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WHAT CAN WE DO WITH 8 INCH CMU IN WISCONSIN?

In building design, 8-Inch Concrete Masonry Unit (CMU) is a versatile building material but is sometimes under-utilized and unnecessarily replaced with its bigger siblings, 10-inch, 12-inch or 16-inch units. There are many situations where an 8-inch masonry wall can be used when you have knowledge of actual local material strengths, masonry design experience, utilize up-to-date spreadsheets and software programs, and current methods for design that don't rely on outdated empirical height limitations simply based on wall thickness. As David Biggs, Principal, Ryan-Biggs Associates, points out in the article *Designing Tall Masonry Walls*, "...whether you design unreinforced or reinforced masonry walls, these height limitations can be exceeded if the walls are engineered using criteria from the Masonry Standards Joint Committee (MSJC) code." So with appropriate software design tools and knowledge, there is no rationale for specific wall height limits for 8-inch masonry walls.

Using proven masonry design practices you will find there is no need to unnecessarily thicken the wall or replace masonry with one of its closely related cousins, cast-in-place concrete or concrete precast elements at a premium cost. Again, there are situations that may warrant this, but when the client is requesting an aesthetically pleasing "exposed" structural element like masonry, it is important to have an in-depth knowledge of what can be designed with masonry, rather than have your client find out later that a change was made without sound reasoning.



Figure 1 - Aesthetic 8-inch masonry wall in school gymnasium.⁵

REINFORCED MASONRY FOR OUT-OF-PLANE WALL LOADS

Most exterior masonry walls are reinforced due to the out-of-plane wall pressures from wind. An 8-inch reinforced masonry wall can provide efficient, safe designs that can easily exceed a height-to-thickness ratio of 30, and possibly as much as 50. Some of you might be saying, "Really, how do we do that?" To understand designing tall walls, consider how concrete floor systems can be designed with a length-to-thickness ratio of 35, 40, or more. In nearly every situation, floors have more than twice the load in the out-of-plane direction as a wall. Quality control is essential, proper placement of reinforcement, adequate cover, and the design considerations that account for the deflected shape are all very important for the concrete floor, as well as the 8-inch thick, tall masonry wall.

Wall thickness & reinforcement	Wall clear height, support top & bottom	h/t ratio
8-inch, #5 @ 48" o.c.	20' - 8"	-30
8-inch, 2 - #5 @ 24" o.c.	32' - 8"	-50

Table 1 - Examples of reinforced masonry wall designs using 8" masonry. Assumptions: $f'_m=2250$ psi, wall pressure = 15 psf, partial grout, Strength Design.

Reinforced walls with openings are also able to be analyzed for out-of-plane loadings and designed more effectively with the recent introduction of finite element software tools such as RISA 3D², and RAM Elements V8i³. Previously many structural engineers relied on conservative methods to simplify the out-of-plane wall analysis. However, today these same engineers can understand the actual behavior of the wall much better and are getting more effective use of reinforcement in the walls which allows for 8-inch masonry in more situations.

HAVE YOU EVER HEARD “WHY DO WE NEED ALL THIS REINFORCEMENT, IN THE PAST WE BUILT THAT WALL AS AN UNREINFORCED WALL?”

Unreinforced 8-inch CMU walls have sufficient capacity for relatively short walls. The MSJC code makes provisions for unreinforced exterior and interior walls. When a relatively tall, unreinforced 8-inch masonry interior wall doesn’t comply with code requirements, one option is to make the wall loadbearing. In most situations, you gain capacity for out-of-plane bending in an unreinforced wall by adding concentric vertical load to the wall.

Wall thickness & loading condition	Wall clear height, support top & bottom
8-inch, non-loadbearing	14’ - 0”
8-inch, load bearing (DL=500 lb/ft)	17’ - 4”
8-inch, load bearing (DL=1,000 lb/ft)	20’ - 0”

Table 2 - Examples of reinforced masonry wall designs using 8” masonry. Assumptions: f’_m=2250 psi, wall pressure = 5 psf, (interior partition loading), Strength Design.

MASONRY SHEAR WALLS

The in-plane shear (shear wall) capacity of a masonry wall is typically sufficient because of the reinforcing already required from other loading scenarios like out-of-plane bending or axial loading. This is certainly true when you have perimeter walls on all sides of a single story building. Shear wall designs for masonry only start to require additional reinforcement for relatively tall buildings or certain other situations with low axial loads and low out-of-plane bending.

With non-loadbearing walls loaded with in-plane shear such as the Hybrid Masonry Design (Type I), when the vertical load is supported by the steel frame and not by the masonry, additional reinforcement will be required so the wall can act in shear (Figure 2). With Hybrid Design, the cost of adding a few bars to the ends of the CMU infill walls is easily offset by allowing engineers to eliminate cross braces to save the project significant costs and allow the designer freedom to locate openings.



Figure 2 - Good example of interior loadbearing walls.

Stair and elevator shafts are also good examples of walls that are traditionally masonry, and are excellent at resisting lateral load for most buildings. Because of the box-shape of these walls, the wall “group” is much more rigid than the individual walls would have been if designed separately. This increase in stiffness, generally allows the masonry stair and elevator wall groups to resist the lateral load for the entire building.

With box-shaped wall groups, hybrid masonry frames, or other shear wall considerations, having finite element software such as RAM Elements V8i and RISA 3D is essential to appropriately account for masonry’s actual stiffness and design strength. With finite element software, walls with openings can easily be considered as shear walls when they might have been previously ignored because of the complex analysis required. With these programs, engineers are able to recognize the strength of these perforated masonry shear walls, hybrid

masonry design, and stair and elevator shafts. As a result 8-inch masonry is more effective for masonry shear walls, and more accurate analysis is leading to more accurate and efficient design.



Figure 3 - The 8-inch masonry design for the shear walls of the elevator shaft and stair towers were not only sufficient in this model, but required no additional reinforcement for lateral design load combinations.

In seismic design situations, masonry walls do require special attention to detailing similar to other concrete products, especially as you move from an ordinary reinforced masonry wall to a special reinforced masonry wall. But again, even with seismic loading, there are no provisions in the code to make the wall thicker simply because of seismic design. In fact, lighter, thinner, reinforced wall performs better in seismic regions, so reinforced 8-inch masonry is a better choice than thicker walls.

Masonry is exceptional at resisting lateral load, as defined by the structural engineer’s standard for determining loads, ASCE 7. In this document, masonry is not only allowed to be used in seismic loading situations, it gives special reinforced masonry walls the exact same value for the Response Modification Factor as a special reinforced concrete shear wall (see Table 3) in bearing wall situations. When reinforced and detailed properly, masonry walls are equivalent to concrete walls of equal strength even in the most extreme in-plane shear loading situations that result from seismic events.

Bearing Wall System	Response Modification Factor, R	SDC B	SDC C	SDC D, E
Special reinforced concrete shear wall	5	Permitted	Permitted	Permitted
Special reinforced masonry shear wall	5	Permitted	Permitted	Permitted

Table 3 - Excerpt from ASCE 7-10 Table 12.14-1.

SO WHAT’S HOLDING US BACK FROM USING 8-INCH CMU?

Most likely it’s one of three reasons:

- Lack of knowledge of actual local material strengths.
- Unfamiliarity with current design practices and software programs.
- Inexperience designing with masonry.

The first problem is an easy one to solve. Getting test data from block suppliers for your project is relatively simple. In fact, the Wisconsin Masonry Alliance (WMA) has provided Wisconsin engineers with a letter stating that their member’s *typical* blocks will allow a masonry system strength ($f'm$) to be 2250 psi or greater. This higher block strength is typical in Wisconsin at no additional cost. With additional testing, you can likely even

design for a higher strength in many instances. With that knowledge, projects in Wisconsin can and should now be designed at the higher block strength without hesitation, leading to more economical use of material (mainly grout and reinforcement) and responsible designs. Having increased understanding of actual CMU strengths will allow us to design more with 8-inch CMU, which might have been over-designed with a thicker block previously.

The second issue, which is unfamiliarity with current design practices and software programs, is difficult to determine the root cause. However, at the 2011 NCSEA Annual Conference, the Basic Education Committee identified masonry as one of the materials that is not being offered (or offered too infrequently) at our engineering universities.

Across the nation, many of the universities simply don't give attention to masonry design. As a result many students are graduating from universities with a civil/structural engineering degree with only a few lectures about the design of masonry.

Engineering professionals must get educated on their own by a good mentor and/or continuing education programs offered by reputable masonry industry groups such as International Masonry Institute (IMI) and the National Concrete Masonry Association (NCMA). Unfamiliarity with current software programs is common because masonry analysis and design features are relatively new in finite element analysis programs. However, software vendors offer education for their software programs and IMI offers general masonry design training including design based on using software programs all across the country. Today there are ample opportunities to become educated about masonry software programs.

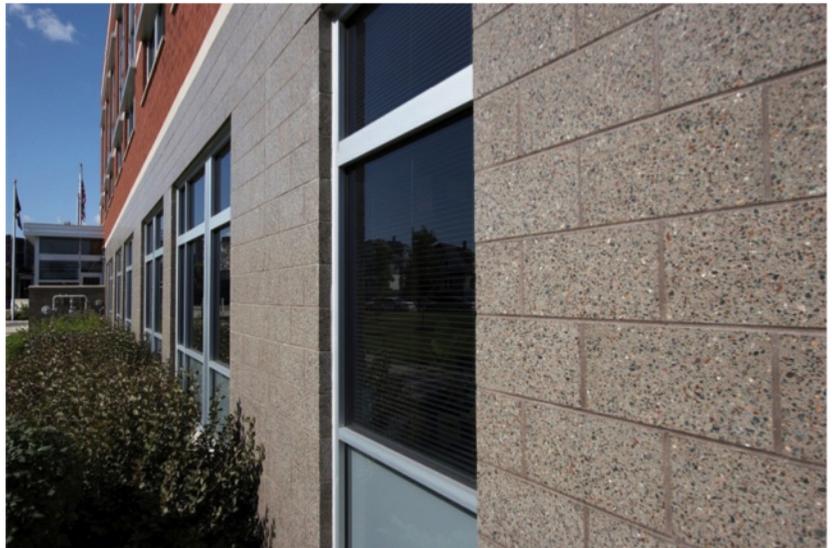


Figure 4 - Ground-faced structural masonry used with modular design dimensions to enhance aesthetics and create lower masonry cost.⁵

The last problem, design inexperience is one that can be solved over time, and hopefully with the help of a good mentor and some good masonry design literature¹. The right design guides, masonry design textbooks, and articles such as “Structural Masonry Done Right” from Diane Throop, P.E., FTMS, IMI’s Director of Engineering, and IMI’s “Structural Masonry Design Tips” will get you headed in the right direction.



Figure 5 - Structural and decorative “Castle Rock” CMUs creates efficient use of masonry material and architectural expression.⁵

Providing a design that is less prone to errors in construction is the art of engineering that only comes with experience. Remember, masonry is a structural element that must be designed. The thought process of “when in doubt make it stout” is not a responsible strategy for any material, including masonry. With help from training groups like the International Masonry Institute, masons are being educated on the reasons why rebar needs to be located per drawings and proper techniques for grout installation. One way to ensure quality masonry on your next project is to insert specification text demanding grouting and reinforcement training for masons⁴. Other options include comprehensive pre-construction meeting with the masonry contractor, mock-up review and or

requiring special inspection on projects, even in situations when it's not code mandated. As engineers it is our duty to develop efficient structural designs and work together with contractors to ensure masonry is built correctly.

We must familiarize ourselves with the design processes and software programs, seek mentoring and education, and make educated decisions about masonry design. The reality is thinner walls such as 8-inch masonry is being designed by many engineers, providing their clients with structurally safe, code compliant, aesthetically pleasing, and economical designs.

FOOTNOTES

- 1 - For a full list of masonry design references, contact Pat Conway (pconway@imiweb.org) from IMI for the Structural Masonry Resources Bibliography
- 2 - RISA Floor and RISA 3D are available from RISA Technologies, LLC
- 3 - RAM Elements V8i is available from Bentley Systems, Inc,
- 4 - For sample specification text, contact International Masonry Institute
- 5 - Images provided by County Materials Corporation

REFERENCES

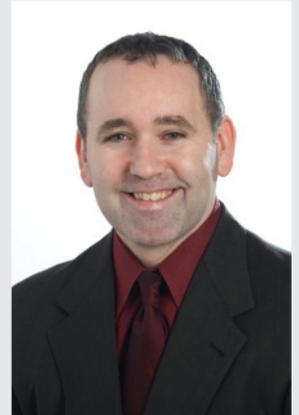
- “Structural Masonry Done Right” Diane Throop, PE; INTERFACE, April 2012
- “Designing Tall Masonry Walls”, David Biggs, PE; Structural Design, May 2008
- ASCE 7-10 Minimum Design Load for Buildings and Other Structures
- Masonry Standards Joint Committee’s (MSJC) 2008 Building Code Requirements and Specification for Masonry Structures (TMS 402/ACI 530/ASCE 5 and TMS 602/ACI 530.1/ASCE 6)

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