Construction Issues

discussion of construction issues and techniques

Bracing Masonry Walls under Construction Using Their Own Strength

By Diane Throop, P.E. and Scott Walkowicz, P.E.

Diane Throop, P.E., is Director of Engineering, International Masonry Institute, Annapolis, MD and was Chair of The Masonry Standards Joint Committee for the development of the 2011 and 2013 editions of the Building Code Requirements for Masonry Structures (TMS 402/ACI530/ASCE5) and Specification for Masonry Structures (TMS602/ACI530.1/ASCE6). She can be reached at ***dthroop@imiweb.org****.*

Scott W. Walkowicz, P.E., heads his own consulting firm, Walkowicz Consulting Engineers located in Lansing, Michigan. He is the President of The Masonry Society (TMS) and is former Chair of the General Requirements Subcommittee for the Masonry Standards Joint Committee (MSJC) – the structural masonry code. He may be reached at ***scott@walkowiczce.com****.*

Bracing of masonry walls under construction using the wall's inherent strength rather than external bracing elements is a newer approach to bracing, and is known as *Internal Bracing*. It has been successfully applied in numerous projects with short to very tall walls. Bracing, in general, provides life safety for workers and other occupants on the job site, essentially keeping the wall up during construction and long enough to provide time for evacuation during a wind event. Protection of property, including the wall or walls under construction, is not the purpose of the bracing … although additional design considerations (such as utilizing higher or even occupancy design level wind speeds) may lead to bracing effective at accomplishing property protection as well. Internal bracing provides an excellent option to accomplish these goals. The Masonry Contractors Association's *Standard Practice for Bracing Masonry Walls Under Construction* (*Standard*) provides the basis for design of external or internal masonry wall bracing. An additional guide specific to internal bracing design is the International Masonry Institute's *Internal Bracing Design Guide for Masonry Walls Under Construction* (*Internal Bracing Guide*).

The Concept of Internal Bracing

Internal bracing of masonry walls under construction is based on the cantilevered performance of the wall and utilizes predicted capacity to resist defined wind loads that may occur during construction and before the wall's final lateral support is in place. Internal Bracing provides verifiable engineering capacity and performance similar to, and in many cases better than, systems that incorporate external bracing components. For most masonry capacity calculations, it utilizes reduced design criteria such as lower values for the masonry's compressive strength, applies lateral loads for specified wind speeds, and provides tangible benefits to the project as described later in this article. *Figure 1* shows a cantilevered wall with two base doweling conditions that influence the ability of a wall to perform as internally braced. The center diagram shows a common *pinned* base condition where the foundation dowel extends only 6 inches into the base of the masonry wall. This condition will provide only minimal capacity before the dowel embedment in the masonry fails and the wall becomes pinned at the base leaving only self-weight to resist over-turning. The right side diagram shows a wall with a 2.5-foot dowel (full development for a #5 bar with grout cured 24 hours). This wall will develop cantilevered capacity as the grout cures and then the wall performs with base fixity and moment continuity. Make sure the structural reinforcement is sized and spaced properly, and that wall is internally braced!

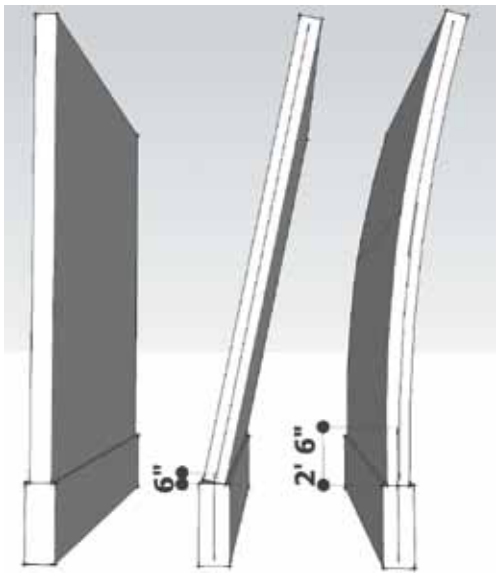

Figure 1. Cantilevered wall diagrams.

The Basics

Restricted Zone

Beyond wall and brace capacity, the other key aspect of masonry bracing is the creation of a Restricted Zone. Because the bracing is typically engineered to resist wind speeds as specified in the *Standard*, which are lower than those required in the *International Building Code*, the Restricted Zone protects persons from serious injury or death by defining an area to be evacuated in the event of mandated wind speeds and prior to a partial or complete wall failure.

Initial and Intermediate Periods

The under-construction definition can be paraphrased as the entire time between when the masonry is first laid and when the wall's final lateral support is in place. That time period is broken into two distinct phases: The *Initial Period* and the *Intermediate Period*. There are different design requirements and restrictions for each.

Walls are generally considered *unbraced* in the Initial Period in that only the wall's self-weight is considered effective in resisting overturning and flexural stresses, since the mortar and grout have not gained sufficient strength to resist load.

The Intermediate Period is defined as being the period of time following the Initial Period until the wall is connected to the elements that provide its final lateral support. That can be interpreted as being the period starting when

the masonry is more than a day old until the wall is connected to a diaphragm or other elements that are sufficiently capable of transferring lateral force from the wall through other elements to the foundation. Bar joists or beams bearing on, or connected to, the wall may not qualify as 'final lateral support'. Each project condition should be evaluated independently to determine when the Intermediate Period ends.

Materials

Masonry Assemblies

Masonry Assemblies – Reinforced masonry walls are the best candidates for internal bracing. This article focuses on low pour and low lift heights to generate capacity at the base of the cantilevered wall, although there are ways to use internal bracing with high lift and high pour heights or with unreinforced masonry (both the *Standard* and the *Internal Bracing Guide* offer guidance). Pour height refers to the masonry wall height that is constructed prior to grout placement. Limiting the ungrouted wall height as the construction progresses by using low-pour heights takes advantage of strength that develops very quickly in constructed masonry and uses that strength, along with connection to the foundation, to internally brace the wall without an external brace system.

Reinforced walls are the best candidates for application of Internal Bracing principles due to the significant strength that the reinforcement can add as the grout cures. If the wall reinforcement is properly doweled to the foundation, base fixity can create the desired cantilevered performance typically within 12 to 24 hours after grout placement. The short term design provisions in the *Standard* are modeled after those in the *Masonry Standards Joint Committee's Building Code Requirements for Masonry Structures* except that compressive stresses or strengths are reduced based on the reduction in masonry compressive strength. Analysis must consider axial and flexural tension and compression, as well as global over-turning. The bracing engineer must know the unit size and properties, unit weight, net area unit compressive strength, and mortar type and placement, and especially the reinforcement bar size and spacing to be used in construction. If the reinforcement shown in the design documents proves insufficient for a cantilevered wall condition, consider increasing reinforcement size and/or decreasing reinforcement spacing. Reinforced masonry walls have been internally braced for heights in excess of sixty feet, and design engineers are often open to modifying bar sizes, spacing and even foundation dowel lengths.

Foundation and Soils

Foundation analysis and, more specifically, soil capacity analysis can significantly impact the ability to use Internal Bracing. Recognizing that the demand placed on foundations is short term, only during the braced period, allows a more generous foundation evaluation: higher bearing pressures and minor potential rotation are acceptable because property protection is not the primary goal of a bracing scheme. Higher allowable bearing pressures should be utilized, and consideration be given to passive and active pressure for providing resistance to sliding and rotation. Safety factors on bearing pressure are often in the range of 3.0 to 4.0 or higher, so the ultimate bearing capacity of the soil provides much higher capacity for short term loads. A common approach for bracing foundation evaluation is to take the reported allowable bearing capacity, multiply it by 3.0 and then factor it down by some smaller reduction factor, such as 25%, to obtain the design pressure.

Internal Bracing Analysis

Initial Period Analysis

During the Initial Period, the mortar, and grout where applicable, has not gained sufficient strength to resist load. Walls have only their self-weight available to resist overturning and flexure. As noted above, masonry walls are not considered to be braced during the Initial Period. Therefore, there isn't bracing engineering to be done – but there are limits that must be met. The *Standard* contains two provisions: Evacuate the Restricted Zone whenever the wind speed exceeds 20 miles per hour, and the height of masonry above the base or highest line of support shall not exceed that shown in tables in the *Standard*. A bracing plan should incorporate height limits for all new masonry based on the Initial Period requirements.

Intermediate Period Analysis

Advantages of internally braced masonry walls become apparent during the intermediate period. Masonry walls can spend a significant amount of time in the Intermediate Period, depending on when diaphragms and the final lateral system are fully implemented. It's a good thing that masonry begins gaining strength early, often providing its own support for resisting short term loads even as the construction is on-going. During the Intermediate Period, the Restricted Zone must be evacuated when the wind speed exceeds 35 miles per hour. That evacuation wind speed, coupled with a design wind speed of 40 miles per hour, provides a time and load buffer to facilitate evacuation.

The primary focus of Internal Bracing is bracing to resist wind load during the Intermediate Period. Reinforced masonry analysis for Internal Bracing design can be

Standard and Guide

The article mentions two documents specific to masonry bracing – the *Standard Practice for Bracing Masonry Walls Under Construction* (*Standard*) and the *Internal Bracing Design Guide for Masonry Walls Under Construction* (*Internal Bracing Guide*).

The *Standard* is an industry standard prepared by masonry professionals under the voluntary umbrella group called the Council for Masonry Wall Bracing. While not a building code, it is referenced in the current edition of the MSJC and has been used to meet OSHA mandated bracing requirements. As masonry is often site-built, at the time of construction the strength of masonry most likely will be below that assumed while it is in service. So, from a practical point of view, it is impossible to prevent walls under construction from blowing down under some circumstances. (Note that in most cases, the loads imposed during construction are also likely to be less than service loads.) As a result, the *Standard* is intended to permit masonry construction to continue during low wind speed conditions, but requiring workers to evacuate designated areas of the job under high wind conditions.

achieved through hand calculations, and spreadsheets or software solutions. Most software packages allow the masonry net area compressive strength to be set by the user so the appropriate value can be entered for the Intermediate Period. Because the steel can be fully developed once the grout has cured for 12 to 24 hours, no change is needed for the tension portion of the analysis. The *Internal Bracing Guide* provides detailed examples.

Internal bracing design philosophy is based on the masonry code and basic principles of mechanics, so bracing design should start with the reinforcement denoted in the construction drawings. Basic masonry analysis equations found in masonry design texts, such as The *Masonry Designer's Guide*, can be used with the modified design values from the *Standard*. For example, allowable stress analysis can be conducted using Equation 9.4-11, $f_b = (2*M)/(jkbd^2)$, for when masonry compression controls, and Equation 9.4-12, $f_s = M / (A_s jd)$, for when tension in the reinforcement controls. Those equations can be re-arranged to solve for moment capacity within the wall, while substituting the proper f'_i for f_b and the proper elastic modulus for the intermediate period masonry. Those limiting equations become, respectively: $M \le f'_i * (jkbd^2)/2$ and $M \le f_s A_s jd$. With a little work to find k and j, the analysis can be easily completed. Iteration would be required if different masonry strengths or bar size/spacing values are found to be necessary.

Written Summary

- All base assumptions and conditions such as:
- Material properties
  - Unit strength
  - Resulting f'm and the related f'i
  - Unit size and density
  - Reinforcement and grouting
  - Mortar type and placement
- Required dowel and lap lengths
- Grout pour and lift heights
- Masonry construction sequence
- Restricted zone summary and sequence
- Foundation size and reinforcement confirmation or modification
- Soils criteria

Graphic Representation

- Plan view of all masonry walls to be braced
- Graphic representation of the Restricted Zone including:
  - dimensions
  - wall signage location
  - ground signage location
- Control joint location
- Intersecting walls and corners used as buttresses
- Changes to the occupancy design drawings that were accepted
- Consider elevation views for showing bar placement and lap locations
- Consider sections and details for showing specific requirements

Figure 2. Bracing plan content. Courtesy of IMI – Internal Bracing Guide.

Option to Eliminate Restricted Zones

Eliminating the Restricted Zones can be done but requires the use of design level wind speeds and higher lateral pressures. More significant masonry reinforcement and foundations typically result and their cost must be considered when evaluating bracing concepts.

Deliverables: Internal Bracing Plan

Once an Internal Bracing scheme has been evaluated and designed, it is important to properly and fully represent that design through verbal and graphic documentation. Such documentation provides the field staff with explicit information regarding sequencing of construction and Restricted Zones, as well as foundation, masonry and reinforcement requirements. Those same documents also provide opportunities for review by the prime contractor and designer of record. The bracing documentation also provides supplemental information for Special Inspectors to use as the basis for their inspections.

Figure 4. Masonry walls under construction utilizing internal bracing. Courtesy of Koch Masonry, Dexter, Michigan and IMI – Internal Bracing Guide.

Written Content

One key element of an Internal Bracing plan is the written portion, which provides the base assumptions and requirements represented graphically in drawings or, for simple projects, may provide the entire bracing plan. The content should include material properties, foundation and soils criteria, masonry construction sequencing and any assumptions relative to surrounding construction or site sequencing that were utilized in the bracing design.

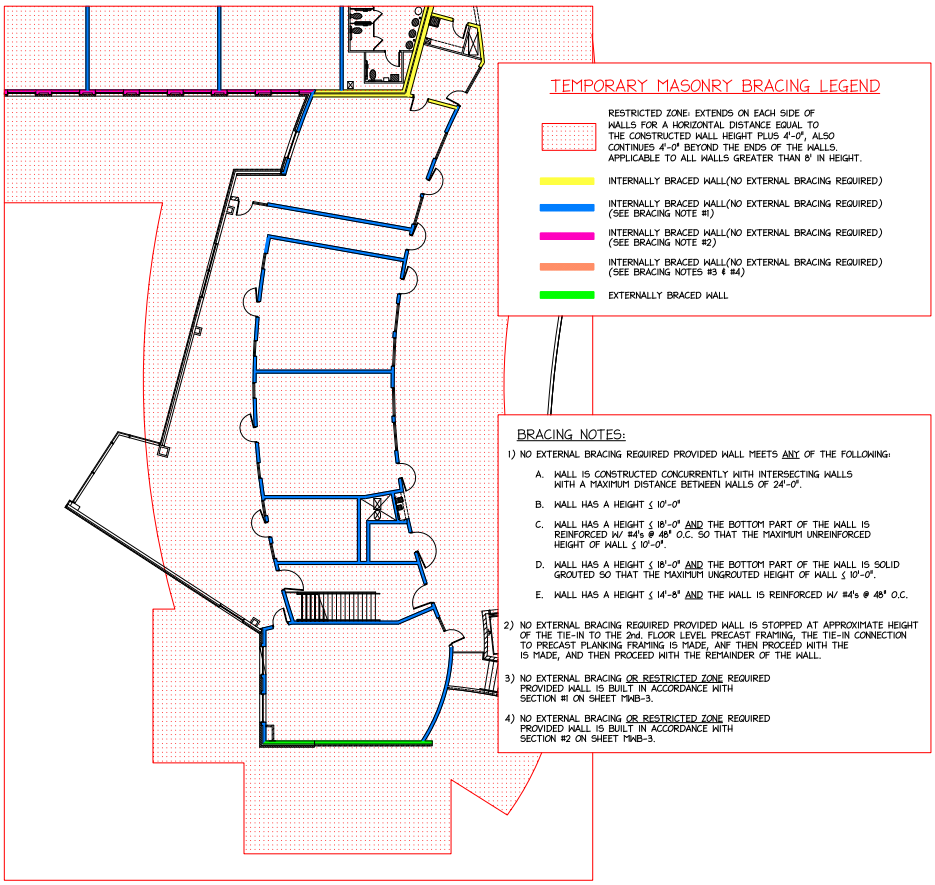

Figure 3. Sample bracing plan graphics, notes and legend. Courtesy of Dailey Engineering, Onsted, MI and IMI – Internal Bracing Guide.

Figure 5. School under construction. Courtesy of Rudolph/Libbie Inc., Walbridge, OH.

Graphic Content

The other portion of a bracing plan is the graphic content. For Internal Bracing this may simply be the foundation, and possibly framing plans, showing the walls and identifying the Restricted Zone. The plan(s) should include basic dimensions, notes regarding sequencing of the masonry construction and Restricted Zone implementation. Additional content could include ground and wall sign locations, control joints and walls used to buttress horizontal spans. Elevations, sections, and details can also be used to show important information, especially with regard to areas around openings and other points of discontinuity in the masonry. Proposed and accepted changes to the construction drawings also must be clearly represented in the bracing plan. Suggested bracing plan content is shown in *Figure 2* and sample graphics, notes and a legend are shown in *Figure 3*, to illustrate some of the requisite items as utilized for this particular project.

Conclusion

Masonry walls must be braced while they are under construction to provide safety to construction workers and other persons that may occupy the space adjacent to those walls. The *Standard* provides the engineering basis for analyzing bracing methods for masonry walls under construction, and the *Internal Bracing Guide* offers more detailed instruction on designing internal bracing. Internal bracing utilizes the strength provided by the wall as it is being constructed, without relying on external components. Cooperation with, and collaboration between, bracing design engineers, mason contractors and controlling contractors or construction managers are critical, and can yield highly efficient Internal Bracing schemes with significant benefit to projects in terms of safety, schedule and cost.

Figures 4 and *5* show two projects that utilize internal bracing. What is striking is the absence of external bracing on both projects. *Figure 5* shows a well-organized construction site that can lead to greatly improve site safety.

The *Internal Bracing Guide* is a document developed by IMI for engineers and other qualified persons designing masonry internal bracing systems. It outlines the process and illustrates the application of engineering principles for bracing using the wall's inherent strength rather than external elements, i.e. internal bracing. The *Internal Bracing Guide* applies the content of the *Standard* and other documents, along with knowledge gained through experience, to provide users with one approach to designing internally braced masonry walls.▪

References

Standard Practice for Bracing Masonry Walls Under Construction, Mason Contractors Association of America, 2012. The Standard is available for purchase at **www.masoncontractors.org**

Internal Bracing Design Guide for Masonry Walls Under Construction, International Masonry Institute, 2013. The Internal Bracing Guide is available as a free download at **www.imiweb.org**

Masonry Designers' Guide, Sixth Edition, The Masonry Society, 2010 The Designers' Guide is available for purchase at **www.masonrysociety.org**