Software, Sustainability, Design, Detailing, – Through the Lens of Concrete Masonry

MASONRY INSTITUTE OF HAWAII

Masonry Institatue of Hawaii – August 5, 2022

Jason Thompson – VP Engineering, NCMA
(jthompson@ncma.org)

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Logistics – Ask Questions!

Ask questions any time!

Or shoot me an email if you forget:
Jason Thompson
jthompson@ncma.org
703-713-1900

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Logistics – Downloading Software

Free trial here:
https://ncma.org/resources/software/

Applies to both EleMasonry and the Direct Design software packages.

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Logistics – Today's Schedule

Todays' Topics

- EleMasonry Software Package
- Direct Design Software Package
- Key Design Changes for Concrete Masonry
- Detailing for Energy Efficiency
- Carbon Footprint and Resiliency
- Other items on your mind…open Q&A

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The Humble Cinder Block…
From it's early beginnings…

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The Humble Cinder Block…
From it's early beginnings…

CMU Eras
1880s: Birth
1920s – 1960s: Faster, cheaper, more consistent.
1960s – 2000s: Product and application innovation
Today: Material evolution

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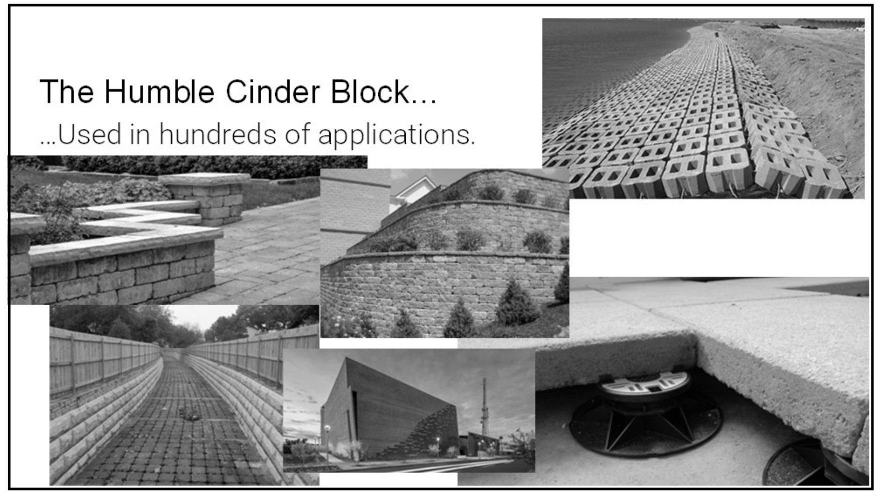
The Humble Cinder Block…
To thousands of products…

7

The Humble Cinder Block…
…Used in hundreds of applications.



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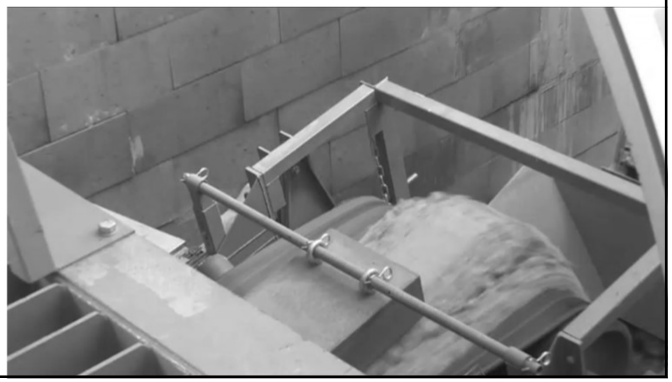
Dry-Casting – Production Overview



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Dry-Casting – Production Overview

Other unique production variables:

Aggregate Size

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Dry-Casting – Production Overview

Other unique production variables:

Regrind

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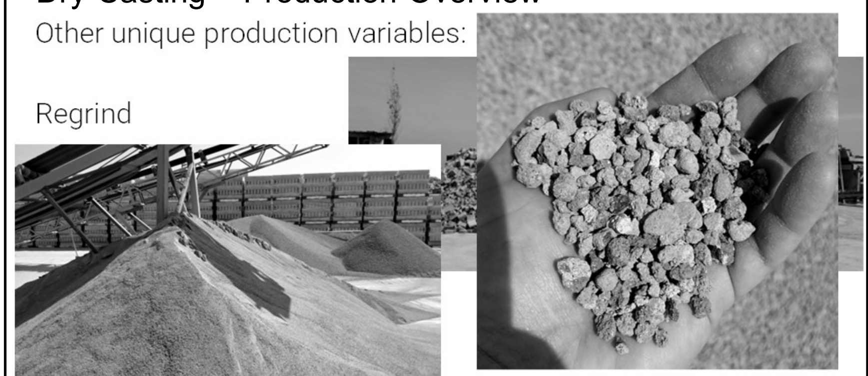
Dry-Casting – Production Overview

Other unique production variables:

Regrind



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Dry-Cast Manufactured Concrete

While dry-cast manufactured concrete is concrete, its combination of constituent materials, manufacturing methods, and curing process facilitate innovations in material use.



And…

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Dry-Cast Manufactured Concrete

The modular, segmental characteristics of manufactured concrete products are uniquely suited for adaptive reuse…with some challenges.

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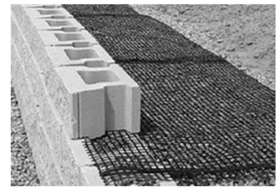
Dry-Cast Products – Circular Concepts

Design Intent vs. Inherent Attribute?

Segmental Retaining Walls

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Dry-Cast Products – Circular Concepts

Design Intent vs. Inherent Attribute?

Segmental Retaining Walls


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Dry-Cast Products – Circular Concepts

Design Intent vs. Inherent Attribute?

Interlocking Concrete Pavers

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Dry-Cast Products – Circular Concepts

Design Intent vs. Inherent Attribute?

Concrete Masonry

Mortar, grout, and rebar present challenges.

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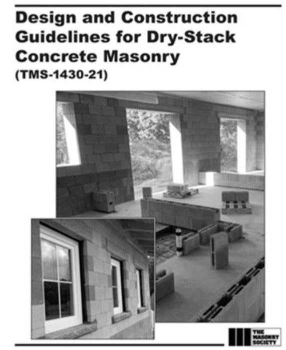
Dry-Cast Products – Circular Concepts

Design Intent vs. Inherent Attribute?

Concrete Masonry

Dry-stack CMU



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Dry-Cast Products – Circular Concepts

Dry-cast manufactured concrete products (by accident?) are specifically tailored to adapt and align with circular economy objectives.

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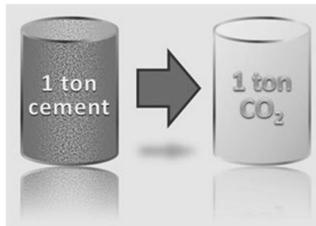
Dry-Cast Products – Carbon Sequestration

The other key market driver for the industry is minimizing our carbon footprint.

Production of portland cement is carbon intensive.



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Dry-Cast Products – Carbon Sequestration

There are numerous carbon capture, accelerated carbonation, and related technologies in use and in development today that permanently sequester CO_2.

While it was well known that concrete carbonates, we didn't have a good baseline for dry-cast concrete carbonation.

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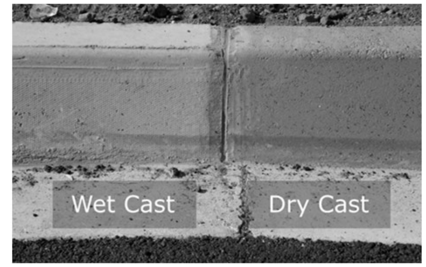
Dry-Cast Products – Carbon Sequestration

The assumption was that dry-cast and wet-cast concrete carbonate at roughly the same rate and therefore sequester about the same amount of CO_2.



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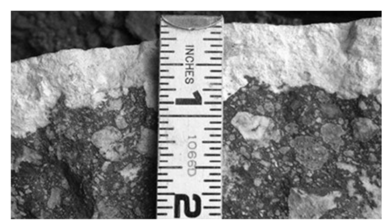
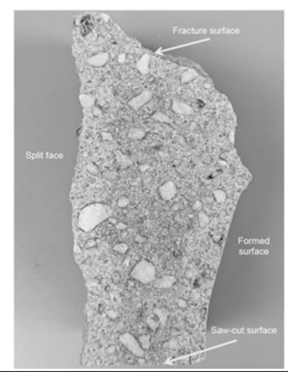
Dry-Cast Products – Carbon Sequestration

In reality wet-cast and dry-cast concrete carbonate at vastly different rates.





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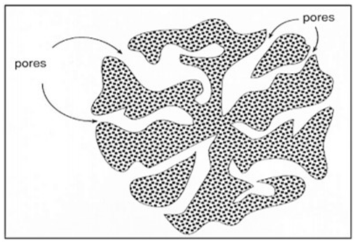
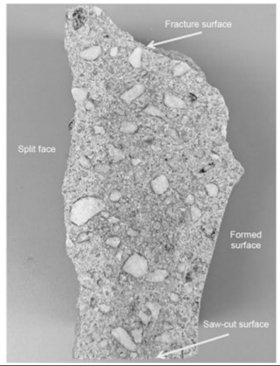
Dry-Cast Products – Carbon Sequestration

In reality wet-cast and dry-cast concrete carbonate at vastly different rates.





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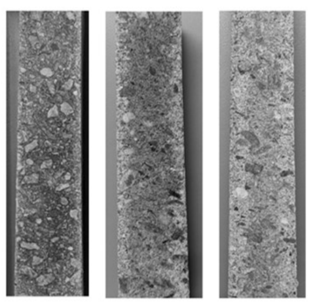
Dry-Cast Products – Carbon Sequestration

Research Underway:

CMU were collected from across the U.S. and Canada and allowed to naturally carbonate. TGA was performed periodically to measure carbon uptake.



Set 6 4 Week | Set 6 13 Week | Set 6 26 Week

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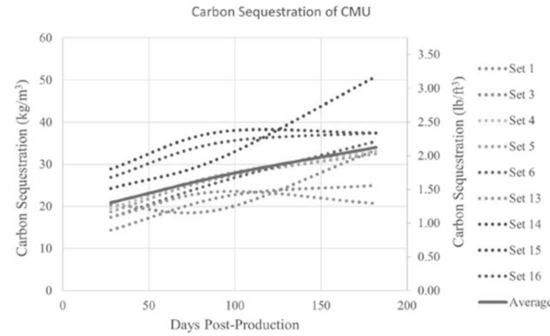
Dry-Cast Products – Carbon Sequestration

Research Underway:

28 Day Uptake:
21 kg/m^3



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Questions?

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EleMasonry

EleMasonry – Structural Masonry Design Software (V6)

Revision August 2, 2021

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EleMasonry

Software Navigation and Overview

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Access

Free trial here:
https://ncma.org/resources/software/

Applies to both EleMasonry and the Direct Design software packages.

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Overview

EleMasonry – Elemental Masonry Design

- Designs individual masonry elements:
  - Columns
  - Walls
  - Beams
  - Pilasters
- Sister software to QuickMasonry (through IES)

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Overview

EleMasonry – Elemental Masonry Design
- Intuitive interface
- Transparent reporting.
- Real-time design results.
- Annual license subscription (free upgrades)

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EleMasonry vs. Direct Design Software Packages

Direct Design is a platform for designing masonry buildings…

Direct Design

EleMasonry is a platform for designing masonry elements…

EleMasonry

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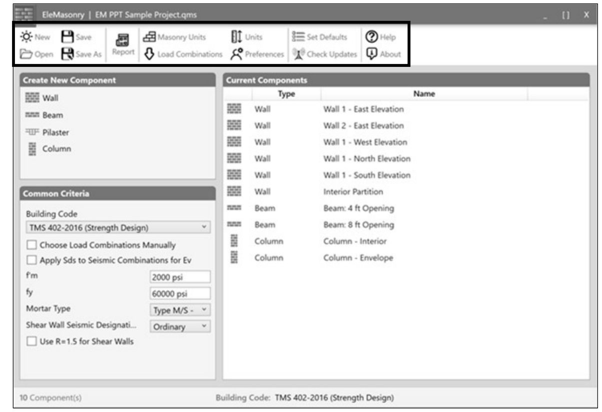
Navigation: Menu Ribbon

General Navigation



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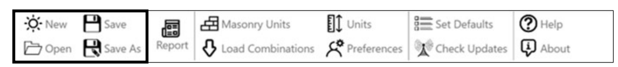
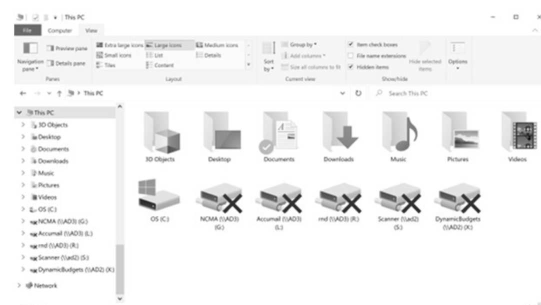
Navigation: Menu Ribbon



Project File Navigation (open, save, etc.)



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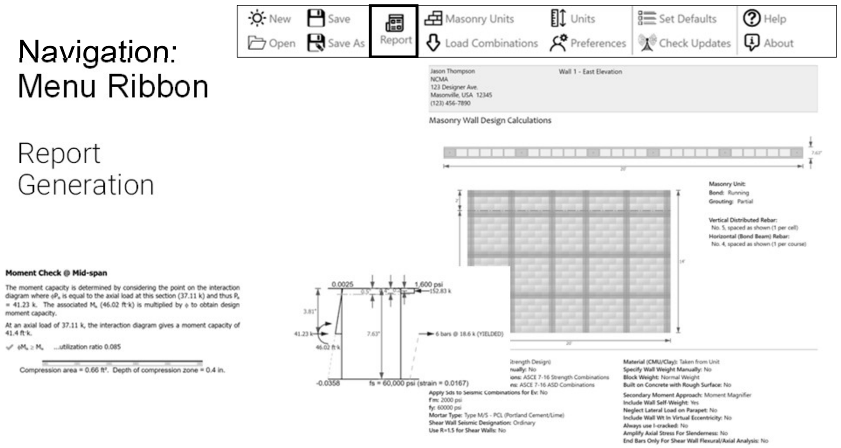
Navigation: Menu Ribbon

Report Generation



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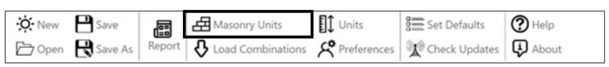
Navigation: Menu Ribbon

Masonry Unit Configurations

Standard Units



Masonry Unit Sizes

Standard | Proprietary

Name	Thickness (actual) (in)	Thickness (nominal) (in)	Height (in)	Face Shell Thickness (in)	Web Thickness (in)	Cell Module Spacing (in)	Grouted Cell Volume (in^3)	Ungrouted Cell Volume (in^3)
CMU - 6 in.	5.63	6	8	1	0.75	8	360	149.75
CMU - 8 in.	7.63	8	8	1.25	0.75	8	488	190.75
CMU - 10 in.	9.63	10	8	1.25	0.75	8	616	202.75
CMU - 12 in.	11.63	12	8	1.25	0.75	8	744	214.75
CMU - 14 in.	13.63	14	8	1.25	0.75	8	872	226.75
CMU - 16 in.	15.63	16	8	1.25	0.75	8	1,000	238.75

OK

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Navigation: Menu Ribbon

Masonry Unit Configurations

Custom Units

Masonry Unit Sizes

Standard | Proprietary

Name	Vendor	Material	Thickness (nominal) (in)	Cell Module Spacing (in)	Can be Partially Grouted	Valid Through
Atlas 6x4x16	Interstate Brick	Clay	6	8	True	12/16/2021
Atlas 8x4x16	Interstate Brick	Clay	8	8	True	12/16/2021
HI-R 10" (2.5" insul.)	Concrete Products Group	Concrete (CMU)	10	8	True	1/21/2022
HI-R 12" (2.5" insul.)	Concrete Products Group	Concrete (CMU)	12	8	True	1/21/2022
HI-R-H 10" (3.5" insul.)	Concrete Products Group	Concrete (CMU)	10	8	False	12/14/2021
HI-R-H 12" (3.5" insul.)	Concrete Products Group	Concrete (CMU)	12	8	False	12/14/2021

Find Units — Proprietary units must be downloaded and installed.

OK

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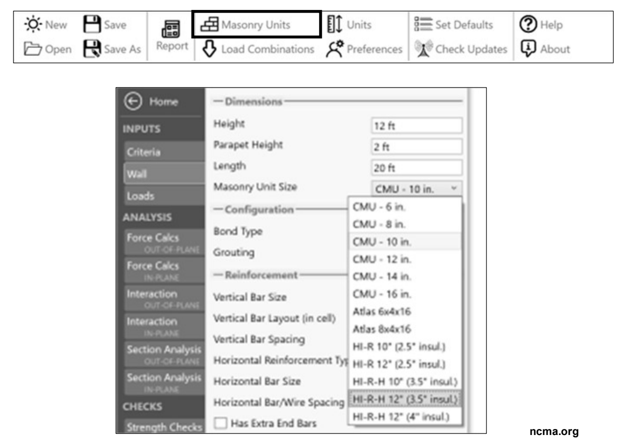
Navigation: Menu Ribbon

Masonry Unit Configurations

Custom Units



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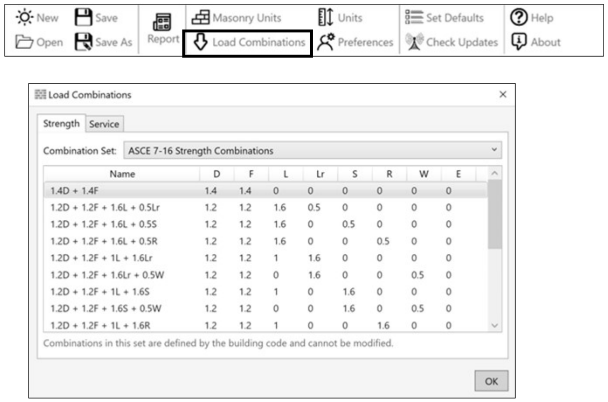
Navigation: Menu Ribbon

Load Combinations

2002-2016 ASCE 7 (strength and allowable stress)



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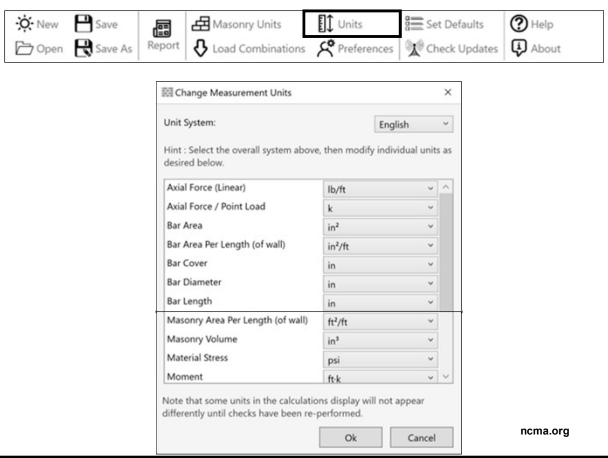
Navigation: Menu Ribbon

Units of Measurement

User Defined Options



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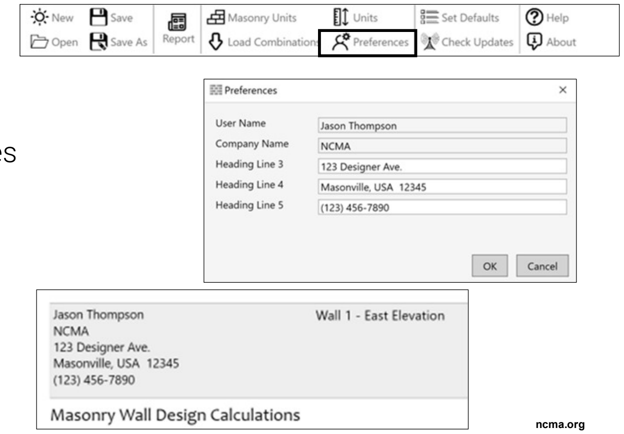
Navigation: Menu Ribbon

User Preferences

Included on reports.



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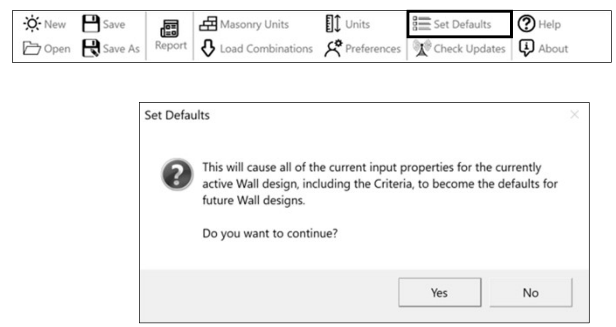
Navigation: Menu Ribbon

Set Software Defaults to User Preferences



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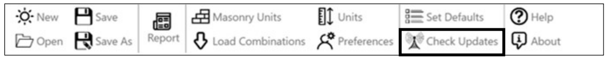
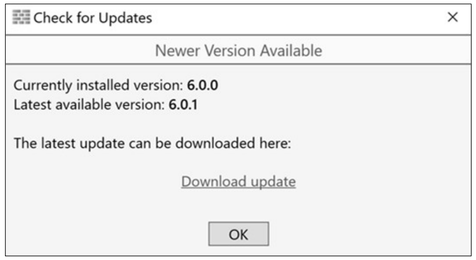
Navigation: Menu Ribbon

Check for Software Updates





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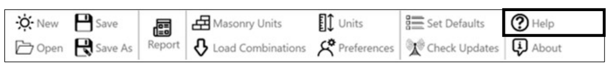
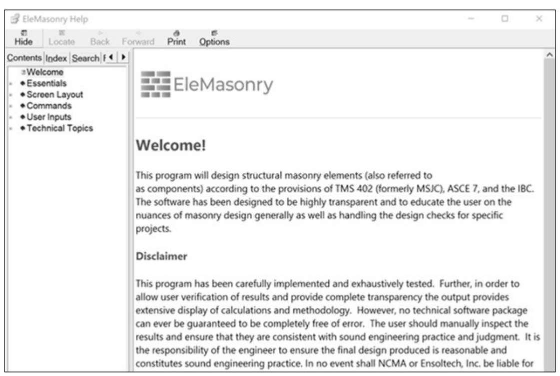
Navigation: Menu Ribbon

Access Help Files





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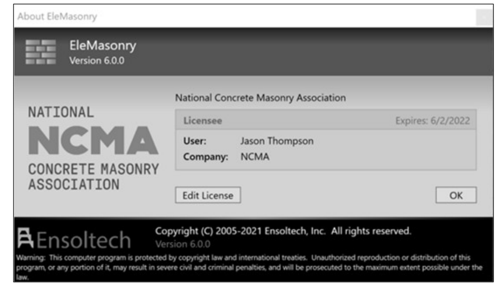
Navigation: Menu Ribbon

Check Licensing Information and Expiration



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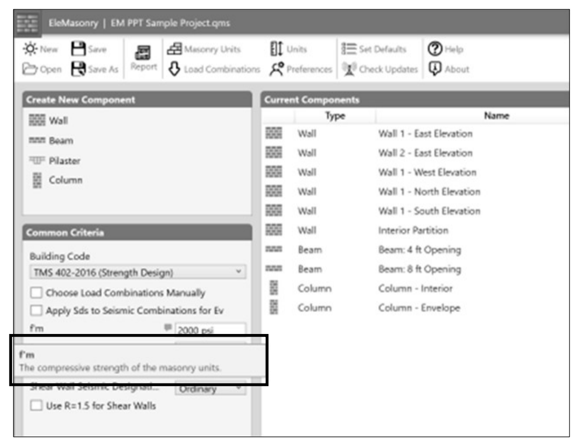
Navigation: Tool Tips

Hover over to bring up content tips.



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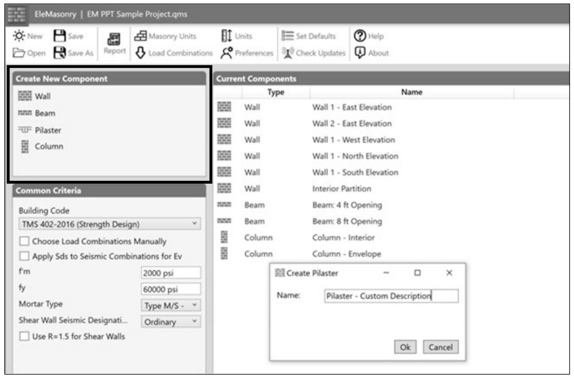
Navigation: Creating New Components

Adding New Elements

Multiple elements…single project file



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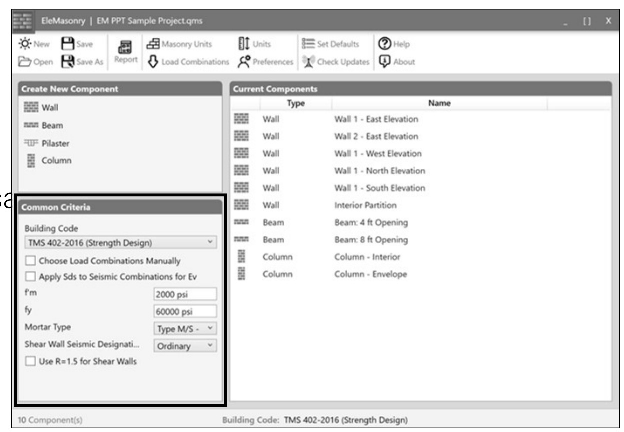
Navigation: Universal Criteria

Defining Universal Design Criteria



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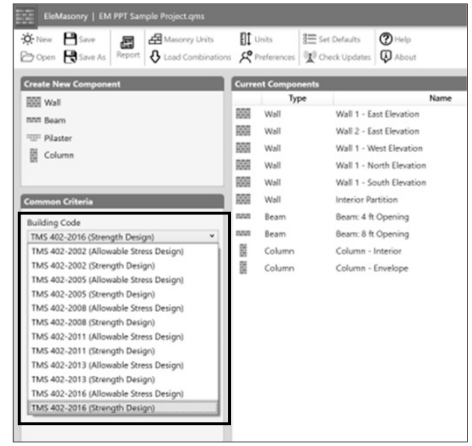
Navigation: Universal Criteria

Defining Universal Design Criteria

- Code Edition:

2002-2016 TMS 402



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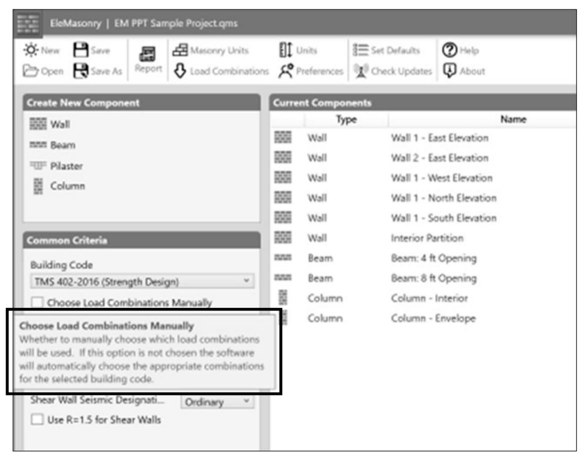
Navigation: Universal Criteria

Defining Universal Design Criteria

- Code- or User-defined load combinations



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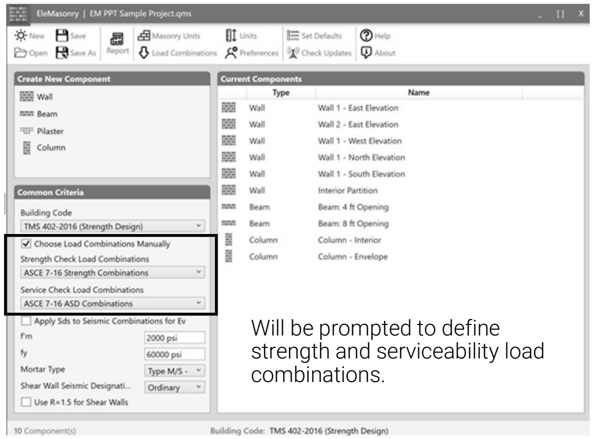
Navigation: Universal Criteria

Defining Universal Design Criteria

- Code- or User-defined load combinations

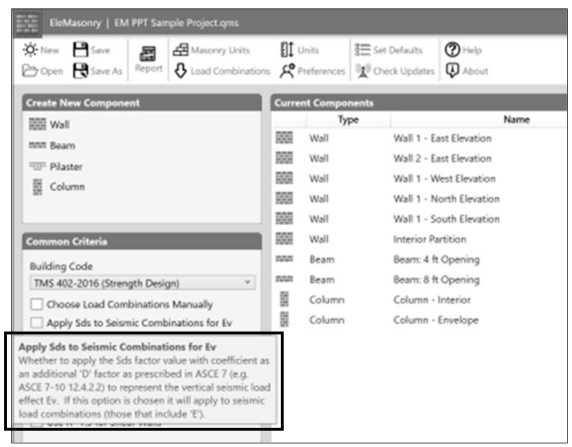


Will be prompted to define strength and serviceability load combinations.

Navigation: Universal Criteria

Defining Universal Design Criteria

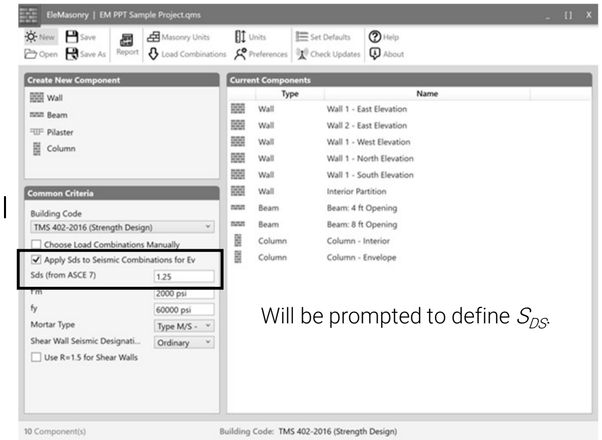
- Include vertical seismic loads



Navigation: Universal Criteria

Defining Universal Design Criteria

- Include vertical seismic loads

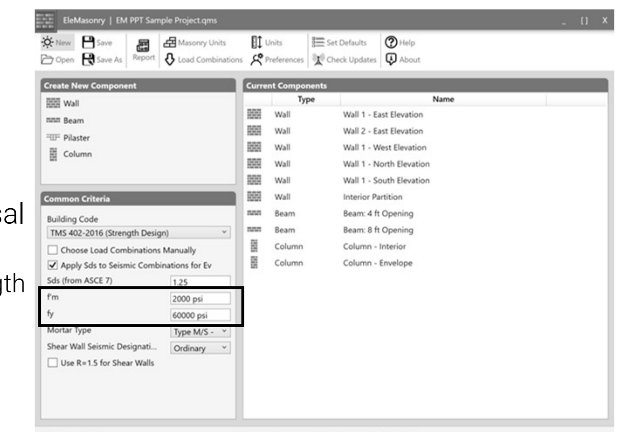


Will be prompted to define S_{DS}.

Navigation: Universal Criteria

Defining Universal Design Criteria

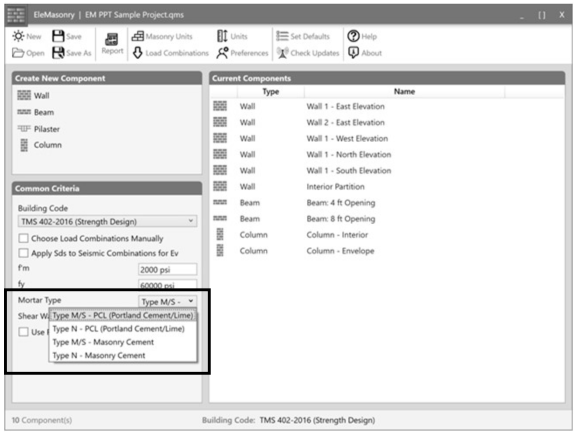
- Masonry strength (f'_m)
- Reinforcement yield (f_y)



Navigation: Universal Criteria

Defining Universal Design Criteria

- Mortar type



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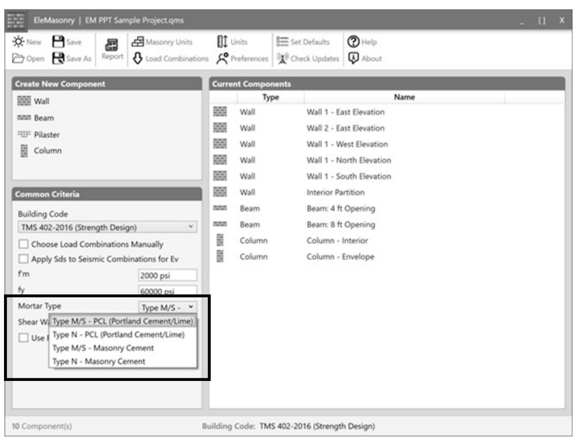
Navigation: Universal Criteria

Defining Universal Design Criteria

- Mortar type



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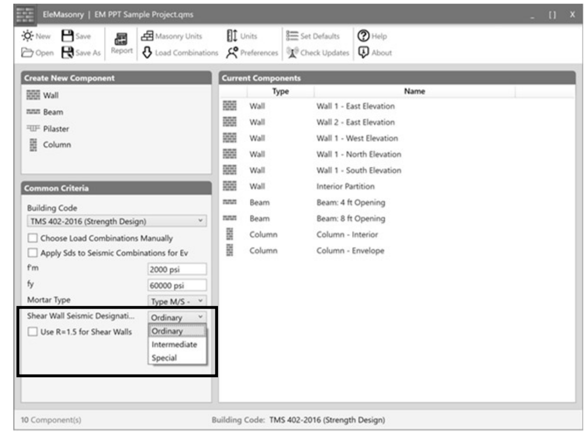
Navigation: Universal Criteria

Defining Universal Design Criteria

- Shear wall type



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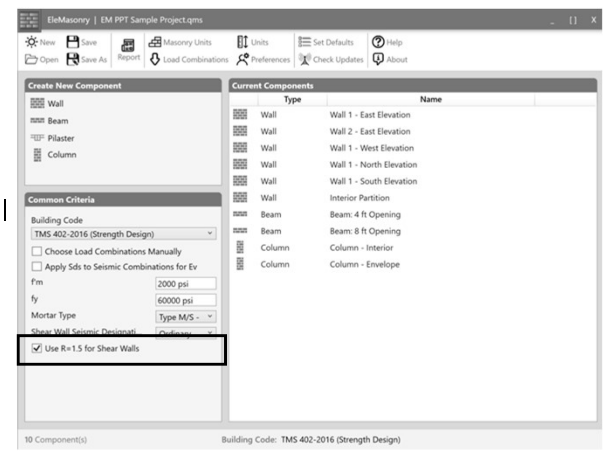
Navigation: Universal Criteria

Defining Universal Design Criteria

- Assume elastic response



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EleMasonry

Wall Design Module

Designing for In-Plane and Out-of-Plane Loads

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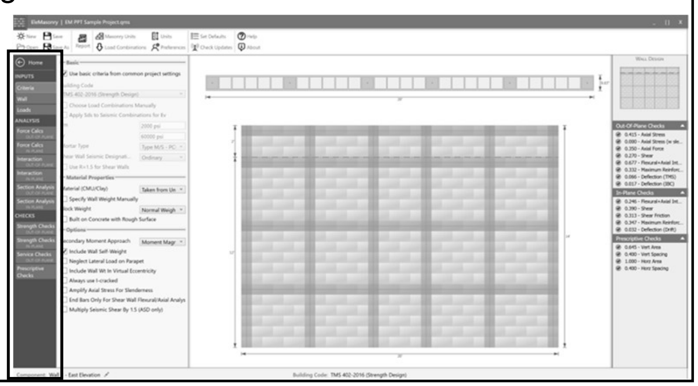
Wall Design Module



Screen Navigation

- Design Inputs
- Structural Analyses
- Design Checks

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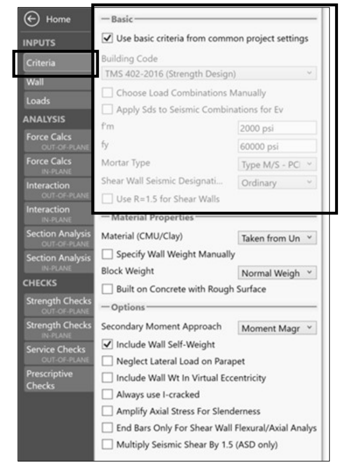
Wall Design Module

Inputs: Criteria Screen

Basic – Allows users to override the general project settings (if desired) for each element.



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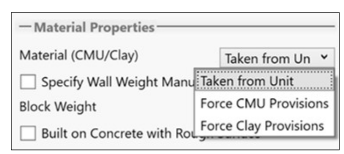
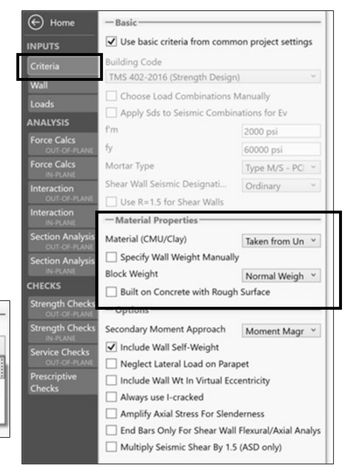
Wall Design Module

Inputs: Criteria Screen

Material Properties – Define the masonry as either clay or CMU. Defaults to unit type selected.





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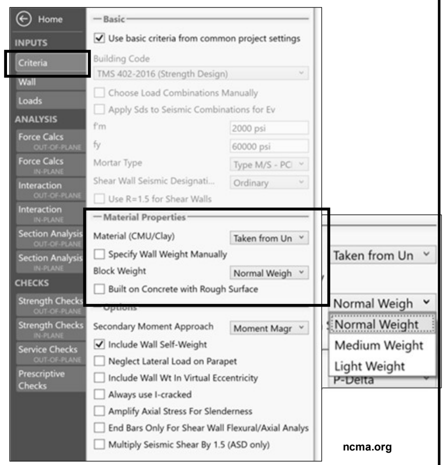
Wall Design Module

Inputs: Criteria Screen

Material Properties – Specify wall density or allow the software to calculate based on CMU density.



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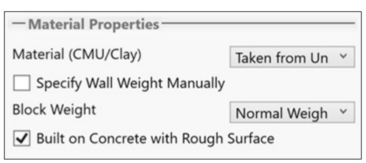
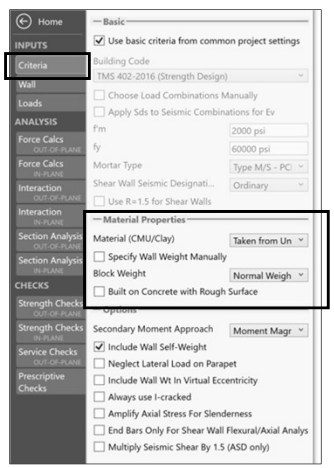
Wall Design Module

Inputs: Criteria Screen

Material Properties – For shear friction checks, define interface at base of the wall.





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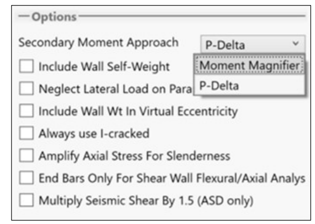
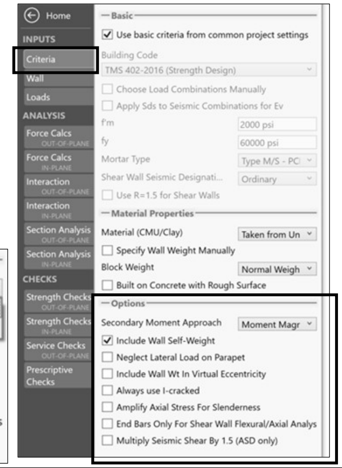
Wall Design Module

Inputs: Criteria Screen

Design Options – Selecting second order analysis method.





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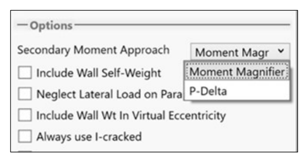
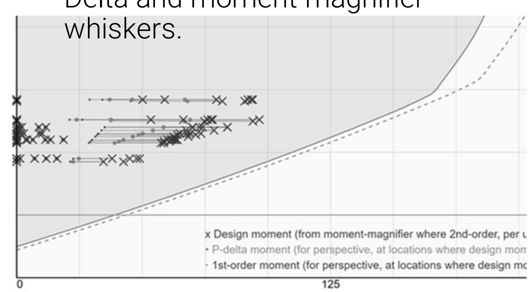
Wall Design Module



Option selected will be used for pass/fail design checks.

Second Order Checks:

Interaction diagram will plot P-Delta and moment magnifier whiskers.



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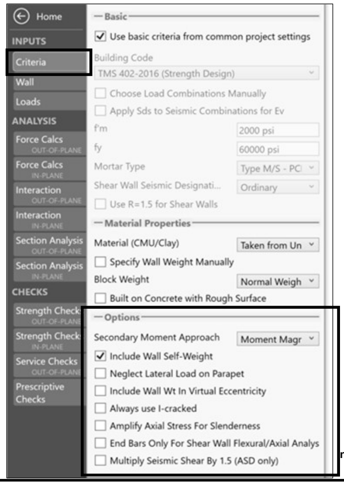
Wall Design Module

Inputs: Criteria Screen

Design Options – Option of including wall self-weight to design dead loads. Alternatively, wall weight can be added under design loads.



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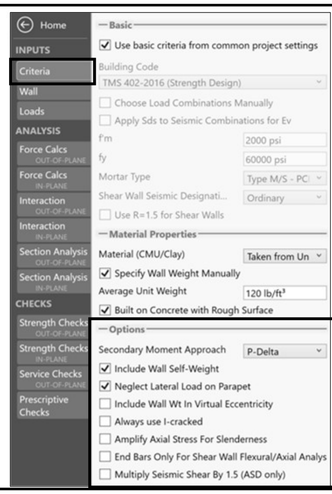
Wall Design Module

Inputs: Criteria Screen

User Preference

Design Options – Discount beneficial contribution of lateral loads on the parapet.



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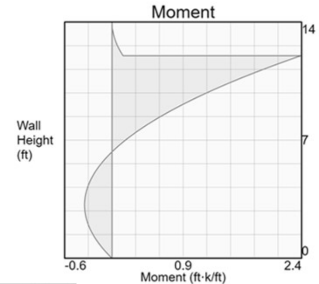
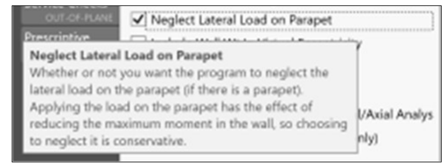
Wall Design Module

Inputs: Criteria Screen

User Preference

Design Options – Discount beneficial contribution of lateral loads on the parapet.





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Wall Design Module

Inputs: Criteria Screen

User Preference

Design Options – Include concentrically applied wall weight with eccentrically applied axial loads for buckling checks.

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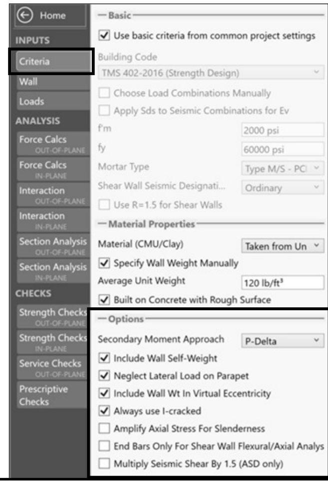
Wall Design Module

Inputs: Criteria Screen

<u>User Preference</u>

Design Options – Always use cracked section properties; otherwise uses gross section properties for pre-cracking loads and cracked section properties for post-cracking.



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Wall Design Module

Inputs: Criteria Screen

<u>User Preference</u>

Design Options – Scale axial load for slenderness checks. Only for ASD in the 2002 and 2005 TMS 402.

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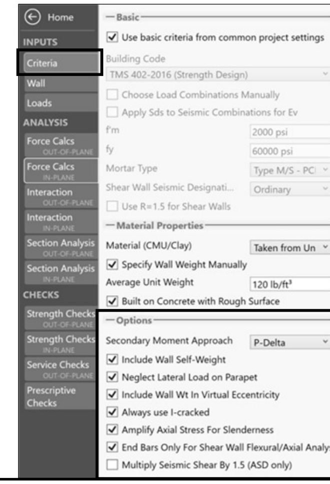
Wall Design Module

Inputs: Criteria Screen

<u>User Preference</u>

Design Options – Neglect distributed vertical reinforcement for in-plane analysis; consider only lumped reinforced at the ends of the wall.



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Wall Design Module

Inputs: Criteria Screen

Design Options – For SDC D+, in-plane shear loads are increased by 1.5 for ASD.

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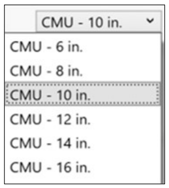
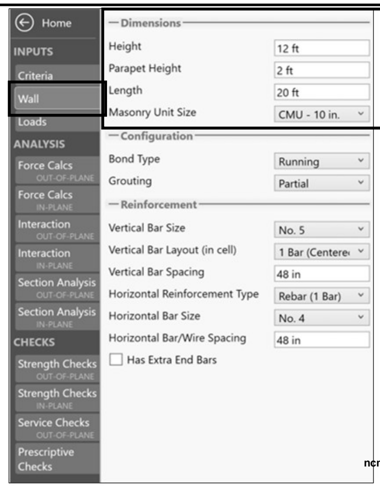
Wall Design Module

Inputs: Wall Screen

Dimensions – Define wall length and height, masonry unit width, and parapet height.





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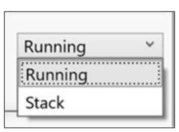
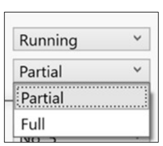
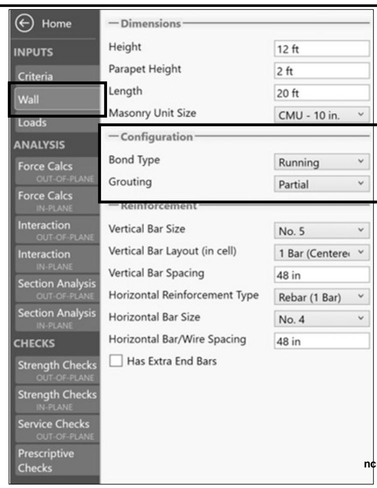
Wall Design Module

Inputs: Wall Screen

Configuration – Set unit bonding and grouting preferences.







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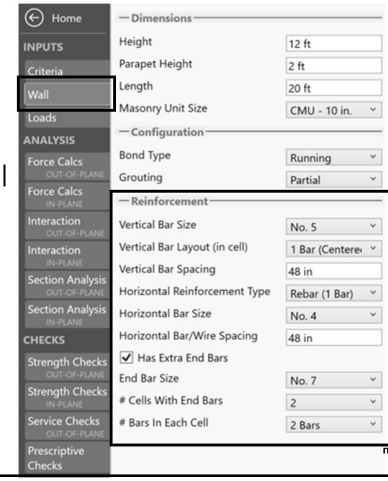
Wall Design Module

Inputs: Wall Screen

Reinforcement – Sets vertical and horizontal reinforcement preferences. Includes option for lumping vertical reinforcement at the ends of the wall.



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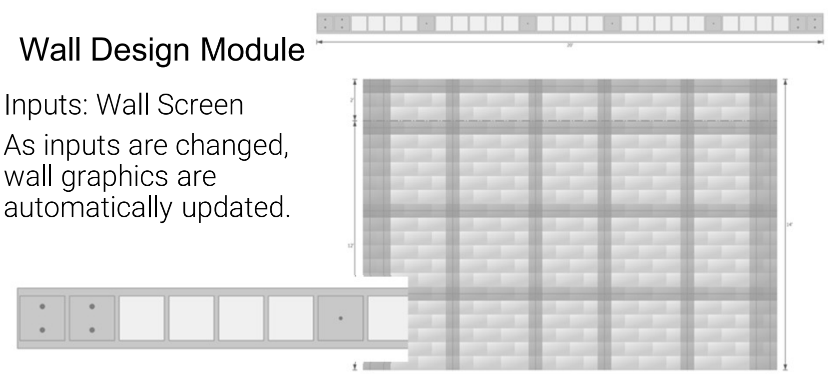
Wall Design Module

Inputs: Wall Screen

As inputs are changed, wall graphics are automatically updated.



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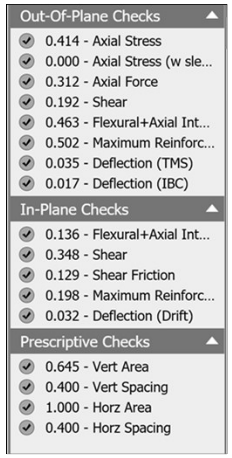
Wall Design Module

Inputs: Wall Screen

As inputs are changed, all design checks are automatically updated and the critical/controlling conditions summarized with utilization ratio.



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Wall Design Module

Inputs: Wall Screen

Click-through to see details on each critical load combination.

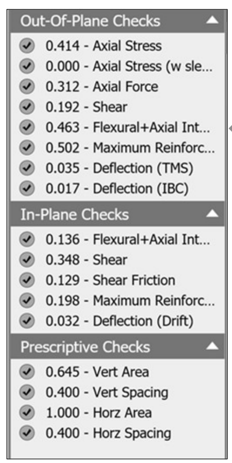
Moment Check @ Axial Load Application Point

The moment capacity is determined by considering the point on the interaction diagram where ϕP_n is equal to the axial load at this section (370.04 k) and thus P_n = 411.15 k. The associated M_n (220.86 ft·k) is multiplied by ϕ to obtain design moment capacity.

At an axial load of 370.04 k, the interaction diagram gives a moment capacity of 198.73 ft·k.

✓ $\phi M_n \geq M_u$ ...utilization ratio 0.463

Compression area = 2.63 ft². Depth of compression zone = 2.48 in.



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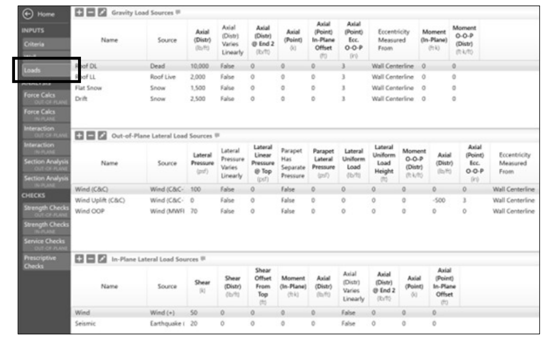
Wall Design Module

Inputs: Loads

Define axial, out-of-plane, and in-plane design loads.



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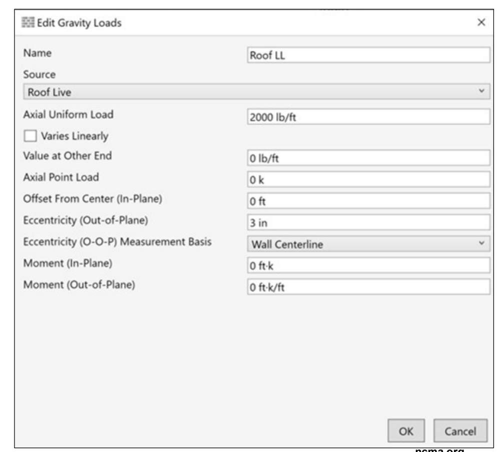
Wall Design Module

Inputs: Loads

Each load type is highly customizable



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Questions?

Direct Design – Structural Masonry Design Software (V3)

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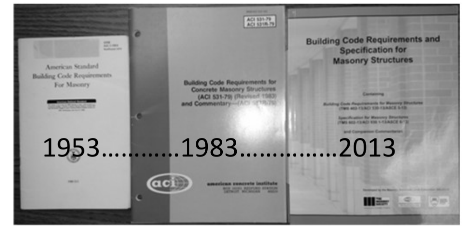
Why was Direct Design Created?

Code complexity…



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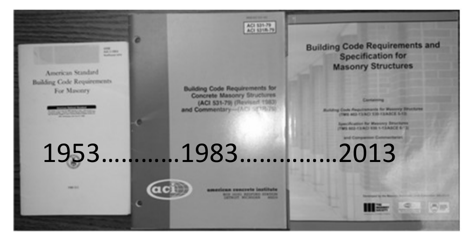
Why was Direct Design Created?

Code complexity…

1953 = 40 pages
1983 = 40 pages
2013 = 400 pages



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Why was Direct Design Created?

Codes (not just masonry) become more complex with each cycle. The Direct Design Software combines all the relevant structural masonry requirements in one package.

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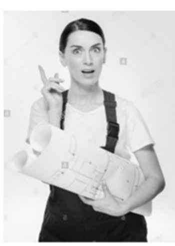
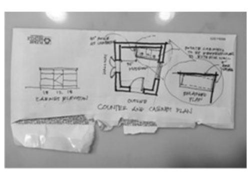
Why was Direct Design Created?

Also in recognition that how we design has evolved.

We now go from idea…to concept…to design much faster.





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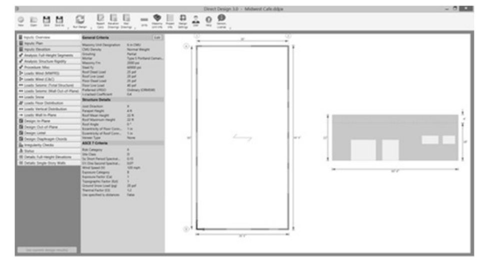
Software Inputs

What you need to design a project:

- Building location; and
- Building dimensions



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Software Inputs

Mapped Grout Snow Load

Need to know this…

Software will calculate this…

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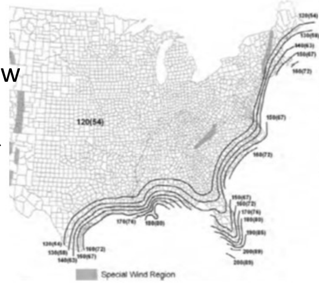
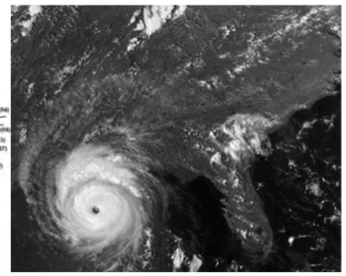
Software Inputs

Mapped Wind Speed

Need to know this…





Software will calculate this…

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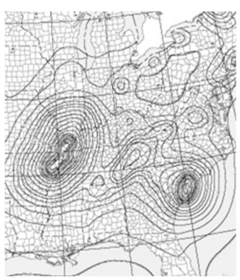
Software Inputs

Mapped Spectral Accelerations

Need to know this…



Software will calculate this…

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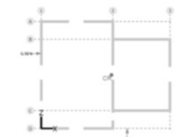
Software Outputs

Entire structural analysis calculations…



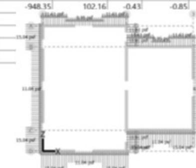
Vertical distribution factor (C_{v1}), Equation 12.8-12, p. 91:

$$C_{v1} = \frac{w_1 h_1^k}{\Sigma w_i h_i^k} = \frac{(333.33\ k)(12.00\ ft)^{1.00}}{22{,}000.00\ ft{\cdot}k} = 0.18$$

Lateral seismic force (F_1), Equation 12.8-11, p. 91:

$$F_1 = C_{v1}V = (0.18)(197.33\ k) = 35.88\ k$$

	Reactions at Base of Segment				Relevant Internal Forces			
	Axial Reaction (k)	In-plane Moment Reaction (ft·k)	Distributed Reaction Force Left Value (lb/ft)	Distributed Reaction Force Right Value (lb/ft)	Axial Force At Top (k)	Axial Force At Middle (k)	Out-of-plane Eccentric Moment At top (ft·k)	Out-of-plane Eccentric Moment Middle (ft·k)
Dead	2.76	-0.60	2,283.33	472.22	0.33	1.96	-0.06	-0.03
Snow	0.67	-0.28	750.00	-83.33	0.33	0.67	-0.06	-0.03
$Wind_{C\&C-}$	0.56	-0.23	631.15	-70.82	0.28	0.56	-0.05	-0.02
$Wind_{MWFRS-}$	0.25	-0.10	276.15	-30.68	0.12	0.25	-0.02	-0.01
Seismic	-0.85	0.35	-948.35	102.16	-0.43	-0.85	0.07	0.04
10	0.18	-0.08	[illegible]	[illegible]	[illegible]	[illegible]	02	-0.01
11	-0.63	0.26	[illegible]	[illegible]	[illegible]	[illegible]	05	0.03
Rain	0.00	-0.21	[illegible]	[illegible]	[illegible]	[illegible]	00	0.00
12	0.00	3.74	[illegible]	[illegible]	[illegible]	[illegible]	00	0.00



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Software Outputs

Entire structural analysis calculations…

Segment 1 in Wall along grid C from 2 to 3, Story 3

This segment is 16' 8" long and reinforced with 9 #6 bars.

✓ **Moment check**

ϕM_n = 1,426.40 ft·k, M_u = 4.17 ft·k

✓ **Shear check**

V_m = 203.69 k, V_s = 287.03 k, V_n = 345.55 k, ϕV_n = 276.44 k, $V_{FlexComp}$ = 184.38 k, $V_{FlexTens}$ = 178.30 k, V_u = 20.00 k

✓ **Deflection check**

$\delta_{elastic}$ = 0.01 in, $\delta_{inelastic}$ = 0.01 in, δ_{max} = 1.20 in, I_{gross} = 5,083,333.33 in^4, I_{cells} = 2,660,517.33 in^4, I_{net} = 5,083,333.33 in^4, I_{eff} = 2,033,333.33 in^4

✓ **Rho Max check**

P_u = 10.00 k, $P_{u\_max\_SBE}$ = 305.00 k, SBE condition 1 met = True, M_u/V_ud_v = 0.60, SBE condition 2 met = True, A_{nv} = 1,525.00 in² True, ρ_{max} check required = False, ε_y = 0.00, ε_{mu} = 0. $A_{s\text{-}max}$ = 225.88 in², A_s = 3.96 in²

Step 3 - Structural Irregularities Check

The presence of irregularities impacts the design procedure and the general applicability of Direct Design.

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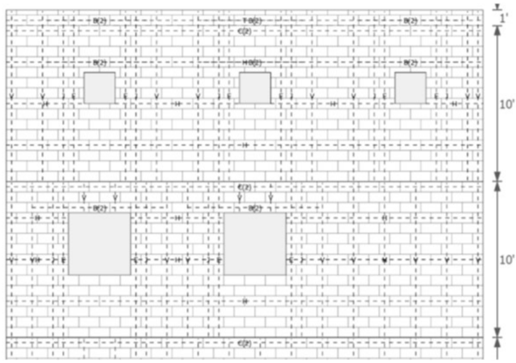
Software Outputs

To the final design…



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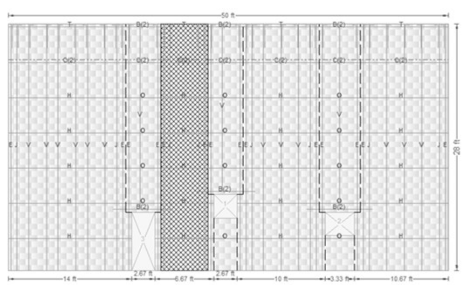
Software Outputs

While flagging sections that the software couldn't find a solution to.



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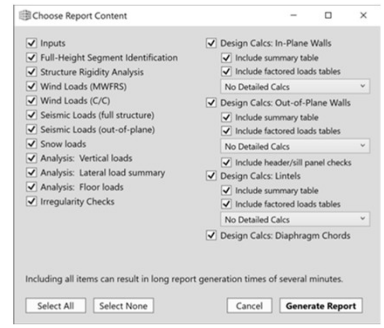
Software Outputs

With options for detailed or summarized reports.



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What Direct Design Does Not Do…

Does not design the diaphragms (roof/floor).

Does not design the foundation.

Does not design the connection system between the masonry and supports.

Limited to the structural and non-structural masonry components.

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Limitations

Mapped wind speed < 250 mph

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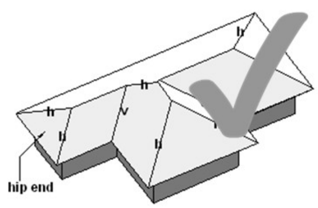
Limitations

Building height < 60 feet.

No funky roofs.



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Limitations

Architectural features

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Limitations

- Cladding weight < 50 psf.
- No complex diaphragms.

3.2.8.4 *Diaphragm Classification* – Diaphragms shall be classified as either flexible or rigid in accordance with Table 3.2.8.4.

Table 3.2.8.4 – Diaphragm Classification

Diaphragm Construction	Diaphragm Classification
Wood structural panels	Flexible
Untopped steel decking	Flexible
Concrete slab	See Section 3.2.8.4.1
Concrete filled deck	See Section 3.2.8.4.1
Other – flexible diaphragm	Flexible
Other – rigid diaphragm	Rigid

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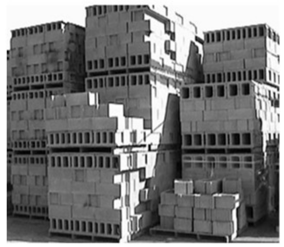
Limitations

- Standard ASTM C90 block.
- Grade 60 reinforcement.
- Conventional mortar and grout.
- No extreme loading (e.g., blast).



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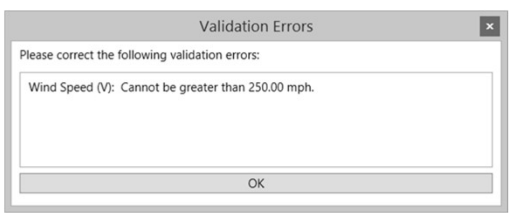
Limitations

If a software input isn't covered by Direct Design, an error message will appear.



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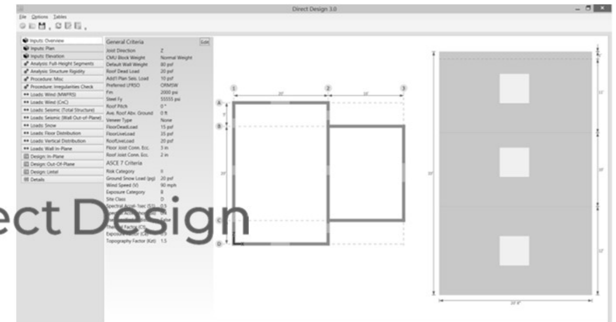
Software Demo

Using the software…



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Questions?

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Evolution of Concrete Masonry Design – Key Code Changes

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The Evolution of the CMU

- Concrete masonry unit/CMU
- Cinder block
- Cement/Concrete block
- Breeze block

Product of many names…

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The Evolution of the CMU

Once upon a time…

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The Evolution of the CMU

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The Evolution of the CMU

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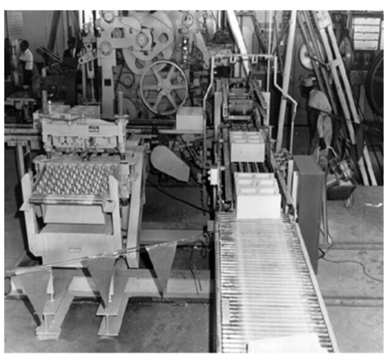
The Evolution of the CMU



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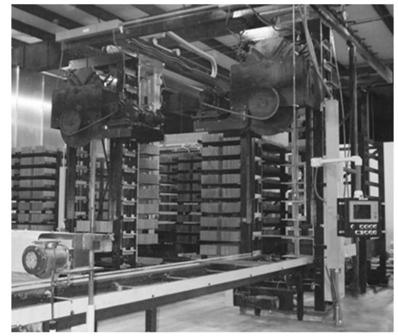
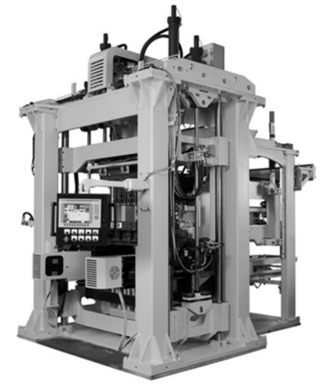
The Evolution of the CMU





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The Evolution of the CMU

- 1860s – first block machine patents issued.
- 1910s – unit dimensions standardized.
- 1924 – first version of ASTM C90 published; covered only the very basic properties.
- 1930s – advancements in manufacturing technology allowed thinner face shells and webs…to what end?

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The Evolution of the CMU

- 1940s – CMU configurations were standardized through ASTM.

TABLE 1 Minimum Thickness of Face Shells and Webs[A]

Nominal Width (W) of Units, in. (mm)	Face Shell Thickness (t_{fs}), min, in. (mm)[B,C]	Web Thickness (t_w): Webs[B,D,C] min, in. (mm)	Web Thickness (t_w): Equivalent Web Thickness, min, in./linear ft[E] (mm/linear m)
3 (76.2) and 4 (102)	¾ (19)	¾ (19)	1⅝ (136)
6 (152)	1 (25)	1 (25)	2¼ (188)
8 (203)	1¼ (32)	1 (25)	2¼ (188)
10 (254) and greater	1¼ (32)	1⅛ (29)	2½ (209)

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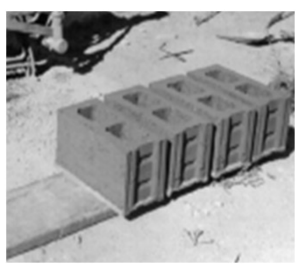
The Evolution of the CMU

If visiting a job side in 1940 versus 2010, the CMU would look nearly identical.



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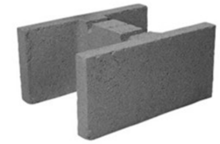
The Evolution of the CMU

But the marketplace evolved faster than ASTM.



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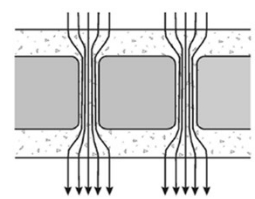
The Evolution of the CMU

The big driver, however, was the push in recent years to reduce carbon footprints and increase energy efficiency.

- Heat flows through the webs.
- Reduce the webs – increase the R-value



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The Question:

Why do we need a three web, two cell unit??

Structurally, the webs play a key role in the performance/integrity of the assembly. Shear transfer for out-of-plane flexure, tensile splitting under axial compression, etc.

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The Question:

Research followed to determine how much we is necessary…

$$I_n = \left(\tfrac{1}{12}\right)(15.625)(7.625)^3 - \left(\tfrac{1}{12}\right)(7.4375)(5.125)^3(2)I_n$$
$$= 410.4 \text{ in.}^4$$

$$Q = (1.25)(15.625)(3.1875) + (0.75)(2.5625)(1.28125)$$
$$Q = 64.7 \text{ in.}^3$$

$$b = 0.75 \text{ in.}$$

$$V = (220)(16)/12 = 293.3 \text{ lb}$$

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The Findings:

A standard three web, two cell unit provides a worse case factor of safety of 37…about 10 times higher than what we generally target for a reasonable factor of safety.

Way, way more than what is needed.

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The Changes:

TABLE 1 Minimum Face Shells and Web Requirements[A]

Nominal Width (W) of Units, in. (mm)	Face Shell Thickness (t_{fs}), min, in. (mm)[B,C]	Webs: Web Thickness[C] (t_w), min, in. (mm)	Webs: Normalized Web Area (A_{nw}), min, in.²/ft² (mm²/m²)[D]
3 (76.2) and 4 (102)	¾ (19)	¾ (19)	6.5 (45, 140)
6 (152)	1 (25)	¾ (19)	6.5 (45, 140)
8 (203) and greater	1¼ (32)	¾ (19)	6.5 (45, 140)

[A] Average of measurements on a minimum of 3 units when measured as described in Test Methods C140.
[B] When this standard is used for units having split surfaces, a maximum of 10 % of the split surface is permitted to have thickness less than those shown, but not less than ¾ in. (19.1 mm). When the units are to be solid grouted, the 10 % limit does not apply and Footnote C establishes a thickness requirement for the entire faceshell.
[C] When the units are to be solid grouted, minimum face shell and web thickness shall be not less than ⅝ in. (16 mm).
[D] Minimum normalized web area does not apply to the portion of the unit to be filled with grout. The length of that portion shall be deducted from the overall length of the unit for the calculation of the minimum web cross-sectional area.

ASTM C90 was changed to allow less web(s) in CMU.

ells and Web Requirements[A]

Webs: Web Thickness[C] (t_w), min, in. (mm)	Webs: Normalized Web Area (A_{nw}), min, in.²/ft² (mm²/m²)[D]
¾ (19)	6.5 (45, 140)
¾ (19)	6.5 (45, 140)
¾ (19)	6.5 (45, 140)

ed in Test Methods C140.
of the split surface is permitted to have thickness less than those shown, but not less
ot apply and Footnote C establishes a thickness requirement for the entire faceshell.
shall be not less than ⅝ in. (16 mm).
ed with grout. The length of that portion shall be deducted from the overall length of

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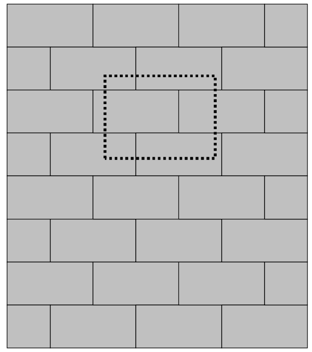
The Changes:

Literally, this new requirement means that for every square foot of wall surface, no less than 6.5 in.^{2} of web must connect the front and back face shells, with no web measuring less than 0.75 in. in thickness.



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The Changes:

Today there is more flexibility in CMU configurations to meet varying project objectives/demands.

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The Changes:

Three web assembly:

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The Changes:

Two web assembly:

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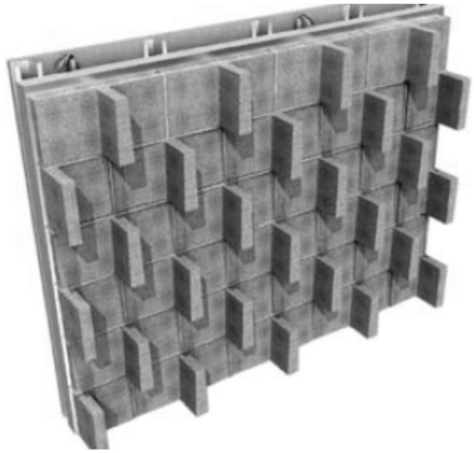
The Changes:

One web assembly:



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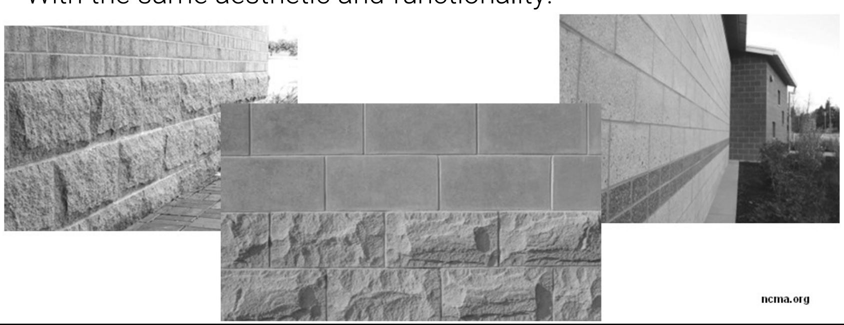
The Changes:

With the same aesthetic and functionality.



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Design Implications

Design of alternative web configurations is exactly the same, except if designing unreinforced masonry or if incorporating integral insulation – which requires a supplemental check of the web shear stresses.

$$f_v = \frac{VQ}{I_n b} \leq 1.5\sqrt{f'_m}$$

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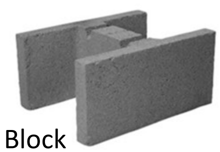
Design Implications

Section Properties:



H Block

Corner Block

Stretcher Block

A Block

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Design Implications

Section Properties:

		Three-Web Corner Unit	Three-Web Stretcher Unit
Face Shell Bedding Only	Net Area (An)	30.0	30.0
	Net MOI (In)	308.7	308.7
Full Mortar Bedding	Net Area (An)	38.6	38.6
	Net MOI (In)	327.6	327.6
Solid Grouted	Net Area (An)	90.1	84.3
	Net MOI (In)	440.2	427.5
Grout @ 16 in.	Net Area (An)	61.5	58.6
	Net MOI (In)	383.9	371.3
Grout @ 120 in.	Net Area (An)	34.2	33.8
	Net MOI (In)	317.9	317.0

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Design Implications

Section Properties:

		Three-Web Corner Unit	Three-Web Stretcher Unit	A-Block	H-Block
Face Shell Bedding Only	Net Area (An)	30.0	30.0	30.0	30.0
	Net MOI (In)	308.7	308.7	308.7	308.7
Full Mortar Bedding	Net Area (An)	38.6	38.6	35.8	32.9
	Net MOI (In)	327.6	327.6	321.4	315.1
Solid Grouted	Net Area (An)	90.1	84.3	91.5	91.5
	Net MOI (In)	440.2	427.5	443.3	443.3
Grout @ 16 in.	Net Area (An)	61.5	58.6	65.8	NA
	Net MOI (In)	383.9	371.3	387.0	NA
Grout @ 120 in.	Net Area (An)	34.2	33.8	34.8	NA
	Net MOI (In)	317.9	317.0	319.0	NA

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Design Implications

Summary:

While on the surface this change to ASTM C90 may appear radically substantive, in reality it simply brings the standards in line with today's practice.

Most importantly, it was implemented in such a way that concrete masonry is designed and constructed the same as it has been historically.

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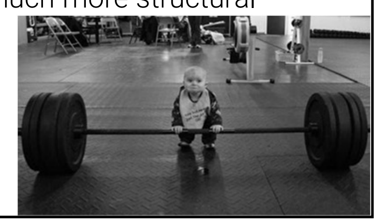
Structural Design Properties

Changes to web requirements can increase the R-value of a CMU assembly by 50%...100%...200%...

Similar changes have also brought much more structural efficiency to concrete masonry.



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Structural Design Properties

Unit Strength Method – Historical

Table 2 — Compressive strength of masonry based on the compressive strength of concrete masonry units and type of mortar used in construction

Net area compressive strength of concrete masonry units, psi (MPa)		Net area compressive strength of masonry, psi[1] (MPa)
Type M or S mortar	Type N mortar	
—	1,900 (13.10)	1,350 (9.31)
1,900 (13.10)	2,150 (14.82)	1,500 (10.34)
2,800 (19.31)	3,050 (21.03)	2,000 (13.79)
3,750 (25.86)	4,050 (27.92)	2,500 (17.24)
4,800 (33.10)	5,250 (36.20)	3,000 (20.69)

[1] For units of less than 4 in. (102 mm) height, 85 percent of the values listed.

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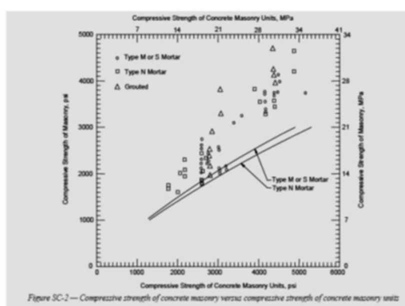
Structural Design Properties

Unit Strength Method – Historical



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Structural Design Properties

Unit Strength Method – New Research Data

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Structural Design Properties

Unit Strength Method

Net area compressive strength of concrete masonry units, psi (MPa)		Net area compressive strength of masonry, psi[1] (MPa)
Type M or S mortar	Type N mortar	
—	1,900 (13.10)	1,350 (9.31)
1,900 (13.10)	2,150 (14.82)	1,500 (10.34)
2,800 (19.31)	3,050 (21.03)	2,000 (13.79)
3,750 (25.86)	4,050 (27.92)	2,500 (17.24)
4,800 (33.10)	5,250 (36.20)	3,000 (20.69)

Table 2: Compressive strength of masonry based on the compressive strength of concrete masonry units and type of mortar used in construction

Net area compressive strength of concrete masonry, psi (MPa)[1]	Net area compressive strength of ASTM C90 concrete masonry units, psi (MPa)	
	Type M or S mortar	Type N mortar
1,750 (12.07)	---	2,000 (13.79)
2,000 (13.79)	2,000 (13.79)	2,650 (18.27)
2,250 (15.51)	2,600 (17.93)	3,400 (23.44)
2,500 (17.24)	3,250 (22.41)	4,350 (28.96)
2,750 (18.96)	3,900 (26.89)	-----
3,000 (20.69)	4,500 (31.03)	-----

[1] For units of less than 4 in. (102 mm) nominal height, use 85 percent of the values listed.

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Structural Design Properties

Unit Strength Method – New Research Data

Historically, ASTM C90 required a minimum CMU compressive strength of 1,900 psi. Now requires a minimum of 2,000 psi. Hence, stock materials will yield f'_m = 2,000 psi.

TABLE 2 Strength, Absorption, and Density Classification Requirements

Density Classification	Oven-Dry Density of Concrete, lb/ft^3 (kg/m^3)	Maximum Water Absorption, lb/ft^3 (kg/m^3)		Minimum Net Area Compressive Strength, lb/in^2 (MPa)	
	Average of 3 Units	Average of 3 Units	Individual Units	Average of 3 Units	Individual Units
Lightweight	Less than 105 (1680)	18 (288)	20 (320)	2000 (13.8)	1800 (12.4)
Medium Weight	105 to less than 125 (1680–2000)	15 (240)	17 (272)	2000 (13.8)	1800 (12.4)
Normal Weight	125 (2000) or more	13 (208)	15 (240)	2000 (13.8)	1800 (12.4)

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Structural Design Properties

Using f'_m = 2,000 psi coupled with several updates to the design provisions for masonry offers free design efficiency.

$$\xi = 1.0 - \frac{2.3A_{sc}}{d_b^{2.5}} \quad \text{(Equation 2-13)}$$

Where : $\frac{2.3A_{sc}}{d_b^{2.5}} \le 1.0$

A_{sc} is the area of the transervse bars at each end of the lap splice and shall not be taken greater than 0.35 in^2 (226 mm^2).

2.3.4.2.2 The compressive stress in masonry due to flexure or due to flexure in combination with axial load shall not exceed 0.45 f'_m provided that the calculated compressive stress due to the axial load component, f_a, does not exceed the allowable stress, F_a, in Section 2.2.3.1.

(a) Grade 40 or Grade 50 reinforcement: 20,000 psi (137.9 MPa)

(b) Grade 60 reinforcement: 32,000 psi (220.7 MPa)

$$q_{n\,inf} = 105(f'_m)^{0.75}\, t_{inf}^2 \left(\frac{\alpha_{arch}}{l_{inf}^{2.5}} + \frac{\beta_{arch}}{h_{inf}^{2.5}} \right) \quad \text{(Equation B-5)}$$

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Structural Design Properties

Resulting impacts:

- 18 ft wall, 8 in. CMU
- 40 psf wind pressure
- 3,000 lb/ft axial

Table 2 – Design Impact of TMS 402/602 Revisions

Code Edition[1]	Reinforcement Size	Reinforcement Spacing
2009 IBC[2]	No. 5	40 inches
2012 IBC[2]	No. 5	48 inches
2015 IBC[3]	No. 5	96 inches[4]

[1]The 2009, 2012, and 2015 editions of the IBC adopt the 2008, 2011, and 2013 editions of TMS 402/602, respectively.
[2]f'_m = 1,500 psi
[3]f'_m = 2,000 psi
[4]Incorporating 9 gage bed joint reinforcement at 16 inches.

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Questions?

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Air, Water, and Vaport Barriers – What's Really Required?

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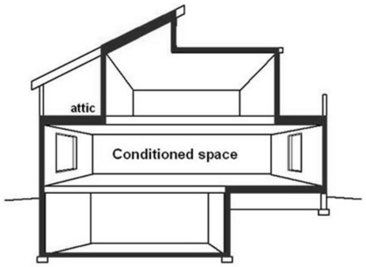
Focus: Building Envelope

Peeling the layers of building code requirements for layers…



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Perception vs. Reality

Peeling the layers of building code requirements for layers…

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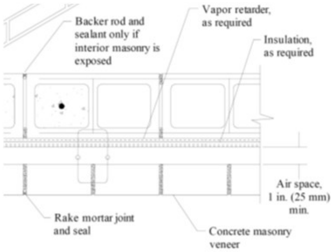
Focus: Building Envelope

Components of the building envelope:

- Exterior Finish
- Water Control
- Thermal Control
- Air Control
- Vapor Control
- Structure
- Interior Finish



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Focus: Building Envelope

Components of the building envelope:

- Exterior Finish
- Water Control
- Thermal Control
- Air Control
- Vapor Control
- Structure
- Interior Finish

The riddle:
Each system (masonry, wood, etc.) has different Code requirements.

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Peeling the Envelope Layers

Components of the building envelope – Light Frame

- ✓ Exterior Finish
- ✓ Water Control
- ⚠ Thermal Control
- ⚠ Air Control
- ✓ Vapor Control
- ✓ Structure
- ✓ Interior Finish

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Peeling the Envelope Layers

Components of the building envelope – Masonry

- ✗ Exterior Finish
- ✗ Water Control
- ⚠ Thermal Control
- ⚠ Air Control
- ✗ Vapor Control
- ✓ Structure
- ✗ Interior Finish

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Peeling the Envelope Layers

Code doesn't treat all systems the same

Code required layers for CMU envelope:

- ✗ Exterior Finish
- ✗ Water Control
- ⚠ Thermal Control
- ⚠ Air Control
- ✗ Vapor Control
- ✓ Structure
- ✗ Interior Finish

Code required layers for wood envelope:

- ✓ Exterior Finish
- ✓ Water Control
- ⚠ Thermal Control
- ⚠ Air Control
- ✓ Vapor Control
- ✓ Structure
- ✓ Interior Finish

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Barriers!

What's the difference?

WATER-RESISTIVE BARRIER. A material behind an *exterior wall covering* that is intended to resist liquid water that has penetrated behind the exterior covering from further intruding into the *exterior wall* assembly.

AIR BARRIER. Material(s) assembled and joined together to provide a barrier to air leakage through the building envelope. An air barrier may be a single material or a combination of materials.

VAPOR RETARDER CLASS. A measure of a material or assembly's ability to limit the amount of moisture that passes through that material or assembly. Vapor retarder class shall be defined using the desiccant method of ASTM E 96 as follows:

Class I: 0.1 perm or less.

Class II: $0.1 < \text{perm} \leq 1.0$ perm.

Class III: $1.0 < \text{perm} \leq 10$ perm.

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Barriers!

Vapor Retarders

Never required over CMU…usually required over wood/stud construction.

The IBC doesn't prohibit the use of vapor retarders with masonry (and may be needed in unique conditions…e.g., natatorium).

Unless you need a vapor retarder, lose it. It's just an added expense and is likely to cause more problems than it solves.

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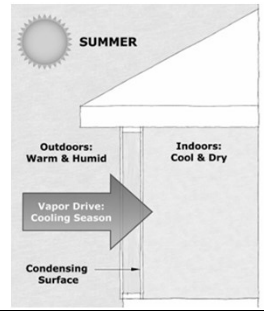
Barriers!

The issue with all vapor retarders.



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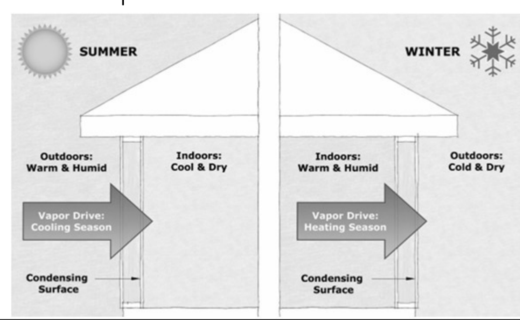
Barriers!

The issue with all vapor retarders.



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Barriers!

Water-Resistive Barrier – Only required for masonry veneer over frame (wood/steel) construction. Not required for veneer over CMU backing.

Codes may not require a WRB…but that doesn't mean water penetration should be ignored.

- Use integral water repellents.
- Use surface sealers.
- Incorporate flashing (unless solid grouted).

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Barriers!

Air Barriers – Always required as part of a CMU assembly (with a few exceptions).

But check first!

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Barriers!

The assembly may already have a complying air barrier integrated into it.

Complying Materials:

- Solid grouted CMU…or…1/2 inch gypsum.

Complying Assembly:

- CMU with one coat of block filler or two coats of paint…or… brick masonry veneer.

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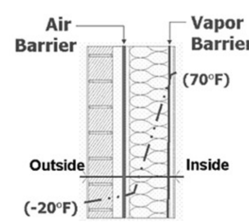
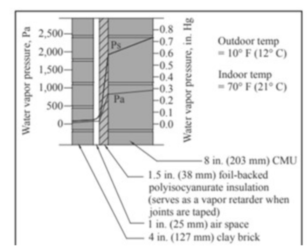
Barriers!

These are not the same assembly…don't detail them the same.





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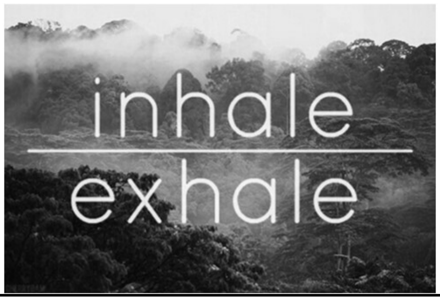
Targeted Performance

Detail masonry assemblies to allow them to breathe.



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When Layers Attack

Adding too many barriers…or placing them in the wrong location…can have unintended consequences.

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When Layers Attack

Overall performance of the store was great, but was ~20 years old and in need of a face lift.

- New roof
- New paint (vapor permeable latex paint!)
- New HVAC
- Etc.

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When Layers Attack

The result wasn't what they wanted…

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When Layers Attack

The cause:

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When Layers Attack

The cause:

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When Layers Attack

The cause:

- Although the paint they were using had a high perm rating, by applying multiple layers it had effectively become impermeable.
- The more efficient HVAC removed less moisture from the interior conditions space.

The interior moisture needed a place to go…

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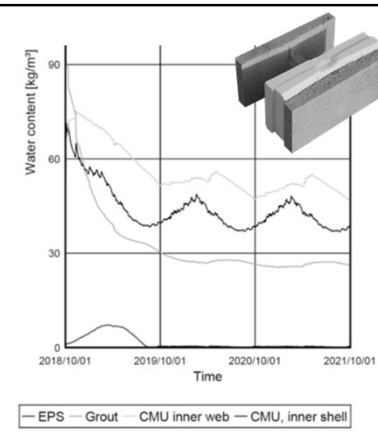
When Layers Attack

Hygrothermal Analyses

- Natatorium
- Climate Zone 5
- Single Wythe CMU
- Integrally Insulated
- Finish:
  - Interior and Exterior: None



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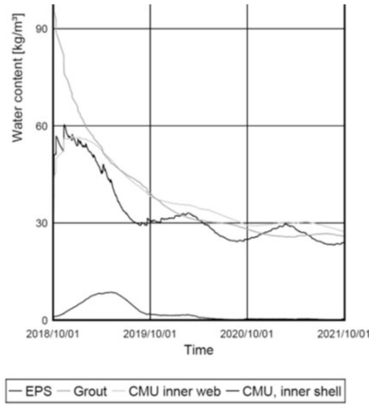
When Layers Attack

Hygrothermal Analyses

- Natatorium
- Climate Zone 5
- Single Wythe CMU
- Integrally Insulated
- Finish:
  - Exterior: None
  - Interior: Paint (7 Perm)



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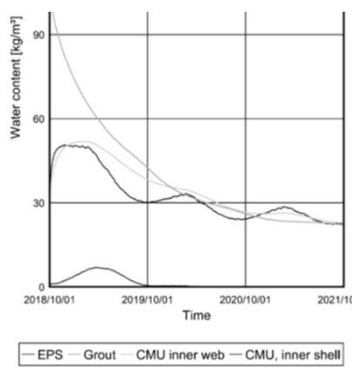
When Layers Attack

Hygrothermal Analyses

- Natatorium
- Climate Zone 5
- Single Wythe CMU
- Integrally Insulated
- Finish:
  - Interior: Paint (7 Perm)
  - Exterior: Vapor Permeable Clear Coating



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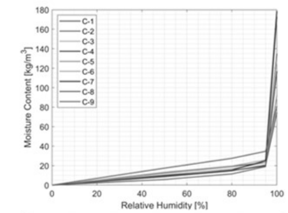
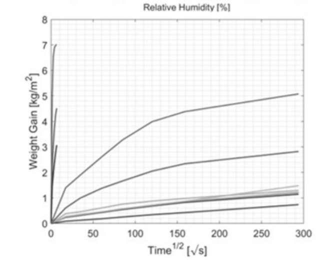
When Layers Attack

Hygrothermal Analyses

CMU can hold a lot of water, doesn't pick it up from ambient water vapor in the atmosphere.





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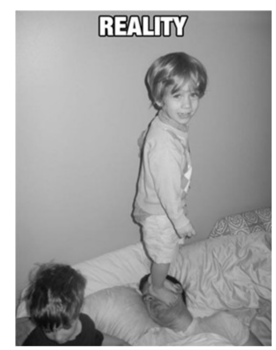
Perceptions vs. Reality



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Perceptions vs. Reality!

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Questions?

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