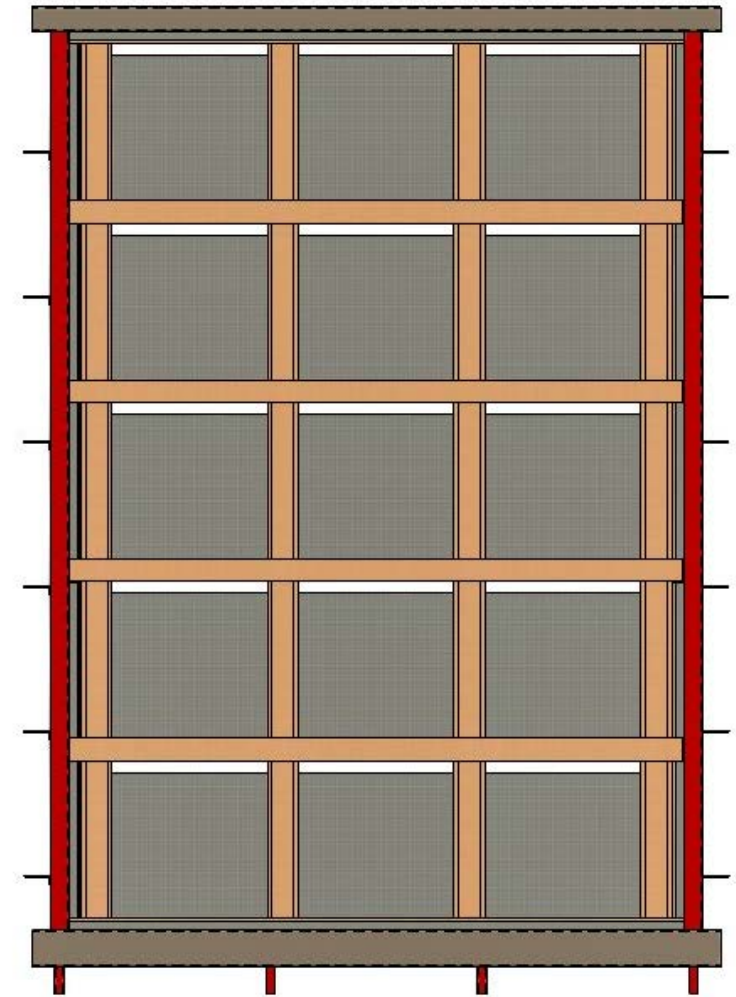


WUFI® is a trademark of Fraunhofer IBP

# Short-Term, High-Value Climate Chamber Tests

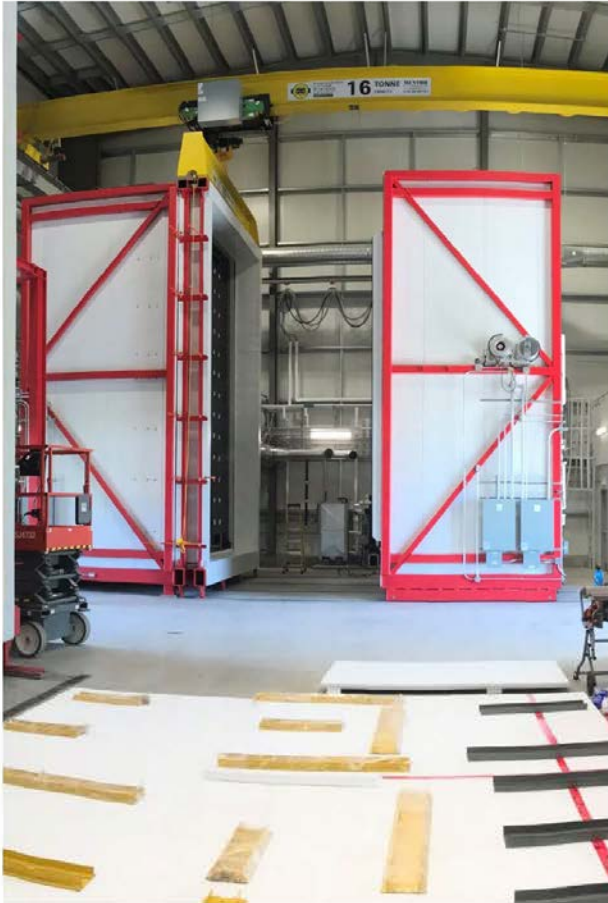
## Carleton CABER Facility – Ottawa, Ontario

- Specimens
  - Up to 15 – 4' x 4' samples – overall opening 16' x 25'
  - Any wall makeup we want to test
- Test Plan
  - Many options
  - -22F (-30C) up to 120F (50C)
  - Full-scale pressurized spray rack
  - 20,000 watt Light Rack
  - Diurnal cycles possible
- Quantification (pre and post)
  - Visual review
  - MgO material property measurements
  - Structural testing – fastener withdrawal and bending



# Short-Term, High-Value Climate Chamber Tests

## Carleton CABER Facility – Ottawa, Ontario



# Multi-Climate Field Exposure and Evaluation

**Goal:** Expose AW products to field conditions and verify durability

- Duration: 24 months – Collect samples every 6 months
- Monitor Temperature and Humidity in-situ
- Evaluate Walls at Time Zero (no exposure) and at 6, 12, 18 and 24 months of exposure in field

## Mini Test Huts for AW Mock Wall Assessment



Tacoma, WA

# Mini Test Hut Locations



Midland, MI



Miami, FL

Jyllinge, Denmark



# Let's Talk!

Dupont Building Knowledge Center - [tyvekbkc@dupont.com](mailto:tyvekbkc@dupont.com)

Adam Broderick - [adam.broderick@dupont.com](mailto:adam.broderick@dupont.com)

Aaron Grin - [aaron.grin@dupont.com](mailto:aaron.grin@dupont.com)

## References / Technical Resources

Rode et al, "Moisture damage with magnesium oxide boards in Danish facade structures"  
(<https://doi.org/10.1016/j.egypro.2017.10.025>.)

Doggett et al, "Magnesium Oxide Panels: Emergence of a Modern Building Material" ([https://built-environments.com/wp-content/uploads/2024/04/Magnesium-Oxide-Panels-Emergence-of-a-Modern-Building-Material\\_032524-3.pdf](https://built-environments.com/wp-content/uploads/2024/04/Magnesium-Oxide-Panels-Emergence-of-a-Modern-Building-Material_032524-3.pdf))

Doggett, "Hygrothermal Analysis of Magnesium Oxide as Structural Insulated Sheathing" (<https://built-environments.com/wp-content/uploads/2024/02/Hygrothermal-Analysis-of-Magnesium-Oxide-as-Structural-Insulated-Sheathing.pdf>)

Aiken et al, "Exposure of magnesium oxide boards to various conditions for extended durations"  
(<https://doi.org/10.1016/j.conbuildmat.2021.124429>)





© 2024 DuPont. All rights reserved. DuPont™, the DuPont Oval Logo, and all trademarks and service marks denoted with ™, SM or ® are owned by affiliates of DuPont de Nemours, Inc. unless otherwise noted. Nothing contained herein shall be construed as a representation that any recommendations, use or resale of the product or process described herein is permitted and complies with the rules or regulations of any countries, regions, localities, etc., or does not infringe upon patents or other intellectual property rights of third parties.

The information provided herein is based on data DuPont believes to be reliable, to the best of its knowledge and is provided at the request of and without charge to our customers. Accordingly, DuPont does not guarantee or warrant such information and assumes no liability for its use. If this product literature is translated, the original English version will control and DuPont hereby disclaims responsibility for any errors caused by translation. This document is subject to change without further notice.