CONCRETE MASONRY & HARDSCAPES ASSOCIATION

Provided By:

STRENGTH DESIGN OF CONCRETE MASONRY WALLS FOR AXIAL LOAD & BENDING

INTRODUCTION

Building structural design requires a variety of structural loads to be accounted for: dead and live loads, those from wind, earthquake, lateral soil pressure, lateral fluid pressure as well as forces induced by temperature changes, creep, shrinkage and differential movements. Because any load can act simultaneously with another, the designer must consider how these various loads interact on the wall. For example, an axial load can offset tension due to lateral load, thereby increasing flexural capacity, and, if acting eccentrically, can also increase the moment on the wall. Building codes dictate which load combinations must be considered, and require that the structure be designed to resist the most severe load combination.

The design aids in this TEK cover combined axial compression or axial tension and flexure, as determined using the strength design provisions of *Building Code Requirements for Masonry Structures* (ref. 3). For concrete masonry walls, these design provisions are outlined in *Strength Design of Concrete Masonry* (ref. 1). Axial load-bending moment interaction diagrams account for the interaction between moment and axial load on the design capacity of a wall. This TEK shows the portion of the interaction diagram that applies to the majority of wall designs. Although negative moments are not shown, the figures may be used for these conditions, since with reinforcement in the center of the wall wall strength will be the same under either a positive or negative moment of the same magnitude. Conditions outside of this area may be determined using *Concrete Masonry Wall Design Software or Concrete Masonry Design Tables* (refs. 4, 5). The reader is referred to Loadbearing Concrete Masonry Wall Design (ref. 2) for a full discussion of interaction diagrams.

Figures 1 through 8 apply to fully or partially grouted reinforced concrete masonry walls with a specified compressive strength, f'm, of 1500 psi (10.34 MPa), and a maximum wall height of 20 ft (6.09 m), Grade 60 vertical reinforcement, with reinforcing bars positioned in the center of the wall and reinforcing bar spacing, s, from 8 in. to 120 in. (203 to 3,048 mm). Each figure applies to one specific wall thickness and one reinforcing bar size. For walls less than 20 ft (6.1 m) high, figures 1 through 8 will be slightly conservative due to PΔ effects.

DESIGN EXAMPLE

An 8-in. (203-mm) thick, 20 ft (6.1 m) high reinforced concrete masonry wall is to be designed to resist wind load as well as eccentrically applied axial live and dead loads as depicted in Figure 9. The designer must determine the reinforcement size and spacing required to resist the applied loads, listed below.

D = 520 lb/ft (7.6 kN/m), at e = 0.75 in. (19 mm)

L = 250 lb/ft (3.6 kN/m), at e = 0.75 in. (19 mm)

W = 20 psf (1.0 kPa)

The maximum moment due to the wind load is determined as follows.

$$M_{max} = WH^2/8 \text{ lb-ft/ft}$$
$$= (20 \text{ psf})(20 \text{ ft})^2/8$$
$$= 1000 \text{ lb-ft/ft } (4.4 \text{ kN.m/m}),$$

which acts at y = H/2 = 10 ft (3.1 m)

The axial load used for design is the axial load at the location of maximum moment. This combination may not necessarily be the most critical section for combined axial load and flexure, but should be close to the critical location. The wall weight is estimated to be halfway between fully grouted and hollow (82 and 38.7 psf (400 and 189 kg/m²), respectively, for 115 pcf (1842 kg/m³) unit concrete density).

$$P_{total\ @\ 10'} = P_D + P_L + P_{wall}$$
$$= 520 \text{ lb/ft} + 250 \text{ lb/ft} + (60.4 \text{ lb/ft}^2)(10 \text{ ft})$$
$$= 1{,}374 \text{ lb/ft } (20 \text{ kN/m})$$

$$P_{DL@\ 10'} = P_D + P_{wall}$$
$$= 520 \text{ lb/ft} + (60.4 \text{ lb/ft}^2)(10 \text{ ft})$$
$$= 1{,}124 \text{ lb/ft } (16 \text{ kN/m})$$

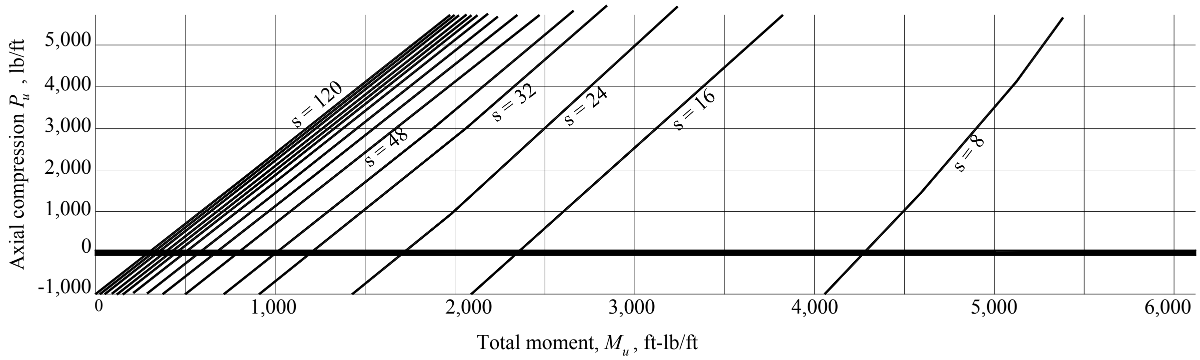

Figure 1—8-Inch (203-mm) Concrete Masonry Wall With No. 4 (M # 13) Reinforcing Bars

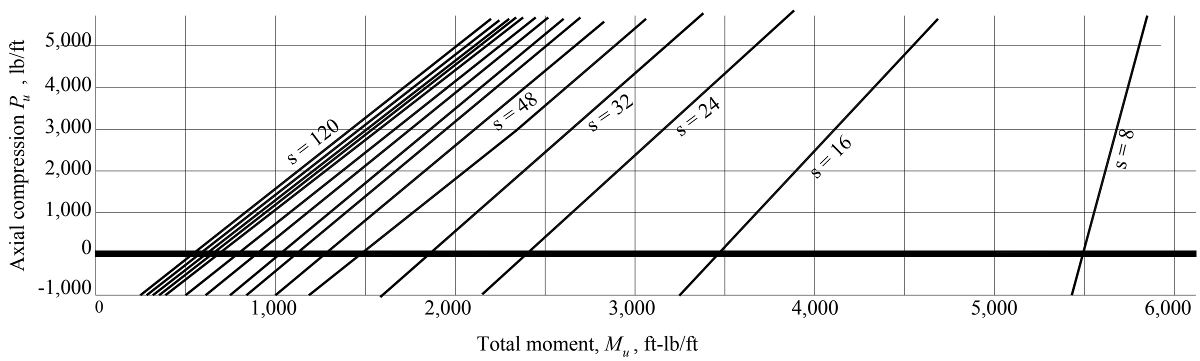

Figure 2—8-Inch (203-mm) Concrete Masonry Wall With No. 5 (M # 16) Reinforcing Bars

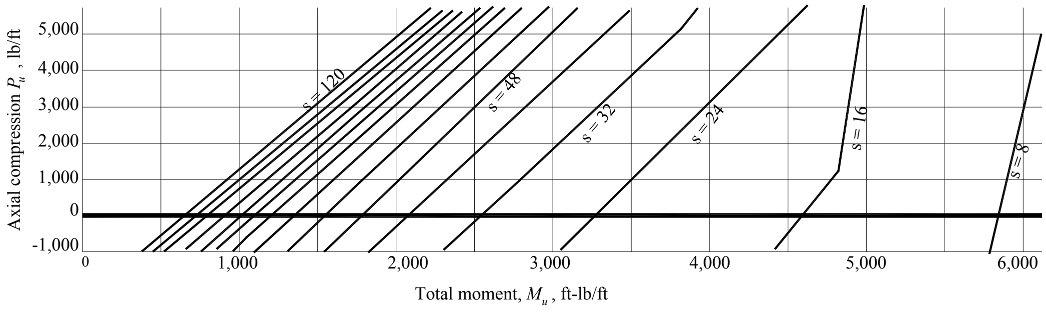

Figure 3—8-Inch (203-mm) Concrete Masonry Wall With No. 6 (M # 19) Reinforcing Bars

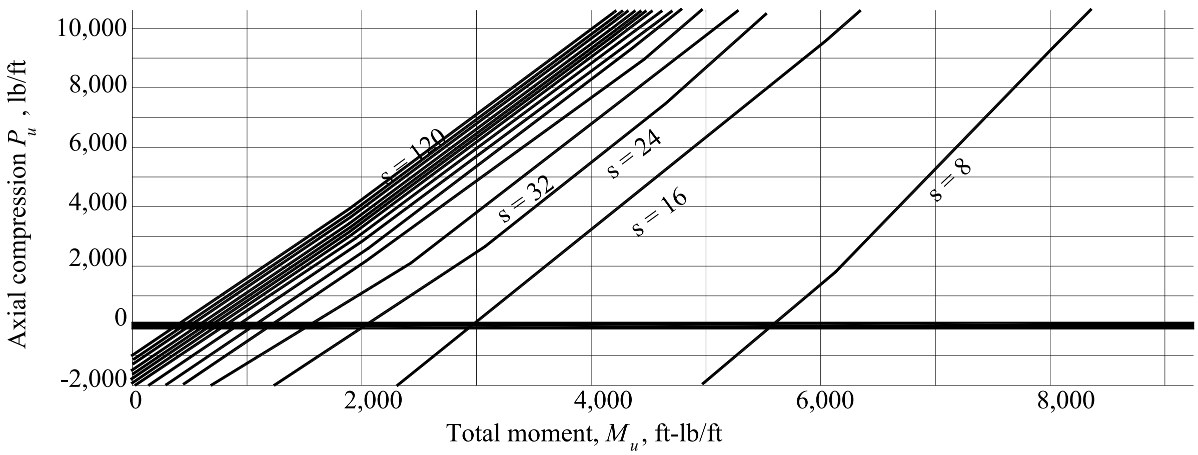

Figure 4— 10-Inch (254-mm) Concrete Masonry Wall With No. 4 (M # 13) Reinforcing Bars

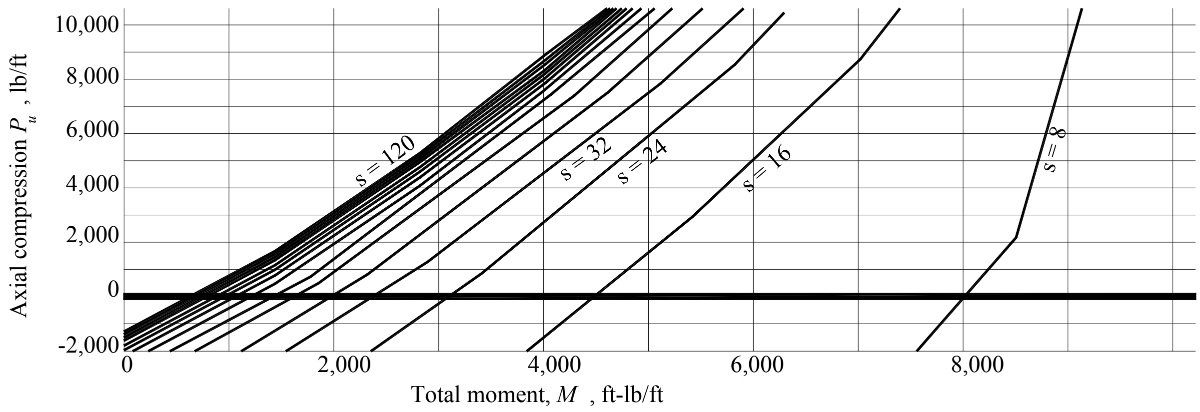

Figure 5—10-Inch (254-mm) Concrete Masonry Wall With No. 5 (M # 16) Reinforcing Bars

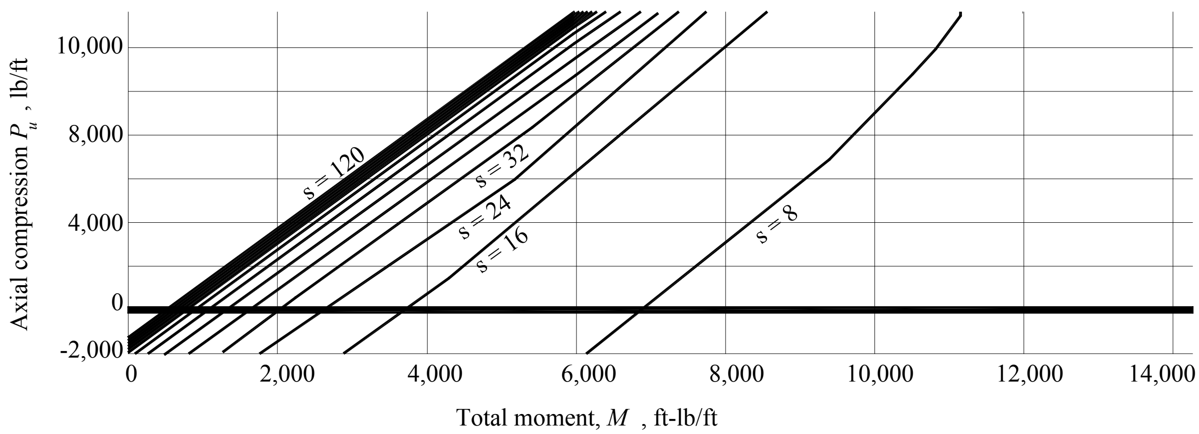

Figure 6— 12-Inch (305-mm) Concrete Masonry Wall With No. 4 (M # 13) Reinforcing Bars

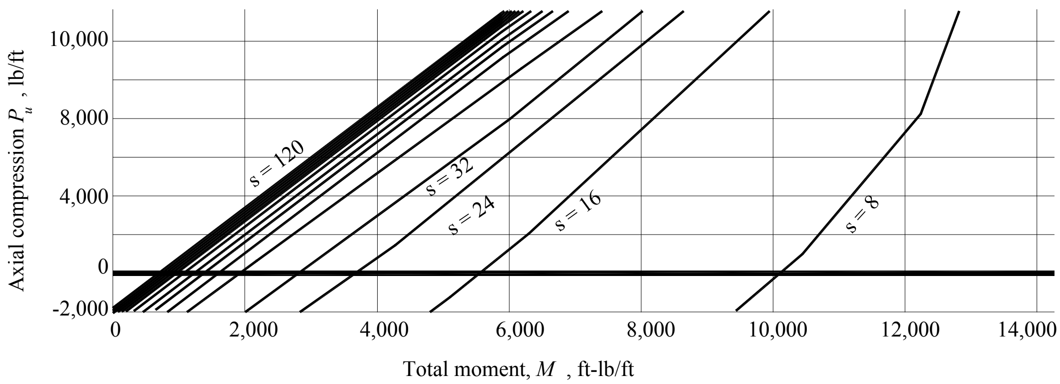

Figure 7—12-Inch (305-mm) Concrete Masonry Wall With No. 5 (M # 16) Reinforcing Bars

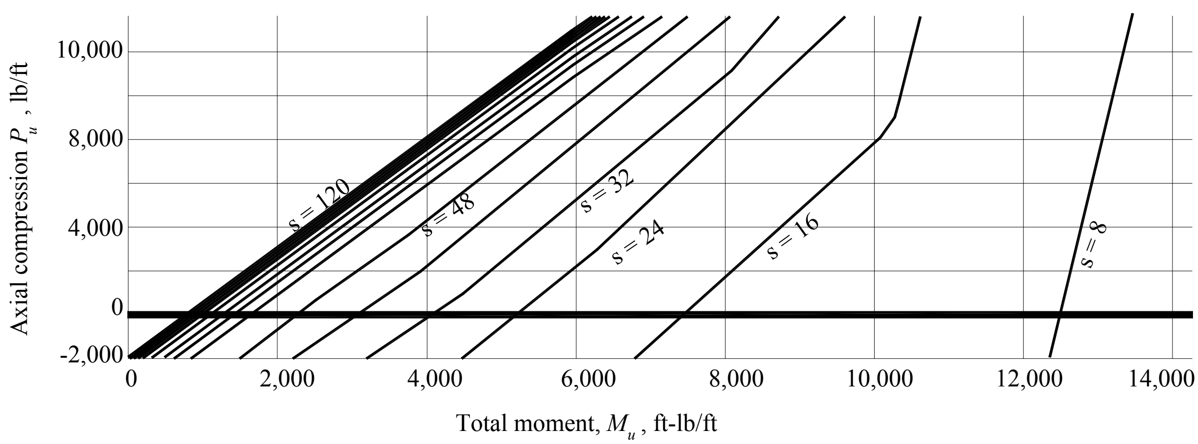

Figure 8—12-Inch (305-mm) Concrete Masonry Wall With No. 6 (M # 19) Reinforcing Bars

The eccentricity of the axial loads also induces bending in the wall and should be included in the applied moment. The magnitude of the moment due to the eccentric axial load must be found at the same location as the maximum moment.

M_{PD} $= P_D e(y/H)$

$= (520 \text{ lb/ft})(0.75 \text{ in.})(10/20 \text{ ft})$

= 195 in.-lb/ft = 16.3 ft-lb/ft (72.5 N.m/m)

M_{PL} $= P_L e(y/H)$

= (250 lb/ft)(0.75 in.) (10/20 ft)

= 93.8 lb-in./ft = 7.8 lb-ft/ft (34.7 N.m/m)

The induced bending moments due to the eccentric axial loads are insignificant compared to that due to wind. However, these will be taken into account where appropriate for specific load combinations.

The applicable load combinations (ref. 6) for this example are:

$1.2D + 1.6W + 0.5^{*}L + 0.5L_T$

$0.9D + 1.6W$

* factor for floor load: = 1.0 for floors in places of public assembly, for live loads in excess of 100 psf (4.8 kPa) and for parking garage live loads; = 0.5 otherwise

During design, all load combinations should be checked, with the controlling load case used for design. For brevity, only the two combinations above will be evaluated here, since the axial load actually increases the flexural capacity for the first combination by offsetting tension in the wall due to the lateral load.

$M_{u\,max}$ = 1.2(16.3 lb-ft/ft) + 1.6(1000 lb-ft/ft) + 0.5(7.8 lb-ft/ft)

= 1,624 lb-ft/ft (7,221 N.m/m))

$P_{u\,@\,10'}$ = 1.2 (1,124 lb/ft)

= 1,349 lb/ft (19.2 kN/m)

To determine the required reinforcement size and spacing to resist these loads, $P_{u\,@\,10'}$ and $M_{u\,max}$ are plotted on the appropriate interaction diagram until a satisfactory design is found.

Figure 2 shows that No. 4 bars at 24 in. (M #13 at 610 mm) on center are adequate. If a larger bar spacing is desired, No. 5 at 32 in. (M #16 at 813 mm) or No. 6 at 48 in. (M #19 at 1219 mm) will also meet the design requirements. Although wall design is seldom governed by out-of-plane shear, the shear capacity should be checked. In addition, the axial load should be recalculated based on the actual wall weight (based on grout spacing chosen), then the resulting required capacity should be recalculated and plotted on the interaction diagram to check adequacy.

NOMENCLATURE

D dead load, lb/ft (kN/m)

e eccentricity of axial load measured from centroid of masonry unit, in. (mm)

f'_m specified masonry compressive strength, psi (MPa)

H height of wall, ft (m)

L live load, lb/ft (kN/m)

L_r roof live load, lb/ft (kN/m)

M_u factored moment, in.-lb/ft or ft-lb/ft (kN.m/m)

P_u factored axial load, lb/ft (kN/m)

s reinforcement spacing, in. (mm)

W wind load, psf (kN/m²)

y distance measured from top of wall, ft (m)

METRIC CONVERSIONS

To convert:	To metric units:	Multiply English units by:
ft	m	0.3048
lb-ft/ft	mN/m	4.44822
in.	mm	25.4
lb/ft	kN/m	0.0145939
psi	MPa	0.00689476

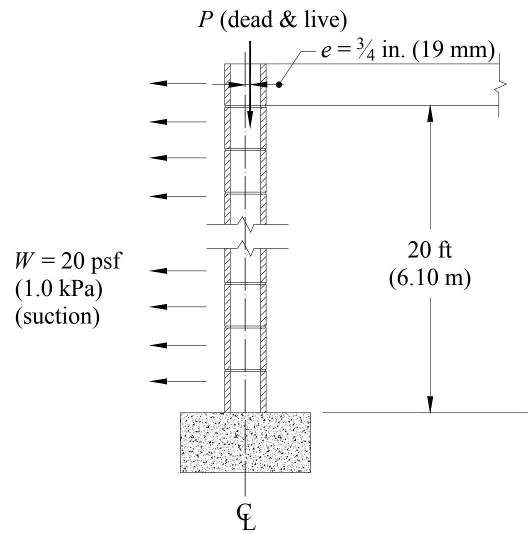

Figure 9— Wall Section for Loadbearing Wall Design Example

REFERENCES

1. *Strength Design of Concrete Masonry*, TEK 14-04B, Concrete Masonry & Hardscapes Association, 2008.
2. *Loadbearing Concrete Masonry Wall Design*, TEK 14-05A, Concrete Masonry & Hardscapes Association, 2006.
3. *Building Code Requirements for Masonry Structures*, ACI 530-02/ASCE 5-02/TMS 402-02. Reported by the Masonry Structures Joint Committee, 2002.
4. *Concrete Masonry Wall Design Software*, CMS-10. Concrete Masonry & Hardscapes Association, 2002.
5. *Concrete Masonry Design Tables*, TR 121A, Concrete Masonry & Hardscapes Association, 2000.
6. *Minimum Design Loads for Buildings and Other Structures,* ASCE 7-02. American Society of Civil Engineers, 2002.

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