NCMA TEK

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ALLOWABLE STRESS DESIGN OF CONCRETE MASONRY PILASTERS

TEK 17-4B
Structural (2000)

Keywords: architectural details, allowable stress design, columns, construction details, design examples, lateral loads, pilasters, reinforced concrete masonry

INTRODUCTION

Concrete masonry walls provide benefits such as structural integrity, fire resistance, thermal insulation and mass, low maintenance, and an aesthetic versatility unmatched by any other single building material. Structurally, concrete masonry walls for warehouses, foundations, loadbearing walls, retaining walls, etc. can carry vertical loads as well as lateral loads imposed by wind, soil, or earthquakes. Where these loads are high or walls are especially tall, the use of pilasters may be advantageous to allow thinner wall sections.

A pilaster is a strengthened section that is designed to provide lateral stability to the masonry wall. Pilasters can be the same thickness as the wall but most often project beyond one or both wall faces. A bonded pilaster may be constructed as an integral part of the wall or, where provisions for crack control are provided such as with control joints, they may be constructed as an unbonded structural member where lateral support is provided through the use of suitable connections. Typical construction details are provided in Figures 1 and 2 which show both bonded and unbonded pilasters. Other methods of providing load transfer across the control joint for the unbonded condition may be utilized than as detailed in this TEK. See TEK 10-2A (ref. 2) for more options.

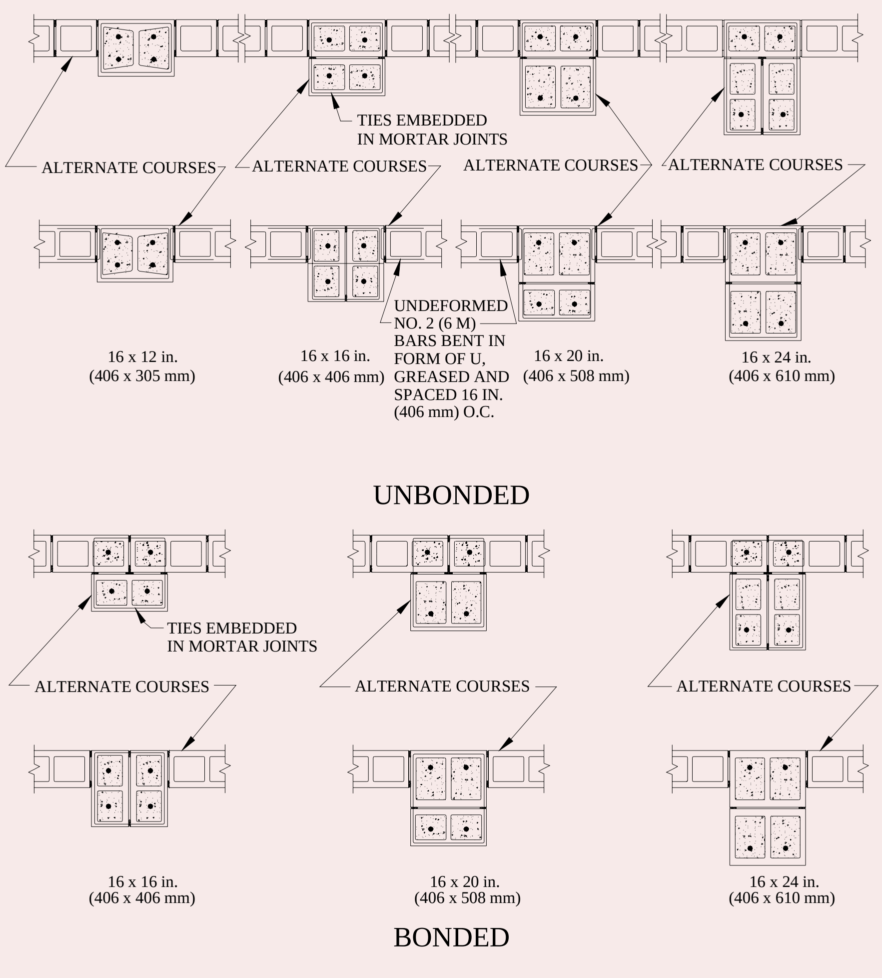


Figure 1—16 in. (406 mm) Pilaster Sections

DESIGN

Typically, pilasters are subject to little or no vertical load other than their own weight, and as such serve as flexural members. Pilasters required in this type of service must be able to resist bending while transferring the applied loads from the walls to the roof and foundation system. While the primary purpose of a pilaster is to provide lateral support, in many cases it may also be required to support vertical loads such as those im-

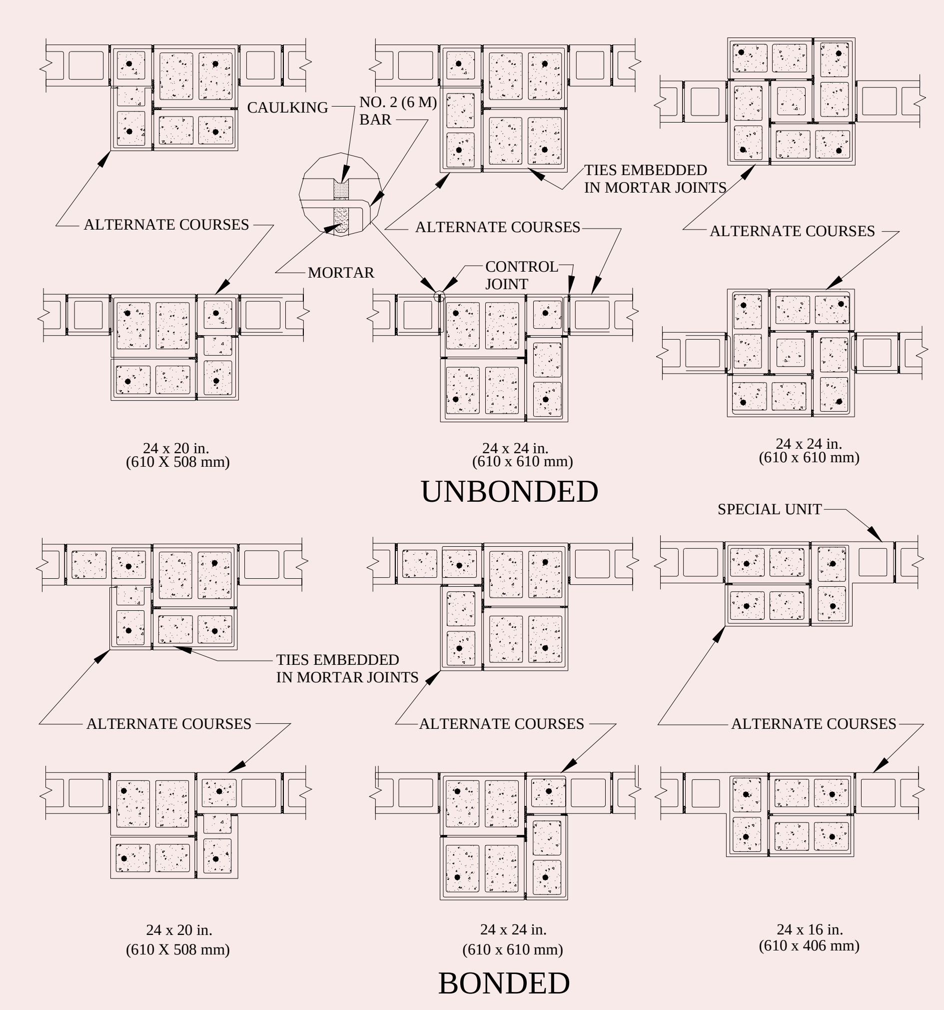


Figure 2—24 in. (610 mm) Pilaster Sections

posed by beams or other framing members. When this occurs, pilasters are designed as columns and function as primarily as compression members. A chart for the selection of appropriate pilaster size and reinforcement for a variety of lateral loading conditions is presented in Table 1.

Table 1 is based on the provisions of *Building Code Requirements For Masonry Structures* (ref. 1). The values in the table include the capacity of the tensile reinforcement only. If lateral ties are provided in accordance with ref. 1, the capacity of the compressive reinforcement may also be considered as shown in Figure 3.

Pilaster spacing is a function of the wall thickness, the magnitude of lateral loads, and the distribution of the lateral load to the vertical and horizontal supports. A relationship exists between the ratio of pilaster spacing to wall height and load distribution. Figures illustrating this relationship are available in *Designing Concrete Masonry Walls For Wind Loads* (ref. 3). Once the wall panel dimensions have been determined, the lateral load which must be resisted by the pilasters may be calculated as follows:

$w_p = w \times l$

where:

w_p = load on pilaster, lb/ft (N/m)

w = lateral load acting uniformly on the wall, psf (Pa)

l = length of wall supported by pilasters (center-to-center spacing of pilasters), ft (m)

DESIGN EXAMPLE

A warehouse requires 24 ft (7.3 m) of clear space between the floor and ceiling for storage. The applicable building code specifies a minimum design wind load of 15 psf (718 Pa). Determine the required pilaster size and spacing for an 8 in. (203 mm) hollow unreinforced concrete masonry wall, constructed with Type S portland cement/lime or mortar cement mortar.

section modulus,
S = 81 in.^{3}/ft (4355 mm^3/m) (ref. 4)

allowable flexural tension parallel to the bed joints (Table 2.2.3.2 ref. 1, increased by 1/3 for load combinations including wind),

F_t = 50 psi x 1.33
= 66.5 psi (0.459 MPa) (ref. 1)

allowable moment,

$M = F_t \times S$
= (66.5 psi)(81 in.^{3}/ft)
= 5386 in.-lb/ft (1996 N·m/m)

Assuming the wall is simply supported, the maximum moment that must be supported is $M_{max} = wl^2/8$, or solving for l,

l^2 = (3240 in.-lb/ft)(8)/[(15 psf)(12 in./ft)]
l = 15.5 ft (4.72 m)

Choose the next lower modular spacing for the pilasters, 15' - 4" (4.67 m).

The lateral load that must be resisted by each pilaster is:

$w_p = w \times l$
= 15 psf x 15.33 ft
= 230 lb/ft (3356 N/m)

Assuming the pilaster is simply supported at top and bottom, the maximum shear and moment on the pilaster are:

$V_{max} = w_p h/2$
= (230 lb/ft)(24 ft)/2
= 2760 lb (12.3 kN)

$M_{max} = w_p l^2/8$
= [(230 lb/ft)(24 ft)^2/8](12 in./ft)
= 198720 in.-lb (22.5 kN·m)

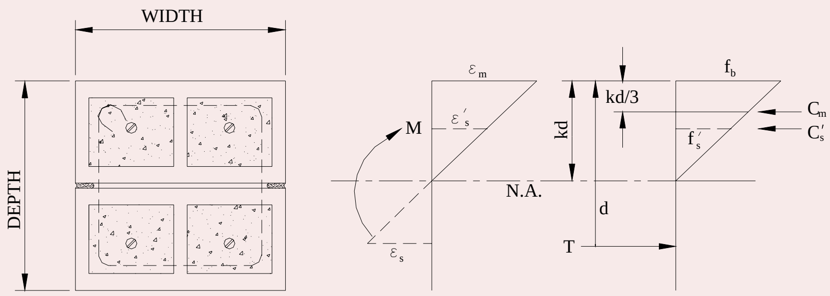
From Table 1, choose a 16 x 16 in. (406 x 406 mm) pilaster reinforced with four #5 bars.

Table 1—Pilaster Selection Chart[a,b]

Nominal Size, in. (mm)		No increase in allowable stresses			Allowable stresses increased by $^1/_3$ for load combinations including wind or seismic		
Width	Depth	Shear strength, V_r, lb (kN)	Reinforcing bar size	Moment capacity, M_r, in.-lb (kN·m)	Shear strength, V_r, lb (kN)	Reinforcing bar size	Moment capacity, M_r, in.-lb (kN·m)
16 (406)	12 (305)	4,732 (21)	No. 4 (13 M)	66,155 (7.5)	6,307 (28)	No. 4 (13 M)	88,185 (10.0)
			No. 5 (16 M)	77,381 (8.7)		No. 5 (16 M)	103,149 (11.7)
			No. 6 (19 M)	86,940 (9.8)		No. 6 (19 M)	115,891 (13.1)
			No. 7 (22 M)	95,173 (10.8)		No. 7 (22 M)	126,865 (14.3)
			No. 8 (25 M)	102,278 (11.6)		No. 8 (25 M)	136,336 (15.4)
			No. 9 (29 M)	108,424 (12.3)		No. 9 (29 M)	144,529 (16.3)
16 (406)	16 (406)	7,150 (32)	No. 4 (13 M)	101,788 (11.5)	9,532 (42)	No. 4 (13 M)	135,683 (15.3)
			No. 5 (16 M)	153,154 (17.3)		No. 5 (16 M)	204,154 (23.1)
			No. 6 (19 M)	173,884 (19.6)		No. 6 (19 M)	231,788 (26.2)
			No. 7 (22 M)	192,213 (21.7)		No. 7 (22 M)	256,220 (28.9)
			No. 8 (25 M)	208,437 (23.6)		No. 8 (25 M)	277,847 (31.4)
			No. 9 (29 M)	222,817 (25.2)		No. 9 (29 M)	297,014 (33.6)
16 (406)	20 (508)	9,569 (43)	No. 4 (13 M)	137,743 (15.6)	12,756 (57)	No. 4 (13 M)	183,611 (20.7)
			No. 5 (16 M)	211,477 (23.9)		No. 5 (16 M)	281,899 (31.9)
			No. 6 (19 M)	281,572 (31.8)		No. 6 (19 M)	375,335 (42.4)
			No. 7 (22 M)	313,192 (35.4)		No. 7 (22 M)	417,485 (47.2)
			No. 8 (25 M)	341,622 (38.6)		No. 8 (25 M)	455,382 (51.5)
			No. 9 (29 M)	367,204 (41.5)		No. 9 (29 M)	489,483 (55.3)
16 (406)	24 (610)	11,988 (53)	No. 4 (13 M)	173,903 (19.6)	15,980 (71)	No. 4 (13 M)	231,813 (26.2)
			No. 5 (16 M)	267,391 (30.2)		No. 5 (16 M)	356,432 (40.3)
			No. 6 (19 M)	379,177 (42.8)		No. 6 (19 M)	505,444 (57.1)
			No. 7 (22 M)	455,020 (51.4)		No. 7 (22 M)	606,541 (68.5)
			No. 8 (25 M)	498,413 (56.3)		No. 8 (25 M)	664,385 (75.1)
			No. 9 (29 M)	537,877 (60.8)		No. 9 (29 M)	716,990 (81.0)
24 (610)	12 (305)	7,154 (32)	No. 4 (13 M)	67,358 (7.6)	9,537 (42)	No. 4 (13 M)	89,788 (10.1)
			No. 5 (16 M)	101,382 (11.5)		No. 5 (16 M)	135,142 (15.3)
			No. 6 (19 M)	115,106 (13.0)		No. 6 (19 M)	153,437 (17.3)
			No. 7 (22 M)	127,241 (14.4)		No. 7 (22 M)	169,612 (19.2)
			No. 8 (25 M)	137,983 (15.6)		No. 8 (25 M)	183,931 (20.8)
			No. 9 (29 M)	147,503 (16.7)		No. 9 (29 M)	196,622 (22.2)
24 (610)	16 (406)	10,811 (48)	No. 4 (13 M)	103,369 (11.7)	14,412 (64)	No. 4 (13 M)	137,791 (15.6)
			No. 5 (16 M)	158,832 (17.9)		No. 5 (16 M)	211,723 (23.9)
			No. 6 (19 M)	225,100 (25.4)		No. 6 (19 M)	300,058 (33.9)
			No. 7 (22 M)	253,691 (28.7)		No. 7 (22 M)	338,170 (38.2)
			No. 8 (25 M)	277,360 (31.3)		No. 8 (25 M)	369,721 (41.8)
			No. 9 (29 M)	298,784 (33.8)		No. 9 (29 M)	398,279 (45.0)
24 (610)	20 (508)	14,469 (64)	No. 4 (13 M)	139,644 (15.8)	19,287 (86)	No. 4 (13 M)	186,146 (21.0)
			No. 5 (16 M)	214,967 (24.3)		No. 5 (16 M)	286,550 (32.4)
			No. 6 (19 M)	305,158 (34.5)		No. 6 (19 M)	406,775 (46.0)
			No. 7 (22 M)	409,702 (46.3)		No. 7 (22 M)	546,132 (61.7)
			No. 8 (25 M)	450,566 (50.9)		No. 8 (25 M)	600,605 (67.9)
			No. 9 (29 M)	487,768 (55.1)		No. 9 (29 M)	650,195 (73.5)
24 (610)	24 (610)	18,126 (81)	No. 4 (13 M)	176,089 (19.9)	24,162 (107)	No. 4 (13 M)	234,727 (26.5)
			No. 5 (16 M)	271,429 (30.7)		No. 5 (16 M)	361,815 (40.9)
			No. 6 (19 M)	385,775 (43.6)		No. 6 (19 M)	514,238 (58.1)
			No. 7 (22 M)	518,503 (58.6)		No. 7 (22 M)	691,164 (78.1)
			No. 8 (25 M)	653,192 (73.8)		No. 8 (25 M)	870,705 (98.4)
			No. 9 (29 M)	709,619 (80.2)		No. 9 (29 M)	945,922 (106.9)
24 (610)	28 (711)	21,783 (97)	No. 4 (13 M)	212,654 (24.0)	29,037 (129)	No. 4 (13 M)	283,468 (32.0)
			No. 5 (16 M)	328,124 (37.1)		No. 5 (16 M)	437,389 (49.4)
			No. 6 (19 M)	466,790 (52.7)		No. 6 (19 M)	622,231 (70.3)
			No. 7 (22 M)	627,931 (70.9)		No. 7 (22 M)	837,032 (94.6)
			No. 8 (25 M)	810,896 (91.6)		No. 8 (25 M)	1,080,924 (122.1)
			No. 9 (29 M)	960,993 (108.6)		No. 9 (29 M)	1,281,004 (144.7)

[a] Based on four reinforcing bars per pilaster.

[b] Assumes f'_m = 1500 psi (10.3 MPa), F_s = 24,000 psi (165 MPa). Compression reinforcement is neglected.



Design expressions:

Stress:

$E_s = f_s / \varepsilon_s$

$E_m = f_b / \varepsilon_s$

Force equilibrium:

$C_m + C'_s - T = 0$

where:

$C_m = \frac{1}{2} f_b bkd$

$C'_s = f'_s A'_s$

$T = f_s A_s$

Requirements for lateral ties (ref. 1):

1. ¼ in. (6.4 mm) minimum diameter.
2. Vertical spacing not to exceed the lesser of: 16 longitudinal bar diameters, 48 lateral tie bar or wire diameters; or the least cross-sectional dimension of the member.
3. Every corner and alternate longitudinal bars must be supported by the corner of a lateral tie which has an included angle of not more than 135°. Longitudinal bars farther than 6 in. (152 mm) from a laterally supported longitudinal bar must also be supported. Lateral ties must be placed in either a mortar joint or in grout.
4. Located not more than ½ the lateral tie spacing above the top of the footing or slab in any story, and not more than ½ a lateral tie spacing below the lowest horizontal reinforcement in a beam, girder, slab, or drop panel above.

Figure 3—Pilaster Design Including Compression Reinforcement

REFERENCES

1. *Building Code Requirements for Masonry Structures*, ACI 530-99/ASCE 5-99/TMS 402-99. Reported by the Masonry Standards Joint Committee, 1999.
2. *Control Joints for Concrete Masonry Walls*, TEK 10-2A. National Concrete Masonry Association, 1998.
3. *Designing Concrete Masonry Walls For Wind Loads*, TEK 14-3A. National Concrete Masonry Association, 1995.
4. *Section Properties of Concrete Masonry Walls*, TEK 14-1. National Concrete Masonry Association, 1993.