



INSIGHTS

FOR MASONRY DESIGN

Non-Participating Masonry Infill

For various reasons, a building frame may need to be constructed prior to the exterior walls which will be filled in later in the construction schedule. At the exterior, a wall needs to resist out-of-plane loads due to component and cladding wind as well as seismic forces. Masonry makes an excellent option for this infill material at the exterior wall due to its durability, security, fire control, sound control, aesthetics, etc. The design and detailing of these walls must adhere to TMS 402-16 Appendix B and relevant seismic and wind load provisions from ASCE 7-16. This paper will focus on the non-participating infill which will be defined in the next section..

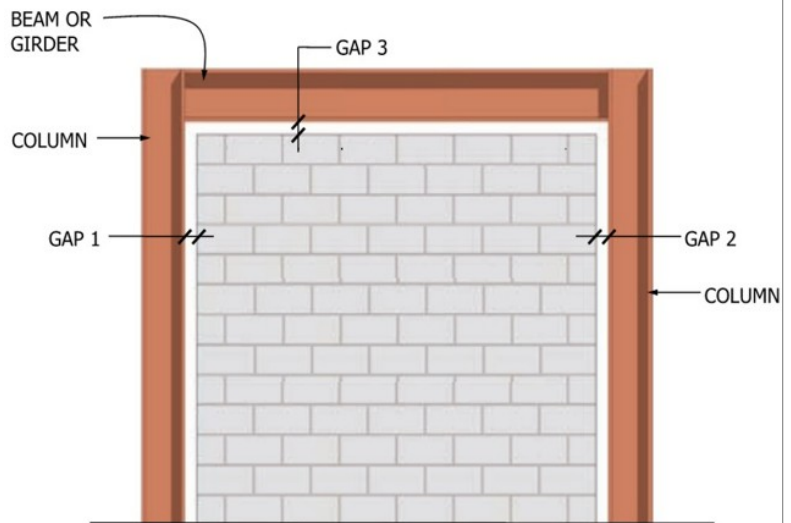


Figure 1: Non-participating Infill Wall

Masonry Infill Definitions

To start this discussion, there are several terms to understand which are all defined as follows per the TMS 402 masonry code.

Infill Wall: “Masonry constructed within the plane of, and bounded by, a structural frame”.

Non-Participating Infill: “Infill designed so that in-plane loads are not imparted to it from the bounding frame.”

Participating Infill: “Infill designed to resist in-plane loads imparted to it by the bounding frame.”

The key takeaway is that infill walls are constructed in line with a steel or concrete frame between columns and underneath a beam or slab (see figure 1). Generally, the structural frame is designed to carry the full vertical gravity loading. Sometimes the infill wall is used to assist with the lateral load resistance (participating infill), and other times the frame resists all of the lateral load (non-participating infill). The behavior and design requirements for each situation are drastically different. For design guidance, TMS 402 Appendix B has three main sections, B.1 for general information, B.2 for non-participating infills, and B.3 for participating infills but this article will only address the first two.

Starting with the general B.1 section, the appendix references parts 1 and 2 of the main code so that all infill walls will be designed using the typical masonry design requirements including chapter 7 for seismic detailing. Note that appendix B does deviate from the main code in two significant ways. First, the appendix only references the strength design method and secondly specifies a reduced resistance factor $\phi = 0.60$ for shear, flexure, and axial loading in place of the main code values of $\phi = 0.90$ for flexure/axial and $\phi = 0.80$ for shear. Be aware that the strength reduction factors for anchorage and bearing remain unchanged and shall be determined per TMS 402-16 section 9.1.4. Table 1 provides reinforcement for a typical building with non-participating infill walls. This table can be compared with table 1 in the companion masonry insight article titled “Masonry Exterior Non-Bearing Wall Design Guide” which provides reinforcement for the same building using $\phi = 0.90$ for standard walls per the main body of the TMS code. Per the B.1 commentary, the design for all infill walls is noted as being based on a combination of experimental research and anecdotal performance which is the likely reason for the lower reduction factor. This makes sense for participating infill walls (not in the scope of this article) as there is a complex interaction between the frame and the infill causing struts to form in the masonry. However, it is unclear why non-participating infill uses the same reduced resistance factor ($\phi = 0.60$) when the infill will be completely isolated from the frame preventing any interaction between the two elements.

Detailing of the connections to the frame are extremely important. The connections at the top and ends of the non-participating infill wall must transfer the out-of-plane loads only while allowing movement both vertically and horizontally to accommodate the deflections of the structural frame. The companion masonry insight article mentioned above provides examples of detailing options available that can meet these demands.

Reinforcement Guidelines for Out-of-Plane Loads

Masonry walls should be reinforced vertically and horizontally to resist out-of-plane bending moments while maintaining structural efficiency. The recommended reinforcement layout follows:

- Vertical bars: Placed at center of grouted cores.
- Horizontal reinforcement: Ladder-type joint reinforcement at every second or third course.

All exterior infill walls must resist out-of-plane wind and seismic loading. As noted earlier, the scope of this article only includes non-participating masonry, thus, in low seismic areas, the wind load will most likely govern. Per the TMS code, there are no minimum reinforcement requirements for wind loading. Similarly, per TMS 402-16 Section 7.4.1, non-participating elements located in Seismic Design Category (SDC) A or B do not have minimum reinforcement requirements. However, be aware that For SDC C or higher: Minimum reinforcement area: $0.0007A_g$ Maximum reinforcement spacing: 48 inches, Make sure to compare with the wind design to determine the final masonry wall reinforcement.

When choosing reinforcement for masonry walls, the general rule of thumb for economy is to space the rebar as far apart as possible to minimize the number of grouted cells meaning less labor is needed from the masons. However, other items affects cost such as reinforcement lap splice length, bond beam locations, and connector capacity. Many factors influence the lap splice length including masonry assembly strength ($f'm$), rebar size, and cover distance. Using $f'm$ values higher than the code minimum is recommended as masonry units off the shelf can easily develop higher strength than many engineers expect. $F'm = 2500$ psi is a good starting point as this can be produced in virtually all locations across the United States. Values of 3000psi or 3500psi (or even higher) can also be achieved fairly easily but verify first with local suppliers. For exterior

walls discussed in this article, it is recommended to use a single bar centered in the masonry cores which also helps to minimize lap lengths. Finally, bar size is the biggest driver of lap lengths. Shorter height walls generally need less reinforcement and may not even need rebar splices at all. Rebar sizes of #4 and #5 generally have low lap lengths. Bar sizes of #6 and larger begin to have much longer lap lengths that makes rebar installation unwieldy. As can be seen in table 1, the recommendation is to use #4 or #5 bars as much as possible and save #6 bars for when it is necessary.

Following is an example of a hypothetical 60ft tall building located in Chicago, Illinois with a wind speed of 107 mph per ASCE 7-16. This location was chosen to represent an example applicable to a majority of the country. The reinforcement is based on component & cladding wind loads in wind zone 5 and the out-of-plane load combination wind coefficient = $0.42W$ for evaluating deflection per ASCE 7-16. Type S mortar with medium weight masonry (115 pcf) is assumed at $f'm = 2,500$ psi. All reinforcement is 60ksi and is a single bar centered in the masonry core. Table 1 shows the required reinforcement for non-participating infill walls designed per Appendix B.1 of the TMS 402-16 code.

	10 ft	12 ft	14 ft	16 ft	18 ft	20 ft	24 ft	28 ft	30 ft
6" Block	#5 @ 72	#5 @ 48	#5 @ 32	#5 @ 24	#5 @ 16	#5 @ 16	-	-	-
8" Block	#5 @ 104	#5 @ 72	#5 @ 56	#5 @ 40	#5 @ 32	#5 @ 24	#6 @ 24	#6 @ 16	#6 @ 16
10" Block	#5 @ 120	#5 @ 96	#5 @ 72	#5 @ 56	#5 @ 40	#5 @ 32	#5 @ 24	#5 @ 16	#5 @ 16
12" Block	#4 @ 120	#5 @ 120	#5 @ 96	#5 @ 72	#5 @ 56	#5 @ 48	#5 @ 32	#5 @ 24	#5 @ 16

Table 1: Infill Wall ($\phi = 0.6$)
Design for Out-of-Plane C&C Wind

Connection Detailing and Frame Compatibility

Frame-to-Infill Interaction

The infill walls must be isolated from in-plane frame deformations to prevent unintended load sharing. Slotted connections and flexible anchors should be used to allow relative movement while transferring only out-of-plane loads.

Common Connection Types

Slip joints at top to allow vertical frame movement.

Side connections using flexible anchors to resist out-of-plane forces but prevent in-plane shear transfer.

Anchorage Requirements

Anchorage to the bounding frame must satisfy TMS 402-16 Section 9.1.4, ensuring adequate bearing and pull-out strength.

For out-of-plane stability: $T_{anchor} > 1.2 W$ where T_{anchor} is the anchorage tensile strength and W is the applied wind load."

Summary

Masonry infill walls, when properly detailed and reinforced, provide an effective solution for exterior enclosure systems in framed buildings. Engineers must carefully consider frame compatibility, reinforcement selection, and anchorage design to ensure that these walls perform as intended under wind and seismic loading conditions.

Further studies using finite element modeling (FEM) can refine design predictions and optimize detailing strategies.

2000 PSI EXAMPLE

MATERIAL NOTES FOR MASONRY	REQUIRED STRENGTH
CMU, ASTM C 90	$f'_{cmu} = 4500$ PSI (MINIMUM) (NET AREA COMPRESSIVE STRENGTH)
MORTAR, ASTM C-270	TYPE S
GROUT, ASTM C-476	$f'_g = 3000$ PSI (MINIMUM)
MASONRY ASSEMBLY	$F'_m = 3000$ PSI (NET AREA COMPRESSIVE STRENGTH)

3000 PSI EXAMPLE

CONCLUSION:

Specifying concrete masonry with a design compressive strength of 2500 psi involves defining the characteristics of the masonry units, selecting the appropriate mortar type, and specifying grout strength in accordance with TMS 602 guidelines. Providing these details ensures that the masonry assembly meets the structural requirements while facilitating proper material selection and construction practices.

References

TMS 602, "Specification for Masonry Structures"

ASTM C90, "Standard Specification for Loadbearing Concrete Masonry Units" ASTM C270, "Standard Specification for Mortar for Unit Masonry"

ASTM C476, "Standard Specification for Grout for Masonry"