MASONRY INSIGHTS

New Openings in Existing Masonry Walls

During building renovations, changes in floor plans often require windows or doors be installed at new locations in existing structural masonry walls. Care must be taken to support all applicable loads before, during, and after the wall opening is cut for removal of the existing masonry. Masonry has inherent advantages for small openings and some special considerations for large openings. This paper will highlight many design considerations and provide some options for reinforcement.

Design Procedure

Before performing any calculations, the best place to start is with the design requirements for the opening and a review of all existing conditions. Initial questions to consider include: 1) What size is the rough opening? 2)Does the opening fit to even modular dimensions allowing saw cutting to occur at mortar joints? 3)Is the existing wall an exterior or interior wall? 4) Will added reinforcement framing around the opening be visible? 5) What is the aesthetic that is needed architecturally in the adjacent space? Following is a discussion to address these issues as part of the structural design and detailing.

Figure 1: Needle Shoring at New Masonry Opening

The next step is to review the existing structural conditions such as the distance to the existing movement joints and the loads tributary to the new lintel and jambs. It is important to consider how much access there is for the contractor as well as possible ways for the contractor to shore the existing masonry, install new framing, and cut the opening. How the work in the field is accomplished falls under the category of means and methods for the contractor to determine, however, the engineer must at least consider if the framing revisions are possible to install for the given situation.

Once all of the design requirements and limitations are known, a logical next step is to start with the lintel design for support of the gravity loads from above the opening. The first item to verify is whether arching action is possible based on the amount of available space above the opening and how close the opening is to the nearest masonry movement joint or end of wall. Arching action is important because it allows the masonry above the opening to transfer the gravity loads to the jambs as if there were an arch

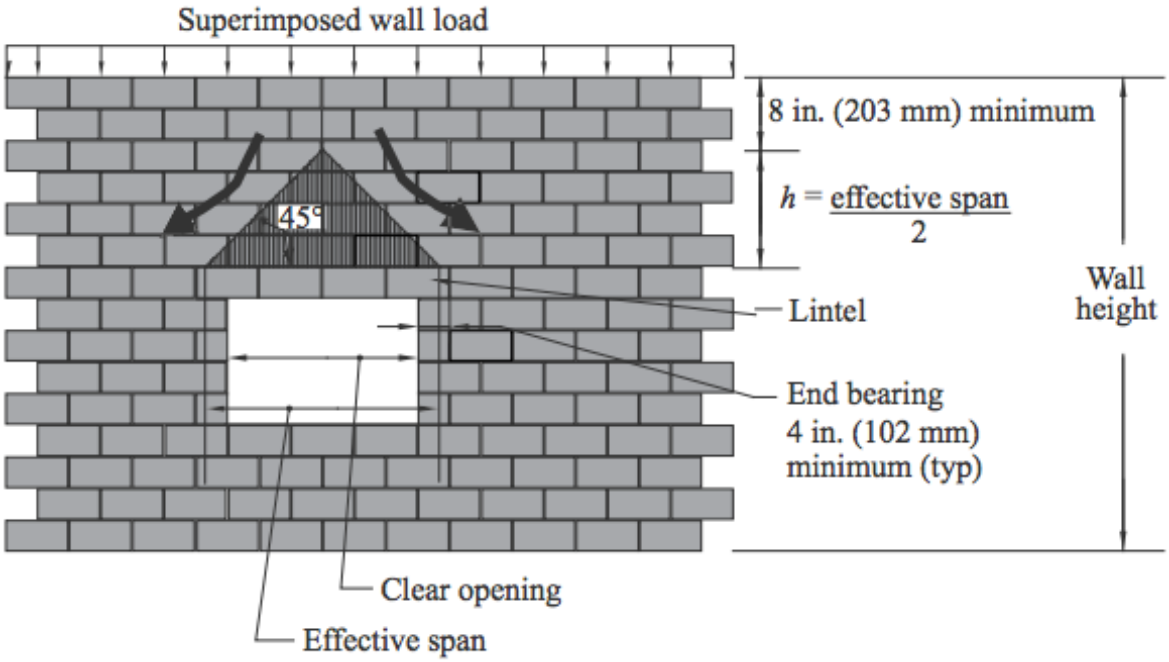

Figure 2: Illustration of Lintel Loading with Arching Action
Reference: NCMA TEK 17-1D (2011)

over the opening. To test for arching action, draw lines extending upward at 45 degrees from each lintel end (see figure 2) and see if there is at least 8" between the apex of the triangle that is formed and the location of the loads on the wall. If yes, then the lintel only needs to be designed for the dead load of the wall material within the triangle as long as there is adequate jamb width to resist the horizontal thrust forces that develop. Without arching action, the lintel will need to be designed for all gravity loads above the opening. The difference in the two loading patterns can result in a large difference in the size of the lintel required. In some cases when adding a new opening, lintel reinforcement may not be necessary.

The next design step is to design the jambs on each side of the opening. The load on the jambs will be a combination of gravity and out-of-plane wind or seismic loadings. Depending on the size of the new opening and the proximity of the existing masonry vertical reinforcement, new jamb reinforcement may or may not be required.

The final step in the design process is to review the existing foundations to see if they have adequate capacity to support the newly concentrated gravity loads under the jambs. Even though the load is concentrated on the small area of the jamb, the load will distribute through the masonry outward each direction below the opening. The tributary foundation area under the jamb can be determined using a combination of engineering judgement and the concentrated load provisions in the TMS-402 code. For the case of small openings, the load distribution on the foundation may be similar to the magnitude of the original load. However, larger openings will have more highly concentrated loads requiring a review of the foundation capacity.

Framing Options

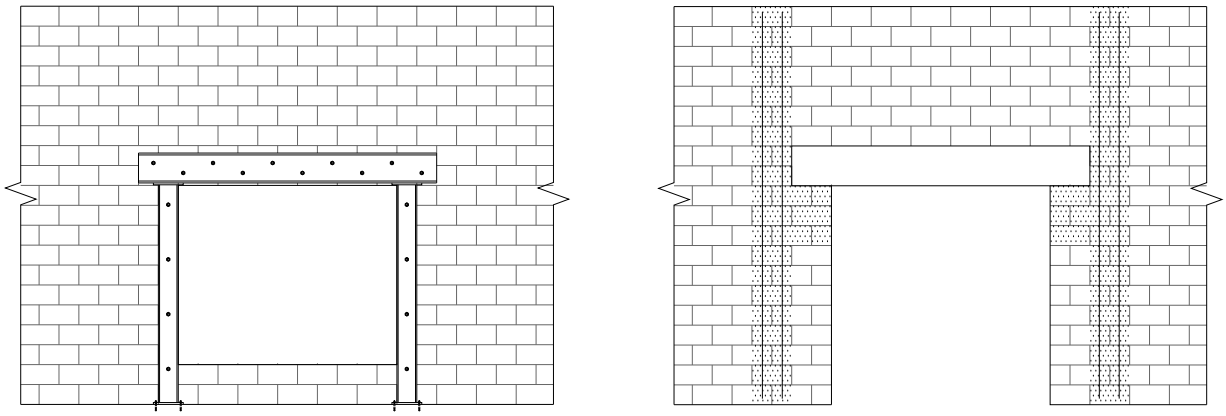

Figure 3: Elevation of Some Framing Options at New Masonry Openings
The left depicts a steel channel lintel bearing on vertical channels.
The right shows a precast concrete lintel with post installed full height jamb rebar.

Lintels:

Post-installed lintels consist of many different materials, sizes, and shapes. Steel is a common choice since it has a high modulus of elasticity to help with the restrictive deflection requirements of masonry (typically L/600). There are various shape options available including angles, channels, wide flanges, or HSS tubes. Additionally, there are many configurations of steel lintels that can be installed prior to cutting the new opening thus avoiding the need to shore the existing masonry. However, due to exterior thermal conditions, steel must be considered carefully as it has a different coefficient of thermal expansion from the masonry which can lead to cracking issues around the opening if the differential movement is restrained too much. Another common option is a precast concrete beam which more closely matches the expansion coefficient of the masonry but will typically require shoring during installation.

Shoring of the masonry above the opening must be considered when choosing the lintel type. Compare, for instance, the two framing options presented in figure 3. The precast beam requires being in line with the wall to support the load above, but how can the beam be installed to support the wall if part of the wall needs to be removed first for the beam to be installed? This is where needle shoring (see figure 1) is required. To support the existing masonry above where the new opening will be, a series of small holes will be cut in the existing wall to insert temporary beams perpendicular to the wall. The spacing of the holes must be close enough to ensure arching action occurs between each

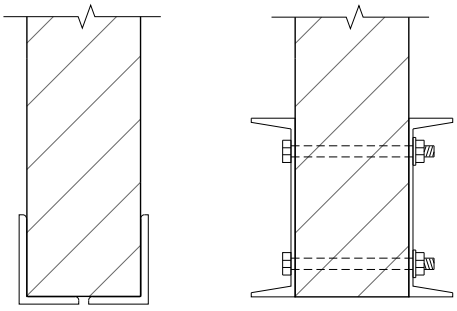

Figure 4: Some Steel Lintel Options that can be installed without shoring.

shoring beam. With the shoring in place, the opening can be cut out and removed as necessary for installation of the lintel. Once the beam is in place, the shoring can be removed and the masonry can be patched. An alternative lintel option is to use two channels (one each side of the wall - see figure 4) when there is access to both sides of the wall and the architectural design can accommodate the steel extending outward from the wall. The steel channels can be installed with closely spaced through bolts prior to cutting the opening. The channels will be ready to support the existing masonry loads as soon as the opening is cut thus eliminating the need for shoring. The down side to the channel option is that it can be difficult during installation for the holes of the through bolts to align on each side of the wall. Additionally, the transfer of load from the wall to the channels occurs through bearing on the bolts which can be limiting and likely require the addition of grout to increase the bearing area. Another option to avoid shoring is a pair of steel angles (see figure 4). To install the angles, a horizontal mortar joint could be removed from one side of the masonry so that the horizontal leg of the angle can slide into the joint space. The process can then be repeated on the opposite side of the wall and afterwards the opening can then be cut and removed.

Jambs:

The jambs on each side of the opening perform two structural functions. First, jambs provide support for the gravity reaction load at the ends of the lintel. Second, the jamb resists the out-of-plane load from the wind and seismic loads acting on the door/window, the masonry above the opening, and the jamb itself. The type of jamb chosen will depend on the magnitude of the loads and the lintel type previously chosen. Options for jambs include installing rebar and grout inside of the empty masonry cores adjacent to the opening (see figure 5) or steel shapes such as channels or HSS tubes placed against the masonry faceshell attached with post-installed anchors (see figure 6). Sometimes a combination of systems will be specified as it is possible for the masonry to have adequate capacity for the vertical load but require external steel to resist the out-of-plane loads.

Figure 5: Faceshell removed to install rebar and grout
Reference: www.imiweb.org
Masonry Detailing Series

Gravity Load Reinforcement

When the masonry supports the gravity load from a lintel located within the wall, the typical minimum bearing length of the lintel on the masonry is 8 inches. To help distribute the concentrated bearing load from the beam into all of the masonry faceshells and webs, grout is added under the bearing point for a height of at least 24 inches. The load distributes further into the jamb along the wall outward from the opening per the concentrated load provisions in the TMS-402 code.

When external steel lintels are used, the jamb support must be reviewed carefully. If the load magnitude is low, it can be possible to transfer the load into the masonry with through bolts. However, when the load is

large, an external steel jamb may be required for direct bearing (see figure 3). If the masonry has adequate capacity for the out-of-plane jamb forces, the external steel jamb would only need to extend from the bottom of the lintel down to the location of support below. When the steel needs to provide out-of-plane resistance as well, the jamb would need to extend the full height of the wall and support the lintel through a side weld or a side bearing connection. The gravity load then needs to transfer to the soil below either through a base plate at the slab or the jamb would have to extend down to the foundation depending on the soil and foundation conditions.

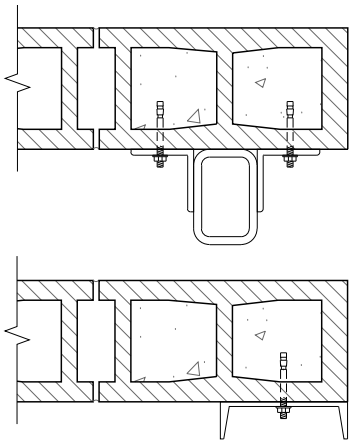

Figure 6: Some Steel Jamb Options

Out-of-Plane Load Reinforcement

For the case of a small new opening, the existing masonry may have adequate capacity to resist the out-of-plane loads on the wall. As openings become larger, there comes a point when the masonry will require additional reinforcement. A common option is to install vertical reinforcement in the empty masonry cores adjacent to the opening beyond the end of lintel bearing (see figure 3). The process involves saw cutting to remove the faceshells vertically along the entire wall height, installing vertical rebar in the center of each core, and grouting the core solid (see figure 5).

Sometimes the labor required for adding internal reinforcement can be high thus making the option for external reinforcement more economical. Common external reinforcement includes steel channels or tubes. Steel channels can be installed with the web flat against the masonry faceshell with either expansion bolts, through bolts, or epoxy grout anchors into the cores (see figure 6). HSS tubes will have higher out of plane strength and stiffness but will need additional steel elements, such as angles, for attachment to the masonry. These attachment angles do not need to be continuous and are commonly spaced at intervals between 24" and 48" on center. Depending on the loading requirements and capacity of the anchors, the masonry cores may need to be grouted first. The anchors typically need to be installed along the entire length of steel jamb to evenly distribute the load from the wall. The steel jamb needs to be designed for the out-of-plane flexure and deflection. As a final step, the connections at each end of the jamb must be designed to transfer the shear into the floor/roof diaphragm, slab on grade, or foundation.

Conclusion

Adding new openings to existing masonry is quite common, but it is a complex engineering task. Most of the work is in the planning stage: reviewing the architectural requirements, the existing conditions, and the design loads. Even though the contractor will determine the means and methods of construction, the engineer should consider site accessibility and constructibility when determining which reinforcement approach to design and detail. If a contractor has already been chosen at the time of design, collaboration between the contractor and engineer can produce economical design choices while allowing for a smooth design and construction process for the project.