Designing Tall Masonry Walls

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Have you ever designed a bearing wall 20 feet high? How about 25 feet or 35 feet or even 50 feet? Have you ever considered the feasibility of a 50-foot tall bearing wall?

There are many options available to engineers who would like to design tall masonry walls. As a result of misconceptions, misunderstandings, or lack of knowledge, masonry is not being used to its full capacity to build tall walls. Let's look at ways to design really tall single-story exterior walls.

Historical Perspective

For years, engineers have relied upon empirical design criteria for determining maximum wall heights and their associated thicknesses. The criteria known as "h/t" limitations (height to thickness) was developed based upon historical data of unreinforced masonry. There is little rational analysis to justify h/t values. The strength of the masonry and the mortar type used in the construction are not included in these limitations. However, a stress calculation for compression based upon gross section properties is required.

Using empirical criteria in the 2005 edition of the *Building Code Requirements for Masonry Structures* (ACI 530/ASCE 5/TMS 402) developed by the Masonry Standards Joint Committee (MSJC), exterior walls are limited to an h/t (height to thickness) of 20 for solid or fully grouted bearing walls, and an h/t of 18 for all other exterior walls (non-loading bearing walls or bearing walls not solid or fully grouted).

Walls	Limiting Height
Bearing Walls	
Solid brick or fully grouted CMU	
8 inch	13'-4”
10 inch	16'-8”
12 inch	20'-0”
Hollow or partially grouted CMU	
8 inch	12'-0”
10 inch	15'-0”
12 inch	18'-0”
Non-bearings Walls	
8 inch	12'-0”
10 inch	15'-0”
12 inch	18'-0”

Table 1: Empirical Limitations

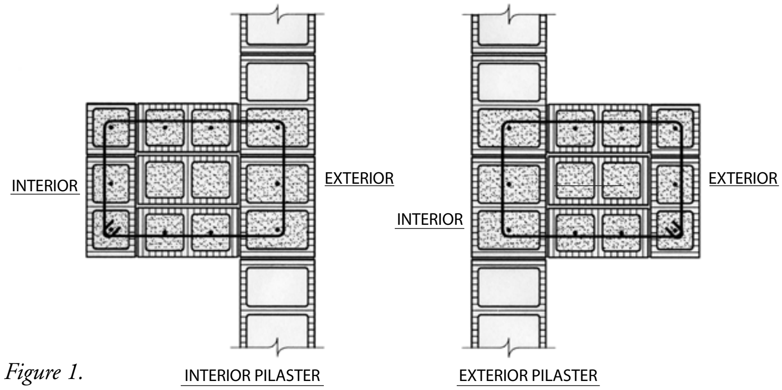

Figure 1.

The heights of exterior walls are therefore limited as noted in *Table 1*.

These values have been in various masonry standards for years, and they are often misused by many architects and engineers for <u>all</u> walls. That's the mistake! These criteria do <u>not</u> apply to "engineered" masonry. Whether you design unreinforced or reinforced masonry walls, these height limitations can be exceeded if the walls are engineered using criteria from the MSJC. Let's review some of the options!

Current Design Options

Engineered Unreinforced Masonry using Allowable Stress Design (ASD)

The height of an unreinforced masonry wall that is engineered is governed by design stresses and buckling capacity. For a loadbearing wall designed in accordance with the Allowable Stress Design methodology, an engineer must design the wall so as not to exceed the allowable stresses for the masonry and the mortar. There is <u>no</u> absolute h/t limit!

For loadbearing walls, there is also a buckling capacity check that could restrict the actual height of the walls. The buckling capacity is reduced for slenderness effects based upon the h/r ratio (height to radius of gyration). The radius of gyration is approximately 30 percent of the thickness "t." While there is no absolute maximum height limit, the maximum h/t is effectively limited based upon the loads applied.

Building really tall with this method requires very thick walls. Possible? Yes. Practical? Maybe not!

Engineered Reinforced Masonry using Allowable Stress Design

Reinforced masonry designed using Allowable Stress Design follows similar guidelines as that used for unreinforced masonry in that there is no maximum height limit. The maximum wall height is controlled by the loadings and slenderness effects. The slenderness effects are based upon the h/r ratio and prevent the wall from buckling.

For single-wythe walls, allowable stress methods generally do not allow really tall walls to be designed without building thick. We'll see later how reinforced methods can be used to go tall.

Engineered Reinforced Masonry using Strength Design

One efficient method for designing tall walls uses Strength Design methods. Since 1985, strength methods have been codified, starting first with the *Uniform Building Code* and now embodied within the MSJC and the *International Building Code* (IBC).

This method has no specific limit on h/t. However, it has design criteria that limit service load deflections and ultimate moment capacity for out-of-plane loads. The service load deflections cannot exceed 0.7 percent of the wall height. For a 30-foot wall, that's 2.5 inches over 30 feet for a simply supported wall.

To create really tall walls, there is an axial load capacity limitation when the h/t exceeds 30. The factored axial load for these walls must be limited to 5 percent of the f′m based upon the gross section properties. The minimum wall thickness is 6 inches also. It is not uncommon to create designs with an h/t from 32 to 50. That could produce wall heights of up to 33 feet for walls built with 8-inch concrete masonry units (CMU), 41 feet for 10-inch CMU, and 50 feet for 12-inch CMU. Regionally, 14- and 16-inch CMU are available, which extend possible wall heights even further.

Many engineers may choose to avoid this method because they are not familiar with it. However, there are code standards from MSJC and several excellent references that explain the method, and there is computer software that makes it relatively easy to create design options. (The online version of this article, **www.STRUCTUREmag.org**, contains specific references.)

Pilasters

Another method to build tall uses pilasters built with the walls. The pilasters are stiffening elements. *Figure 1* shows two options for pilasters. They can be either interior or exterior to the wall.

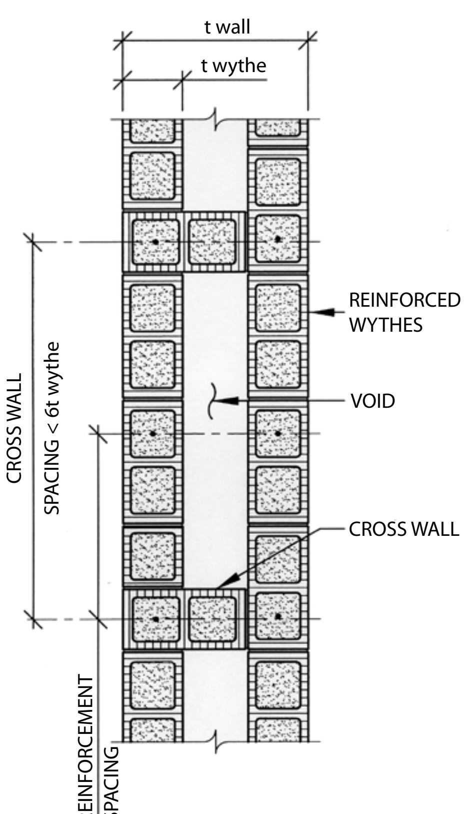

Figure 2.

The advantages of using pilasters include:

a) The wall sections between the pilasters are only as thick as is needed to span horizontally between the pilasters.
b) The system works well with the Allowable Stress Design method, a process many engineers are familiar with.

One disadvantage is that interior pilasters decrease the usable space within the building because of the thickened wall section. Another is that the loadings to the top of the exterior pilaster are normally eccentric to the pilaster and reduce the load capacity.

The height of the wall is governed by the size of the pilaster and its load capacity.

Diaphragm Walls

This wall system is not commonly used in the United States, but provides almost unlimited height possibilities. The walls are basically two wythes joined by cross walls (diaphragm walls) that interlock the two wythes and create a composite wall of variable thickness. The spacing of the cross walls should be less than 6 times the thickness of the wythes. The two wythes are conventionally reinforced by partially or fully grouting the cores. (*Figure 2*)

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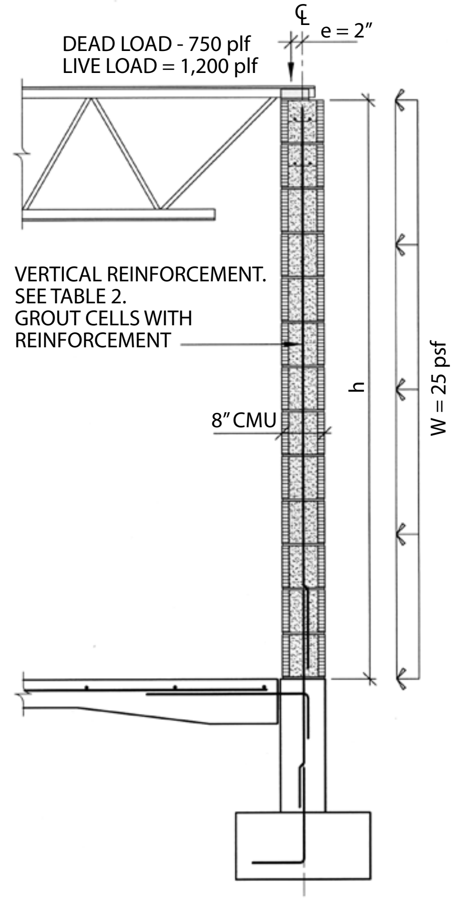

Figure 3.

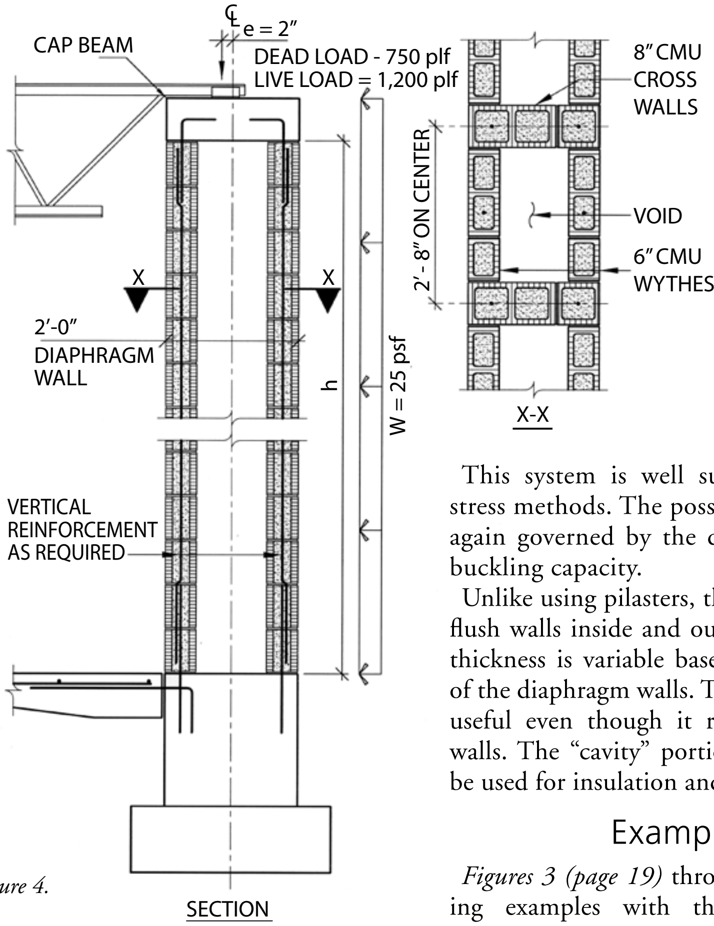

Figure 4.

Design Method	Height (h)	Vertical Reinforcement
Empirical	12'-0"	N/A
ASD	18'-0"	#4 @ 16" oc
Strength	28'-0"	#4 @ 8" oc
Diaphragm Wall (ASD)	56'-0"	#5 @ 16" oc (a)
Diaphragm Wall (ASD)	62'-0	#5 @ 12" oc (b)

Table 2: Example Results (f'm = 2,000 psi)
(a) Grout only at reinforcement; (b) Grout wythes solid

This system is well suited to allowable stress methods. The possible height limit is again governed by the design stresses and buckling capacity.

Unlike using pilasters, this system provides flush walls inside and out. The overall wall thickness is variable based upon the depth of the diaphragm walls. The method is quite useful even though it requires very thick walls. The "cavity" portion of the wall can be used for insulation and to locate utilities.

Examples

Figures 3 (page 19) through *5* show building examples with the walls designed with each of the methods described. In all designs, the f'm is 2,000 psi. The 2005 MSJC and the IBC 2006 were used. The axial loads and lateral loads are the same for each example. The maximum wall heights for each option are calculated. It may be intuitive, but the more sophisticated the design technique, the taller the walls can be.

Figure 3 (page 19) shows the same single-wythe, 8-inch bearing wall designed by Empirical, ASD, and Strength methods. As seen in *Table 2*, the Strength method allows the wall to be constructed 10 feet taller than the ASD method.

Figure 4 shows the diaphragm wall design based upon the same loadings as given in *Figure 3 (page 19)*. The structural thickness is 2 feet and is constructed with 6-inch CMU. The 8-inch CMU diaphragms are spaced at 32 inches on center to be in coursing. The 12-inch "internal cavity"

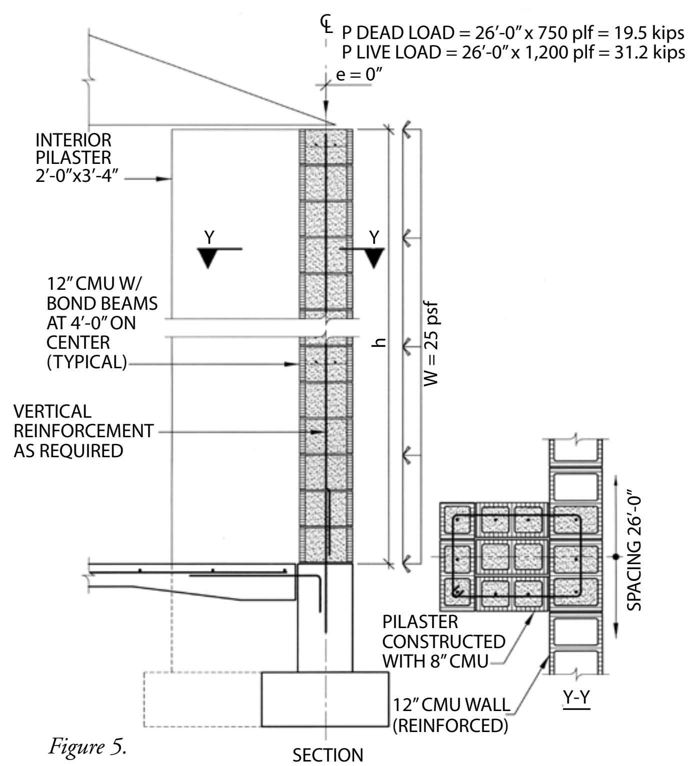

Figure 5.

Figure 6.

provides options for running utilities within the walls. *Table 2* shows the wall height can be 56 feet if the wythes are partially grouted, and 62 feet if the wythes are fully grouted. While these are quite tall, the effective h/t of the 2-foot wall thickness is approximately 30.

Figure 6 shows an actual building with 2-foot thick diaphragm walls constructed with 8-inch CMU. The exterior was faced with insulation and a stone veneer. The walls were built 38-feet high, but could have been constructed as high as 46 feet. To go even higher, the internal cavity could have been made wider thereby increasing the effectiveness of the reinforcement.

Figure 5 shows the wall with an interior pilaster. The pilasters are spaced 26 feet apart using 12-inch CMU with reinforced bond beams at 4 feet on center. The axial loads are the same as those used for *Figures 3* and *4* except they are concentrated on the pilasters without any eccentricity. There must be a perimeter beam spanning between the pilasters to transfer these loadings to the pilasters.

Designing tall single-story walls is possible using "engineered" masonry. The examples provided indicate that 50- and 60-foot walls are quite feasible, depending on the loading conditions. Which method used is a function of the type of structure that is to be supported, concentrated loads or uniformly distributed. Pilasters only make sense when concentrated loads from trusses are present. Otherwise, bearing walls (single-wythe or diaphragm) will work quite well!▪

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References

1) *Tall Slender Walls*, J.E. Amrhein and D.E. Lee, Masonry Institute of America, Los Angeles, CA, 1994
2) *Masonry Tallwall Design Guide Based on the 2003 International Building Code*, D.T. Biggs and J.E. Amrhein, published by the International Masonry Institute, Annapolis, MD, 2003
3) *Structural Masonry Design System, Masonry 4.0*, distributed by National Concrete Masonry Association, Herndon, VA, 2006