MASONRY INSIGHTS

Reinforcing Existing Masonry For New Lateral Loads - Part 1

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Masonry walls are quite versatile in building applications and are common industry wide. What happens, though, when a building retrofit or expansion requires an existing masonry wall to now become a shear wall or for an existing shear wall to now resist more load than its current capacity? This masonry insight will discuss design considerations and options for reinforcement of existing masonry walls to resist lateral forces for wind or seismic loading. This article will focus on in-plane shear and flexural strength increase to existing masonry walls. Part 2 of this article series will focus on code requirements, sliding, overturning resistance, and external reinforcement when increasing shear load demand onto existing walls.

Masonry Shear Walls

When designing masonry shear walls, it is important to review the existing masonry properties, code requirements, and the four main shear wall mechanics which include in-plane shear strength, in-plane flexural strength, overturning resistance, and sliding resistance. The following sections will describe the effects of each portion of the design as well as items to consider when retrofitting an existing masonry wall for increased loads.

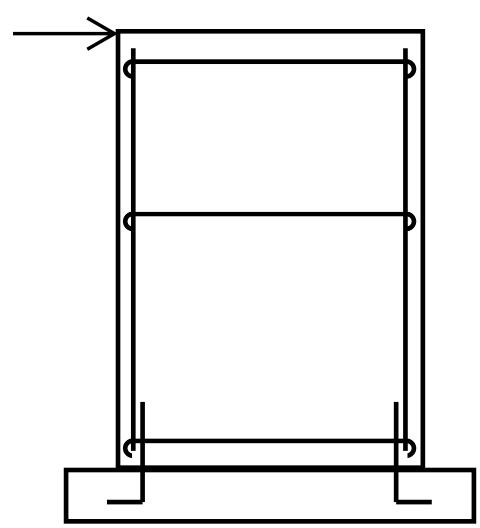
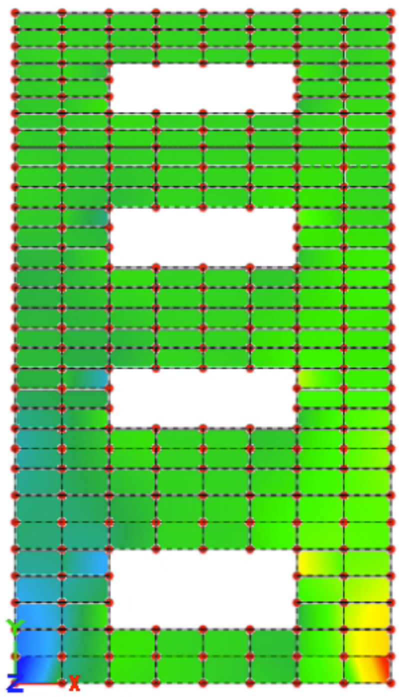


Figure 1: Shear Wall Elevation

Masonry Properties:

Shear and flexural masonry strength is dependent on the specified compressive strength (f'm) of the existing masonry assembly. The value of f'm, in turn, is dependent on the combination of the net compressive strength of the masonry units and the mortar type. The compressive strength of the grout, f'c, in any reinforced cells should also be



considered in case this strength governs f'm. The first place to look for this information is on any existing documentation for the building such as the structural drawings or the project specification. If the design f'm is shown on contract documents, there is a tendency for that value to be conservative as it may not take advantage of the full masonry assembly strength.

If the original design strength information is not available or found not adequate for the new load conditions, sampling and testing of the in-place assembly may be helpful. In this case, a portion of the existing masonry is removed and sent to a laboratory for analysis. This field sample must be removed and shipped properly per the direction of ASTM C1532 as the process of selecting, removing, and shipping the field sample can have an effect on the laboratory results. It may take a considerable amount of time to receive the testing results so it may be prudent to make a preliminary estimate of the assembly strength through the unit strength method described in TMS-402/602 “Building Code Requirements and Specification for Masonry Structures.” The estimate would be based on the likely unit strength, mortar type, and grout strength that is in the existing building. Preliminary design and detailing requirements based on this assembly strength estimate can provide information to determine approximate construction costs. Once the laboratory test results are available with a more accurate f’m value for the masonry assembly, the retrofit design and details can be refined to minimize the amount of work required and associated costs.

Two more pieces of information will be necessary when reviewing the existing building for increased lateral loading. The allowable bearing pressure of the soil beneath the shear walls and the coefficient of friction between the foundation and the soil will play a role in the final design. The allowable bearing pressure is typically noted in the existing building design documents. If it is not available, then the value must be determined either through testing by the geotechnical engineer or a conservative assumption must be made based on IBC prescriptive values. The coefficient of friction may be available in the existing documentation but is less common and conservative values may meed to be assumed based on the soil type present.

The existing masonry elements may also have existing reinforcement depending on the age of construction, element type (beam, pilaster, wall, etc), and the stress level due to the loading. For buildings constructed prior to 1970, it is recommended to assume reinforcement to be of grade 40 steel with more recent construction often having grade 60 rebar. Possible reinforcement includes vertical rebar within the masonry unit cells, horizontal bond or lintel beams, and/or horizontal joint reinforcement. Existing project drawings or specifications may be available to provide some of the information necessary but they will generally only provide bar size and spacings rather than the exact locations of reinforcement. Secondly, there is no guarantee that the as-built condition matches the drawings exactly, thus, it may be necessary to employ one or more of the many methods available to determine the existing reinforcement within the wall. The easiest check is by sounding (or tapping) the faceshells to determine which cores are hollow and which are filled with grout. This sounding test will only demonstrate which parts of the wall do not have reinforcement as the existence of grout does not confirm the presence or size of rebar. Another common test is GPRS (Ground Penetrating Radar System). GPRS can determine the locations of rebar as well as the likely size and depth of the reinforcement. Interpreting the output of the GPRS system can be a bit of an art form for the technicians to master so it is best to understand that bar size and depth information from the test results are more of an approximation. If more exact information is required, then destructive testing may be necessary to determine the exact bar size, depth, and grade. Of course destructive testing always has the possibility of adversely damaging the existing structure should rebar be cut or nicked in the process. After the completion of the testing, the test areas can be patched with grout or concrete.

<u>In-Plane Shear Strength</u>

The primary function of a masonry shear wall is to transfer the lateral shear loads from the building diaphragms to the foundations. When the lateral load exceeds the masonry shear capacity, horizontal shear reinforcement must be added and designed to carry the entire shear force without considering any contribution from the masonry. The amount of shear reinforcement necessary by calculation must also be compared to the minimum code requirements referred to above.

While horizontal reinforcing, or "reinforcing placed parallel to the shear load," is the element resisting the in-plane shear force, this horizontal reinforcing must often be accompanied by a minimum amount of vertical reinforcing to resist in-plane flexure due to shear and to meet any minimum code reinforcement requirements. The installation of vertical reinforcing, if necessary, is described in the next section discussing flexural design.

Figure 2: Temporary Needle Shoring
Source: Superior Scaffold Services

Installation of horizontal reinforcement into an existing masonry wall can be difficult. First, horizontal cuts are likely needed to remove the face shell. Temporary bracing and/or temporary needle shoring may be necessary to support gravity loads bearing on the wall while the retrofit work is performed. If the existing wall does not contain vertical reinforcement, the faceshells and interior webs can be removed with horizontal saw cuts. Intermittent cutting may be desired to reduce shoring requirements. Needle shoring is often used when cutting new openings in existing masonry walls, but can also be used when making horizontal cuts to support existing gravity loads during installation of horizontal reinforcement and grout (See Figure 2). Horizontal rebar can then be

Figure 2: Sawcut existing masonry core and insert vertical rebar. Grout flush to adjacent faceshells. (Note: grout filling at the installation of horizontal rebar will be similar) Source: IMI Masonry Detail Series

installed as needed. Each location with reinforcement will require grout to fully fill the masonry course that is filled flush with the faceshell, similar to the vertical cuts shown in Figure 3. Since the vertical masonry cores are open below, common construction practice is to place mesh netting, insulation, or other materials below this course to prevent grout from filling those cores below unless full height wall grouting is required by the design.

If the existing masonry wall contains vertical reinforcement, the minimum clear cover and spacing of both the new horizontal reinforcement and existing vertical reinforcement must be reviewed for compatibility with code requirements. If adequate space exists for new reinforcement, installation is the same as described above with the exception that extreme care must be taken to avoid cutting or nicking any existing reinforcement bars.

<u>In-Plane Flexural Strength</u>

A shear wall must also have adequate strength to resist the flexure due to the tension and compression force couple that develops between the element delivering the lateral load and the foundation or supporting floor. To resist the moment, the shear wall must serve as a vertical cantilever beam. To achieve this flexural strength, it is common to consider "boundary elements" at the ends of the shear walls to resist the tension and compression force couple due to shear. Vertical reinforcement located within the core(s) at each end of the wall, i.e. the boundary elements, are positioned to resist the resulting tensile forces. Whether or not the existing masonry wall was designed as a shear wall, it may still contain vertical reinforcement serving as boundary elements at each end of the wall. If the existing amount of boundary reinforcement is inadequate, more reinforcement can be added in adjacent cells with the following considerations. First, all new reinforcement must be anchored to the foundation to properly transfer the tension force within the shear wall. Depending on the depth of the foundation, anchoring the rebar can be difficult due to minimal access within the masonry core and the depth of footing/foundation wall below grade or floor level. Options for attaching to the foundation include epoxy grouting the rebar into predrilled holes or welding rebar to steel plates that are mechanically fastened to the foundation (ASTM A706 rebar must be used when welding rebar). Second, as reinforcement is added to more cores adjacent to the end of wall, the design flexural depth "d" will shorten since it is measured to the centroid of the reinforcement group. This design depth "d" must be considered in the design of new flexural reinforcement.

Installing reinforcement into an existing vertical core is similar to the process noted above for horizontal reinforcement. Shoring for vertical loading may not be required if the wall to slab/beam connection is not damaged, and the unreinforced cell is adequate to support loading during construction. Vertical saw cuts to remove the faceshell should be minimally disruptive for the case when the existing masonry wall does not contain horizontal bond beams. Vertical rebar can be installed with one bar in the center of each core followed by grouting the core solid (see Figure 3). Note that it is recommended to only add one new bar centered in each existing empty core. Since the space within the core is small and difficult to access, it is extremely difficult to install more than one bar in a core and still ensure adequate spacing between bars clearance to the edge of the core, and proper grout placement. If the space around each bar is inadequate, the grout may not fully fill the core when placed thus resulting in air pockets called "voids" that could reduce the strength of the wall. This can be a problem particularly at the reinforcement splice locations since there will be twice as many bars.

For the case when existing horizontal bond beams are present, more delicate hand work is required to chip away the bond beam grout to expose the horizontal reinforcing at these locations and make room for the vertical rebar. If there are two horizontal bars located away from the center of the wall, the new vertical rebar must be threaded between. However, if the existing rebar is in the middle of the wall, the new vertical rebar must pass by the side of the existing horizontal reinforcement provided there is adequate cover available.

Concluding Thoughts

Shear wall design has many components to consider which can quickly become complex when an existing shear wall needs to be strengthened for increased lateral loads. Many of the typical internal reinforcement methods are feasible and work well but can require a significant amount of construction labor depending on the extent of retrofit work required. The subsequent article in this series will look closer at additional limit states to consider and explore external reinforcement options.