

Lintels for Masonry Walls

The structural design of masonry lintels plays a crucial role in achieving a robust and efficient masonry wall system. Properly engineered lintels not only enhance the structural capacity but also mitigate crack formation and other serviceability issues. Historically, lintel design has often been oversimplified, which has undermined the potential benefits of masonry systems. This document presents a detailed comparison of masonry and steel lintels, examines arching action principles, and explores advanced design strategies to optimize lintel performance.

Comparison of Masonry vs. Steel Lintels

Recent trends show a growing preference for reinforced masonry lintels over traditional steel lintels due to several engineering, cost, and constructability considerations:

- 1. Reduction in Shoring Requirements:** Traditional thinking has favored steel lintels to minimize shoring needs during construction. However, advancements in construction techniques now allow for in-place construction of reinforced masonry lintels using innovative shoring methods, prefabricated masonry lintels (Figure 1), and precast concrete lintels that seamlessly integrate with masonry walls.
- 2. Serviceability and Durability Challenges with Steel Lintels:** Steel lintels often encounter differential movement due to the contrasting properties of steel and masonry. This leads to serviceability problems such as cracking. Additionally, steel lintels require detailing to accommodate sliding at one end, but rusting and binding the at bearing can restrict movement, causing distress at the support locations.
- 3. Cost and Construction Complexity:** The placement of necessary U-bar reinforcement around steel lintels as shown in Figure 2 adds complexity and cost but is essential to prevent cracking. Shifting vertical jamb reinforcement to accommodate the steel bearing increases the tributary width, necessitating a larger jamb section and additional grout (Figure 2).
- 4. Structural Integration with Masonry Lintels:** Masonry lintels offer a more cohesive structural solution by creating a monolithic connection with vertical jamb reinforcement, leading to greater load distribution efficiency and cost savings (Figure 3). Unlike steel lintels, masonry lintels can be designed with fixed-end conditions, allowing for negative moments to develop at supports, thus reducing the overall positive bending moments and improving load distribution.



Figure 1: Prefabricated Masonry Lintel

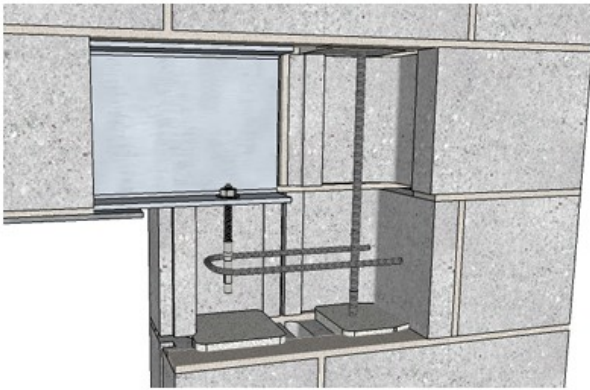


Figure 2: Steel lintel at bearing

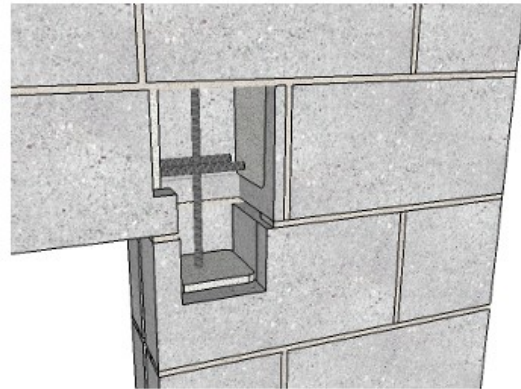


Figure 3: Masonry lintel intersection masonry jamb

- Arching Action in Masonry Lintels:** A significant advantage of masonry lintels is the ability to utilize arching action. When designed integrally with adjacent masonry, lintels can support loads by redistributing forces through the arch mechanism. This reduces the design loads significantly compared to steel lintels, which typically require control joints due to differential movement, thereby precluding arching action.

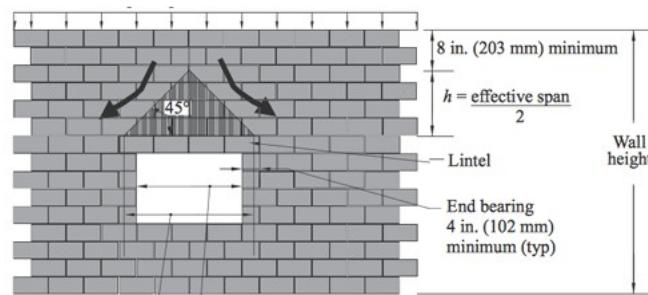


Figure 4: Arching Action Diagram from NCMA TEK

Design Criteria and Analysis

Lintel designs should adhere to stringent criteria to ensure performance. Masonry designs are typically based on an assumed compressive strength ($f'm$) of 2500 psi, using strength design principles. For fixed-end lintel analysis, finite element methods (e.g., RISA3D) can be employed to simulate real-world behavior and optimize the structural configuration. For masonry lintels without considering arching action, the required depth and reinforcement can be substantial; however, incorporating arching action in the analysis greatly reduces these requirements.

Tables 1 through 3 are provided for equivalent masonry and steel lintel comparisons, indicating the necessary lintel depths and reinforcement details for spans up to 12 feet. The tables illustrate cases with (Table 3) and without (Tables 1 and 2) the inclusion of arching action, highlighting the reduction in required masonry depth when arching action is utilized.

Table 1: 8" Masonry Wall Lintels, fixed ends, not considering arching action

length	8 feet ¹	12 feet ¹
to replace steel W8x10	16" deep (1) #4 top& bot	--
to replace steel W8x24	32" deep (1) #5 top& bot	16" deep (1) #6 top& bot
to replace steel W16x26	--	40" deep (1) #6 top& bot

Table 2: 12" Masonry Wall Lintels, fixed ends, not considering arching action

length	8 feet ¹	12 feet ¹
to replace steel W8x10	16" deep (1) #4 top& bot	--
to replace steel W8x24	24" deep (1) #5 top& bot	16" deep (1) #6 top& bot
to replace steel W16x26	--	32" deep (1) #7 top& bot

Table 3: Both 8" and 12" Masonry Wall Lintels, considering arching action

length	4 feet	8 feet	12 feet
to replace steel W8x10, steel W8x24, steel W16x26	8" deep, (1) #4 top& bot	8" deep, (1) #4 top& bot	16" deep, (1) #4 top& bot

Finite element analysis (FEA) allows for a more accurate assessment of masonry lintel behavior by considering the entire wall as a composite system. This approach leverages the integral construction of masonry to distribute loads more efficiently, closely mimicking the effects of arching action. When using FEA, masonry plate elements distribute forces based on the stiffness of the supporting elements, leading to a more precise and economical design compared to traditional beam-based methods.

High Strength Masonry Lintels

The design of masonry lintels can be enhanced for higher load-bearing capacities by incorporating additional solid grouted masonry courses, which significantly increase both shear and bending moment capacities. This is particularly beneficial in cases where high shear forces and positive bending moments exist, such as in large-span openings. Typically, bottom reinforcement alone is sufficient for positive moment resistance, but for lintels subjected to both positive and negative moments, the inclusion of top reinforcement becomes critical to ensuring structural stability.

When higher load demands must be met, the primary solution is to increase the overall height of the lintel by adding multiple courses. In most cases, this eliminates the need for stirrups, as the additional courses can efficiently resist shear forces. However, if vertical space is limited, shear reinforcement, such as stirrups, can be introduced as a secondary option. In this context, the use of single-leg stirrups for 8-inch walls and double-leg stirrups for thicker walls (greater than 12 inches) can be considered. Nevertheless, from a cost-efficiency perspective, increasing the lintel depth remains the most economical solution.

Multi-course masonry lintels, reinforced at both the top and bottom, can be either field-constructed or prefabricated. For instance, a three-course masonry lintel can be built with horizontal reinforcement placed in the first and third courses. This configuration typically utilizes a U-block bond beam unit at the bottom, a regular stretcher unit in the middle, and a flow-through unit at the top, facilitating continuous reinforcement placement.

Enhancing Masonry Lintel Capacity

To further improve the capacity and efficiency of masonry lintels, consider the following design strategies:

1. **Correct Specification of Masonry Compressive Strength f_m' / f_m' :**
 - Lintel designs benefit from selecting an optimal masonry compressive strength. A standard f_m' / f_m' of 2500 psi is commonly used, though higher values can be specified based on project requirements. An increase in f_m' / f_m' directly enhances both the compressive and flexural capacities of the lintel. Refer to [masonry CMU data](#) for detailed specifications.
2. **Optimized Placement of Construction Joints:**
 - To maximize the load-carrying potential of a masonry lintel, construction joints should be strategically placed away from openings. This allows for the development of arching action across the opening, reducing direct loads on the lintel and improving the overall structural performance.
3. **Utilizing Finite Element Analysis (FEA):**
 - FEA provides a refined analysis by simulating the interaction between the lintel and the surrounding masonry wall. By modeling the system holistically, FEA captures the distribution of forces across the entire wall-lintel system, producing more accurate and efficient designs. The FEA approach accounts for stiffness, deformation, and force distribution, which traditional hand calculations may overlook.
4. **Arching Action and Fixed-End Conditions:**
 - **Arching Action:** Arching action redistributes vertical loads into horizontal thrusts at the supports, reducing the bending demand on the lintel. This method allows for a reduction in the required lintel depth and reinforcement.
 - **Fixed-End Boundary Conditions:** Designing the lintel with fixed-end conditions reduces the maximum moment experienced by the lintel but introduces both positive and negative moments. This requires reinforcement at both the top and bottom of the lintel, providing greater structural efficiency.

Increasing Moment and Shear Capacities

Moment Capacity:

- The simplest way to increase the moment capacity of a masonry lintel is to increase its depth. The moment capacity is directly proportional to the section modulus, which increases with depth.

- Additional layers of reinforcement can also enhance moment capacity. When increasing reinforcement, the use of smaller diameter bars distributed across the lintel provides better crack control and load distribution than fewer large bars.

Shear Capacity:

- Shear capacity can be improved by increasing the lintel's depth and grouting the masonry solid. The added mass of the masonry section provides more resistance to shear forces.
- If adding depth is not feasible due to architectural constraints, shear stirrups can be introduced. This option, however, is less preferred due to increased labor and material costs. As a guideline, use single-leg stirrups for 8-inch walls, while double-leg stirrups are recommended for thicker walls.

Deep Beam Lintel Design:

- For large openings, the entire depth of the masonry wall above the opening can be utilized by designing the lintel as a deep beam. Deep beam lintels require a detailed analysis of shear and flexural behavior, and designers should reference the latest TMS code for the most current design and detailing procedures.

Structural Analysis: Torsion in Masonry Lintels

Torsional behavior in masonry lintels is often misunderstood. Masonry lintels, when built integrally with the surrounding wall, typically do not need to be designed for torsion. Instead, the wall itself can resist the applied loads through its bending capacity. The behavior of the masonry wall system, which can resist bending in both vertical and horizontal directions, is sufficient to account for most out-of-plane loads, lateral pressures, and localized point loads.

There are three primary scenarios for torsional load consideration in lintels:

1. **Lintel Integrated with Wall:** In cases where the lintel is fully integrated with the masonry wall, torsion is negligible. The wall's bending stiffness handles most of the load.
2. **Wall with Stiffness Representation:** If the wall has sufficient bending stiffness, the lintel will experience little torsional stress.
3. **Isolated Lintel (No Wall Connectivity):** In rare cases where the lintel is isolated and not integrated with the wall above, torsional forces may become significant, requiring the lintel to be designed to resist torsion.

Architectural Insight: Lintels in Exterior Walls

Steel lintels are often chosen for wide exterior wall openings due to their ease of construction and ability to support veneer loads through beam bottom plates. However, this approach introduces thermal bridging and condensation risks, particularly in climates where temperature differentials between the interior and exterior surfaces are significant. Over time, thermal bridging can lead to deterioration of finishes and reduce the energy efficiency of the building envelope.

An alternative approach is to support the exterior brick veneer using a masonry lintel in the backup wall, coupled with a steel lintel or channel to support the veneer. This configuration minimizes thermal transfer, and the masonry lintel can be designed to provide both structural support and insulation continuity. Figure 5 illustrates how a standoff channel can be used to support the brick veneer while reducing thermal transfer.

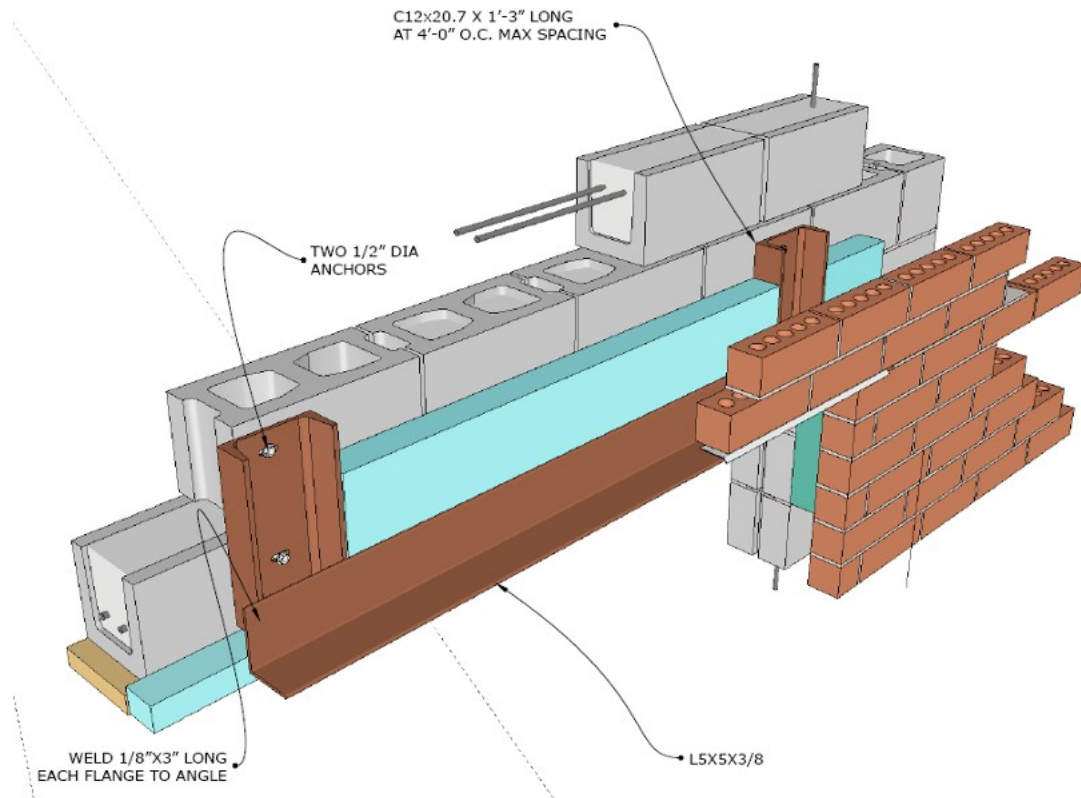


Figure 5: Option to support brick veneer from a masonry lintel using standoff channels to minimize thermal transfer

Detailing the Top of an Exterior Wall Opening

When a masonry lintel supports an opening with a brick veneer, a gap often exists between the exterior face of the masonry lintel and the interior face of the brick veneer. This cavity must be properly sealed to prevent issues such as moisture ingress, poor insulation, and fire hazards. Several detailing options are available:

1. **Use of Extended Window/Door Frames:** Window and door frames can be extended to close the gap.
2. **Metal Frame Extensions:** Metal frame extensions provide a durable and effective solution to bridge the cavity.
3. **Back-to-Back Angles:** Installing back-to-back steel angles can close the gap while extending the length of loose lintels, especially in cases where larger veneer panels are used.
4. **Extended Horizontal Veneer Angles:** In cases where the veneer lintel is directly attached to the structural wall, extending the horizontal leg of the veneer angle can provide adequate closure.

In summary, efficient masonry lintel design requires consideration of the entire wall system, including interaction with vertical reinforcement, proper detailing to avoid thermal bridging, and optimized load distribution through arching action or FEA. By leveraging modern analysis techniques and maximizing the use of available masonry materials, designers can achieve a robust and cost-effective structural solution for spanning openings in masonry wall