Masonry Pilasters: Design Considerations and Comparative Analysis

INTRODUCTION:

In structural design, masonry pilasters offer a viable solution for resisting large, concentrated loads on masonry walls. Engineers must evaluate the capacity requirements and choose among various options, including masonry pilasters, concrete columns, and steel columns. Each type of structural element as unique characteristics, capacities, and implications for construction. This discussion provides a comparative analysis of these elements within typical wall construction and presents design strategies to optimize the use of masonry pilasters. Figure 1 shows a typical load bearing pilaster.

DESIGN REQUIREMENTS FOR MASONRY PILASTERS:

Masonry pilasters are subject to similar design criteria as concrete columns, including requirements for longitudinal steel reinforcement and confinement ties. According to TMS 402-16, longitudinal reinforcement should occupy 0.25% to 4% of the cross-sectional area of the column, with a minimum of four bars. The ties, typically sized at #4, must be spaced at the lesser of 16 times the longitudinal bar diameter, 48 times the tie bar diameter, or the least dimension of the column. These provisions ensure adequate confinement and ductility under axial loading conditions.

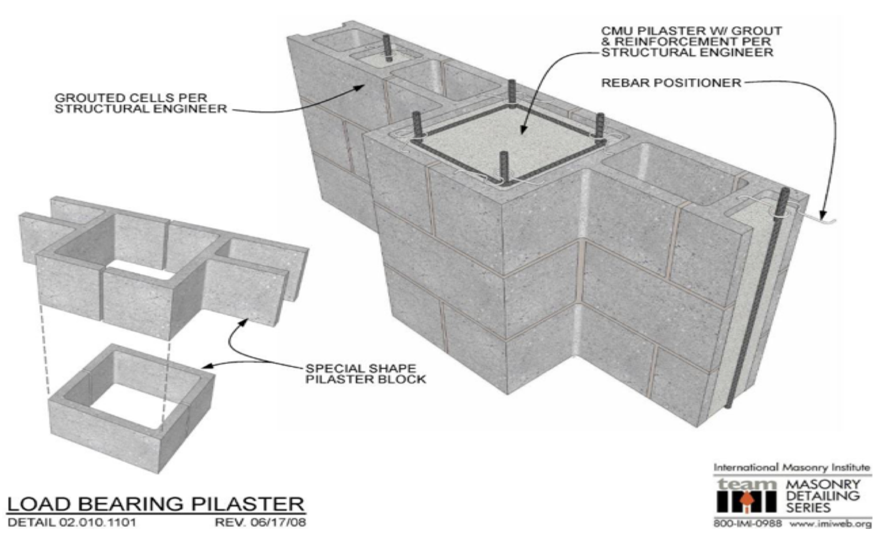

Figure 1. Load Bearing Pilaster (IMI)

For pilasters with an aspect ratio (height-to-thickness) of 99 or less, the ultimate axial load capacity can be

$$P_n = 0.80\left[0.80f'_m(A_n - A_{st}) + f_yA_{st}\right]\left[1 - \left(\frac{h}{140r}\right)^2\right]$$

calculated using the provisions of TMS 402-16, Eqn. 9-15:

When considering reinforced masonry subjected to axial loads, the design uses a strength reduction factor (ϕ) of 0.90 to account for uncertainties in material properties and loading conditions.

CAPACITY COMPARISON: MASONRY vs. CONCRETE and STEEL COLUMNS

To illustrate the performance differences, consider the axial capacity of various column sizes:

16x16 Masonry Column: With four #7 longitudinal bars and a compressive strength of f'm = 2500 psi, the ultimate capacity reaches 445.6 kips. In comparison, a 16x16 concrete column with f'c = 4000 psi offers a slightly higher capacity of 523 kips, representing a 17% increase.

24x24 Masonry Column: Equipped with eight #8 bars, the masonry column has an axial capacity of 1069 kips. A comparable concrete column with the same reinforcement configuration has a capacity of 1203 kips, demonstrating a 13% increase over masonry.

Although concrete columns exhibit higher nominal capacities, the advantages of masonry pilasters, including ease of integration with masonry walls and fewer construction trades, make them a preferable choice in many scenarios.

Another alternative is using steel columns to carry concentrated loads. For example, an HSS12x12x3/8 steel section has an ultimate capacity of 719 kips when designed according to ASTM A1085 specifications. While this capacity is higher than that of a 16x16 masonry column or pilaster, it falls short compared to larger masonry options, such as the 24x24 configurations. Additionally, the use of steel introduces a different trade, potentially increasing construction complexity and coordination efforts.

When increased capacity is required, utilizing a masonry pilaster with integral wall flanges provides a significant advantage, as shown in Figure 1. TMS 402-16, Section 5.4 Pilasters lists the requirements for intersecting walls which must be used to consider the increased capacity and use of these flanges.

For example:

16x16 Masonry Pilaster: Incorporating 8-inch ungrouted flanges into the design, the axial capacity increases to 677 kips (f'm = 2500 psi), exceeding that of a comparable concrete column.

24x24 Masonry Pilaster: With 8-inch ungrouted flanges and #3 ties, the capacity can reach 1418 kips, surpassing both the 24x24 masonry column and concrete column. This demonstrates the efficacy of using flanges to enhance load-carrying capability.

By extending the flanges integrally with the wall, the effective cross-sectional area increases, allowing the pilaster to carry higher loads without significant changes in construction methods. The masonry pilaster's ability to be constructed seamlessly by the masonry crew simplifies logistics and reduces the need for coordinating with additional trades.

Looking at a 16x16 column with a height of 12 feet, (4)#7 longitudinal bars, and a common masonry compressive strength of f'm = 2500 psi, the capacity is 445.6 kips. A similar column built with 4000 psi concrete has a capacity of 523 kips, for an increase of 17 percent. Doing the same check on a 24x24 column with (8)#8, the masonry column can resist 1069 kips, and the concrete column's capacity is 1203 kips (a 13 percent increase).

To increase the masonry capacity, consider a masonry pilaster instead of an isolated masonry column. As shown in the figure on page 1, masonry column can be built integrally with the masonry walls on each side (flanges). To consider the increased capacity and use these flanges, the requirements for intersecting walls must be met; see TMS 402-16[1], Section 5.4 Pilasters. Looking at a 16x16 pilaster with a height of 12 feet and (4)#7 longitudinal bars, and 8 inch ungrouted flanges, the capacity with f'm = 2500 psi is 677 kips. This is more than the concrete column. Checking the 24x24 pilaster with (8)#8 and #3 ties, and 8 inch ungrouted flanges, the capacity increases to 1418 kips, which is also more than the concrete column option.

Yes, the concrete has a higher strength, but less capacity than the masonry pilaster options. The concrete option also introduces another trade into the construction. This requires the masons to stop and allow a concrete crew to come in and build their pilaster before the masons can finish up. If the pilaster were designed as masonry, one trade - the masons - can build it in the way that is most efficient for them, which is probably also the most efficient for the project in general. It is also worth mentioning that a higher strength masonry block can be specified for masonry with a higher grout strength that could be equivalent to concrete. A different masonry material would be an extra effort, but much better than an entirely different trade and new material.

Another option would be to use a steel column to carry the concentrated load. An HSS12x12x3/8 could be hidden inside a 16x16 masonry pilaster with no interruption in the wall's surface. However, such a member that is 12 feet tall and made from ASTM A1085 material has an ultimate capacity of 719 kips, which is more than the 16x16 masonry column or pilaster, but far less than any of the 24x24 masonry options. And again, is the additional capacity needed and worth the different trade and coordination efforts when the masonry piers have significant capacity?

IN SUMMARY:

- 16"x16" masonry column, f'm=2.5 ksi [2,4] : 446k
- 16"x16" concrete column, f'c=4.0 ksi [3] : 523k
- 16"x16" masonry pilaster, f'm=2.5 ksi [2] : 677k
- 24"x24" masonry column, f'm=2.5 ksi [2,4] : 1069k

- 24”x24” concrete column, f’c=4.0 ksi [3] : 1203k
- 24”x24” masonry pilaster, f’m=2.5 ksi [2] : 1418k
- HSS12x12x3/8: 719k

In a situation where a bump-out is not allowed, compare the capacity of a 24”x8” masonry non-projecting pilaster, 24”x8” concrete, and a HSS5x5x3/8:

- 24”x8” masonry pilaster, f’m=2.5 ksi [4] : 283k
- 24”x8” concrete column, f’c=4.0 ksi [3]: 412k
- HSS5x5x3/8: 191k

The integration of masonry pilasters into wall systems offers structural redundancy, as the flanges contribute to overall stability and load resistance. Pilasters built integrally with the masonry wall distribute loads more effectively, leading to a more resilient structural system.

Through a comparative analysis, masonry pilasters have demonstrated the ability to meet or exceed the load-carrying capacity of similarly sized concrete columns, while offering practical construction advantages. For larger columns or pilasters, using integral flanges can significantly increase capacity, making masonry a competitive option. When space allows, and where wall flushness is a concern, masonry pilasters provide an efficient and robust solution for concentrated load resistance in masonry wall construction.

FOOTNOTES:

1. TMS 402-16: Building Code Requirements for Masonry Structures from The Masonry Society
2. Capacity for masonry pilasters was found using TMS-402 and the Structural Masonry Design System.
3. Capacity for steel columns and concrete columns was found using ACI 318 and the Tekla TEDDS software.
4. If masonry with f’m = 4 ksi were used, the capacities would be as follows:
   - 16”x16” masonry pilaster: 654 kips
   - 24”x24” masonry pilaster: 1551 kips
   - 24”x8” masonry pilaster: 403 kips

