MASONRY INSIGHTS

Reinforcing Existing Masonry For New Lateral Loads

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.

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.

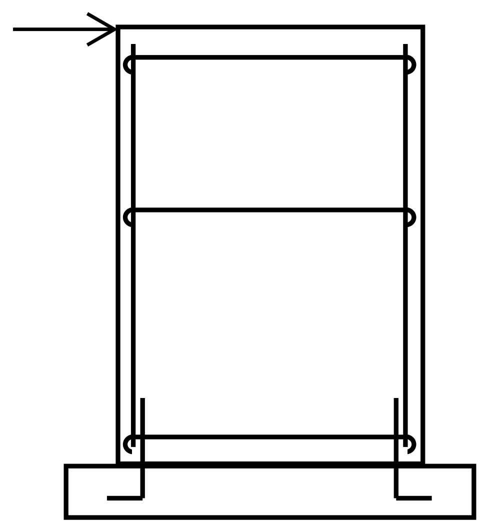

Figure 1: Shear Wall Elevation

<u>Masonry Properties:</u>

The 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, the mortar type, and the compressive strength of the grout within the masonry assembly. The first place to look is on any existing documents for the building such as the structural drawings or the specification. If the original design f'm is available, there is a tendency for that value to be conservative as it may not take advantage of the full masonry assembly strength. If this information is not available, the next option to ascertain the assembly compressive strength is with the prism test method per ASTM C1314 conducted on test prisms sampled from the existing masonry in the field The prism test method will provide an accurate f'm value for the masonry so even if the strength of the existing masonry assembly is known, it may be prudent to perform the prism test to achieve a higher f'm when reviewing walls for increased lateral loading. In general, the prism test would likely minimize the amount of retrofit work required and in some cases could allow enough capacity within the existing shear wall to eliminate the need for any retrofit work.

Code Requirements:

Masonry shear walls must resist lateral loads due to wind or seismic events based on geographic building location per the applicable building code. Depending on the magnitude of the load, shearwalls may or may not require reinforcing. However, when the building is located in areas of low seismic design categories, minimum vertical and horizontal wall reinforcement may still be required even if the shear wall is classified and designed as unreinforced. Higher seismic areas will require even more minimum reinforcement depending on the shear wall classification as laid out in TMS 402. For the case of typical running bond masonry, the minimum horizontal reinforcement in some cases can be met with two W1.7 joint reinforcement bars at 16" on center vertically. Other cases require horizontal reinforcing bars of at least 0.2 in^2 at a vertical spacing between 120" and 48" on center. Additionally, a minimum amount of vertical reinforcement may be required also consisting of at least 0.2 in^2 at a horizontal spacing between 120" and 48" on center. Field installation of reinforcement for existing masonry retrofit situations will be discussed below.

In-Plane Shear Strength

The main 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 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.

Figure 2: Sawcut vertical rebar in existing masonry core from IMI Masonry Detail Series http://imiweb.org/masonry-detailing-series/

Installation of horizontal reinforcement into an existing masonry wall can be difficult depending on the existing conditions. First, verify gravity loading conditions and determine if temporary shoring is required for point loads or if needle shoring is required to support the upper portions of the wall while the retrofit work is performed. If the existing wall does not contain vertical reinforcement, then the faceshells and interior webs could be removed with horizontal saw cuts(intermittent cutting may be desired to lessen shoring requirements). Then horizontal rebar can be installed as needed. Each location with reinforcement will require grout to fully fill the masonry course that it is placed within including the faceshell. 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 wall grouting is required by the design.

If the existing masonry wall contains existing 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 not cut through 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 force couple that develops between the element delivering the lateral load and the foundation. To resist the moment, the shear wall must serve as a vertical cantilever beam. To achieve this flexural strength, vertical reinforcement located within the core(s) at each end of the wall resists the flexural tension. Whether or not the existing masonry wall is a shear wall, it may contain vertical reinforcement serving as a "boundary elements" at each end of the wall. Existing boundary reinforcement may or may not provide adequate flexural strengthIf the existing amount of 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. Second, as reinforcement is added to more cores at the end of the wall, the reinforcement depth "d" will shorten since it is measured to the centroid of the reinforcement group.

Installing reinforcement into an existing vertical core is similar to the process noted above for horizontal reinforcement except that shoring for vertical loading is not likely to be required. 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 2). 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, it is extremely difficult to install more than one bar in a core and still ensure adequate spacing between bars and between each bar and the edge of the core. If the space around each bar is inadequate, the grout may not fully fill the core when placed resulting in air pockets called "voids" which 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 horizontal bond beams are present, more delicate hand work is required at these locations to make room for the vertical rebar to pass by the side of the existing horizontal reinforcement (provided there is adequate cover available) or between if there are two existing horizontal bars that are located away from the center of the masonry unit.

Overturning and Sliding Resistance

Once there is adequate resistance for the internal shear wall forces, soil bearing capacity and global engineering principles need to be reviewed as well. In an existing shear wall scenario, additional shear in the wall also means additional overturning moment with two implications. First, sufficient dead load must be present to prevent the shear wall from turning over including a typical safety factor of 1.5. The resisting dead load includes the weight of the wall itself, tributary roof weight, tributary weight of floors above, the weight of the foundation plus the weight of the soil that is above the foundation. Second, the maximum bearing pressure under the foundation needs to be compared with the allowable bearing capacity of the soil (typically provided in the geotechnical report). If the soil bearing pressure is exceeded, the supporting footing size will need to increase. This requires partial excavation of the footing for access to pour new foundations and attachment to the existing foundation. If additional overturning resistance is required, dead load resistance can be added in a variety of ways.Adding on to the foundation to capture more soil dead load is an option, however, this requires significant field work. Sometimes first reviewing the existing wall layout may reveal adjacent masonry walls that can be tied to for additional weight. Another option is to fully grout all cores within the shear wall. The extra grout weight may be resolve overturning but this extra weight must not exceed the allowable soil bearing capacity under the foundation.

Finally, a sliding resistance check must also be made. Based on the friction coefficient between the foundation and the soil, adequate weight from all building dead load tributary to the shear wall must be present to prevent sliding. To increase sliding resistance, the wall footing size can be increased. In addition, a shear key can be provided at the base of the wall footing to provide adequate sliding resistance. Another option is to attach adjacent building components to the wall, such as the adjacent slab on grade to increase dead load until the required sliding resistance is met.

Alternative Reinforcement Options

Traditionally, shear wall reinforcement is located inside of the masonry cores, however, there are some external reinforcement options available that could produce more capacity or be more cost effective for building retrofits. Research has been conducted on using fiber reinforcing polymers (FRP) and through-bolted steel plates for strengthening masonry shear walls. Figure 3 shows examples of various exterior reinforcing patterns tested. Care must be taken to fully review the research for the full design implications of these methods.

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 when adding reinforcement in multiple directions and locations. It is best to carefully review all options available when determining the best path for increased shear wall capacity of existing structures, as typically the simplest option tends to be the most economical.

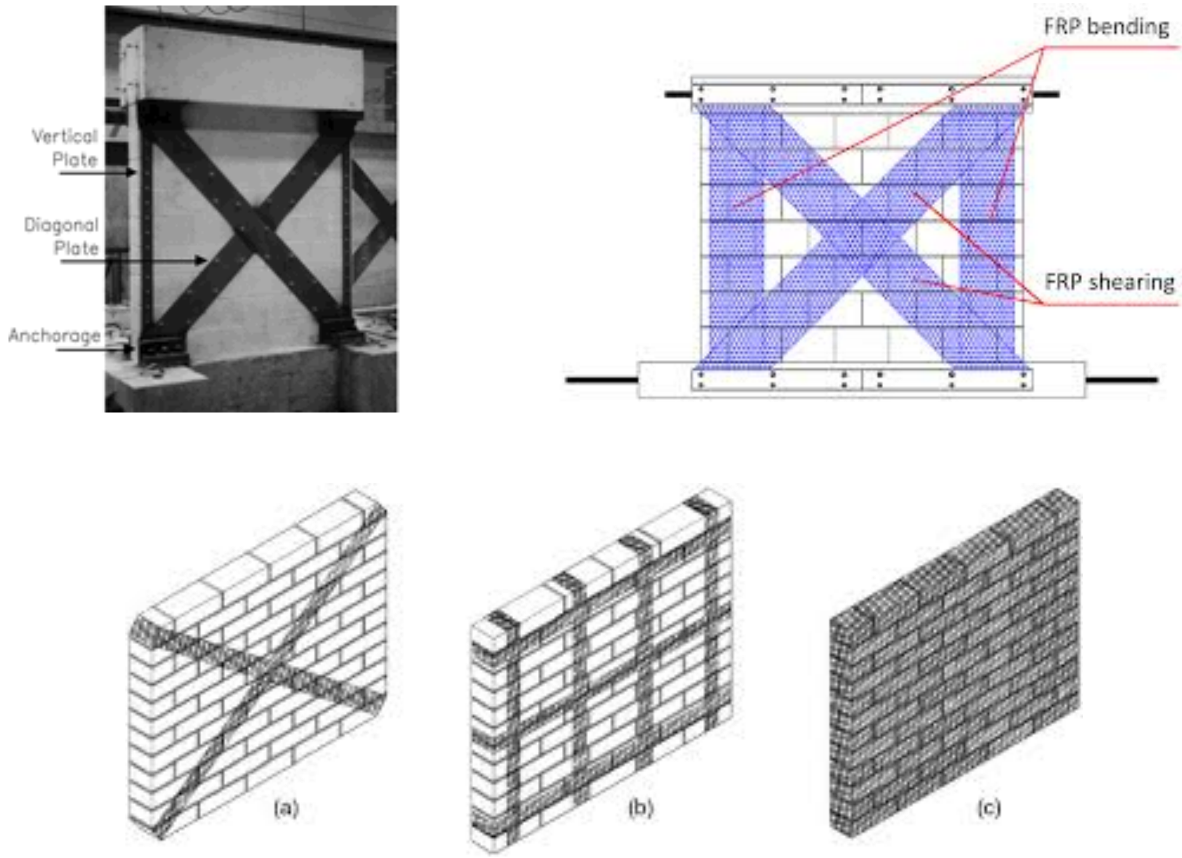

Figure 3: External CMU reinforcement options