NCMA TEK

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DESIGNING CONCRETE MASONRY WALLS FOR WIND LOADS

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INTRODUCTION

Traditionally, empirical requirements have been used for the selection of masonry wall dimensions and lateral support spacing for resistance to wind pressures. These empirical requirements provide satisfactory results for buildings less than 35 ft (11 m) in height where the basic wind pressure does not exceed 25 psf (1197 Pa). This TEK addresses those cases where it is necessary or desirable to undertake a more thorough structural analysis of the lateral wind resistance of a concrete masonry wall or wall-pilaster combination.

Such analysis involves a knowledge of the magnitude and distribution of the wind force to various elements of a masonry structure and the flexural and shear strength of these elements. The information in this TEK provides guidelines for the design of masonry walls supported in both the vertical and horizontal directions.

WALLS

The need to investigate the lateral wind resistance capacity of a wall is usually greater in the case of plain (unreinforced) nonbearing or lightly loaded masonry walls because the vertical load on the wall may be insufficient to completely offset the development of flexural tension. Analysis of masonry walls is often based on the assumption that lateral loads are transmitted in the vertical direction with no end fixity at the lateral supports. Although this approach is straightforward, it may be overly conservative when the ratio of horizontal to vertical distances between lateral supports is relatively small and end fixity is developed. In such cases, end fixity and two-way bending can be utilized.

When wind loads are applied normal to a masonry wall surface, the loads are transmitted to horizontal supports (floors, roofs, beams) and/or vertical supports (cross walls, pilasters). Wall panels are usually assumed to function structurally as thin plates or slabs. For simplicity, walls are often designed to span horizontally between vertical supports or to span vertically between horizontal supports. However, walls can be designed assuming two-way bending using pilasters or cross walls as well as the roof structure and footing as supports. Assuming that the flexural resistance and rigidity of the walls in both the vertical and horizontal spans are known, the lateral load capacity and the proportion of the lateral load transmitted vertically and horizontally to the edge supports will depend on the restraint developed at the edges, the horizontal to vertical span ratio of the panel, and the distribution of the loads applied to the wall panels.

The curves in Figure 1 can be used to approximate the proportion of wind load transmitted in the vertical and horizontal directions. These curves are based on the assumption that the moment of inertia and modulii of elasticity of the walls will be the same in both the horizontal and vertical directions. The curves were derived by equating the theoretical formulas for calculating the maximum deflection for a strip of wall in both directions. It was further assumed that the walls either have no openings, or that any wall openings are located so that their effect on the stiffness of the wall panel is the same in both directions, and that the wall panels on each side of the support are similar in length and height.

When calculating the wind load to be carried by a vertical support, such as a pilaster, a value for K corresponding to the assumed support conditions at the edges of the wall panels and the appropriate wall panel length-to-height ratio is selected from the curves. Then, the value of w_p is determined from the formula given at the top of Figure 1. This value, w_p, represents the load which, when applied as a uniformly distributed load over the height of the pilaster, will approximate the actual wind load transmitted to the pilaster by the walls under the design conditions.

Design Example

To illustrate the use of the curves and formula given in Figure 1, assume a building with exterior walls spanning 12 ft

(3.7 m) vertically between the floor and the roof is designed to resist a wind pressure of 20 psf (958 Pa). The walls are also supported horizontally at 18 ft (5.5 m) by pilasters which are built integrally with the wall. The roof loads will be carried by trusses simply supported on the pilasters, so the walls will be considered free at the top and fixed at the bottom and at the pilasters.

Selecting the appropriate value for K from the curve given for Case 1-A and a wall length-to-height ratio of 18/12 or 1.50, the wind load per foot of height to be carried by the pilasters, w_p, may be calculated as follows:

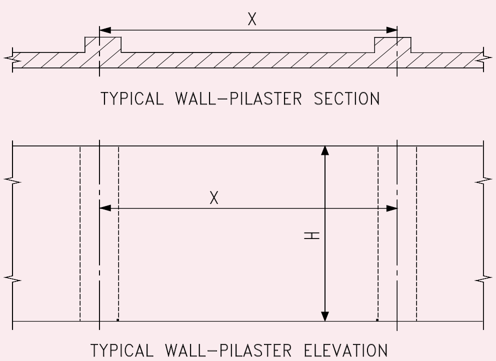
$w_p = Kw_d X$
$w_p = (0.91)\ (20 \text{ psf})\ (18 \text{ ft})$
$\quad = 328 \text{ lb/ft} \quad (4787 \text{ N/m})$

The value of 328 lb/ft (4787 N/m) represents the uniformly distributed load which, when considered to be applied over the full height of the pilaster, will approximate the actual load transmitted to the pilasters by the adjacent walls under the design conditions. The moment and shear developed in the pilasters as a result of this load will depend on the assumed top and bottom support conditions for the pilaster.

The wall construction consists of 12 in. (305 mm) hollow concrete masonry units laid in running bond with face shell mortar bedding, using Type N portland cement lime mortar. Additional design information includes:

Section modulus, S = 159.9 in.^{3}/ft (0.009 m^3/m)
Net area, A_n = 36 in.^{2}/ft (0.08 m^2/m)
Allowable tensile stress parallel to bed joints =
1.33 x 38 psi = 50.5 psi (0.35 MPa) (ref. 1)
Allowable tensile stress normal to bed joints =
1.33 x 19 psi = 25.3 psi (0.17 MPa) (ref. 1)

As already determined, the horizontal span carries 91% of



Calculate the approximate wind load on pilasters using the following formula:

$w_p = Kw_d X$

where:
K = coefficient describing the proportion of wind load transmitted horizontally to pilasters or cross walls, determined from the curves below
w_d = design wind load on wall, psf (Pa)
w_p = approximate wind load on pilasters, lb/ft of height (N/m)
X = horizontal span, center to center, ft (m)

CASE 1: WALLS FIXED AT PILASTERS OR CROSS WALLS
A. fixed at bottom, free at top
B. supported top and bottom
C. fixed at bottom, supported at top

CASE 2: WALLS SUPPORTED AT PILASTERS OR CROSS WALLS
A. fixed at bottom, free at top
B. supported top and bottom
C. fixed at bottom, supported at top

CASE 3: WALLS FIXED AT ONE END, SUPPORTED AT OTHER
A. fixed at bottom, free at top

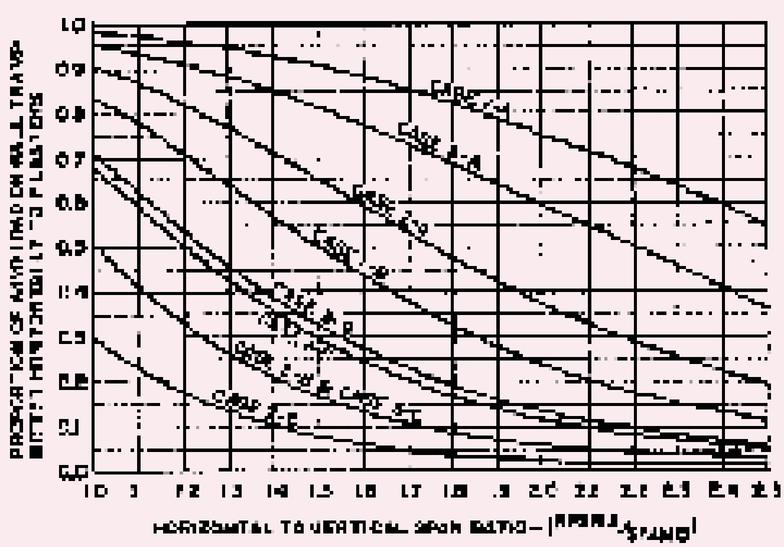


Figure 1—Approximate Horizontal and Vertical Wind Load Distribution

the wind load. With the wall fixed at the ends, the maximum moment, M, in the horizontal span (from Figure 2) is:

$$M = \frac{wH^2}{12} = \frac{0.91(20 \text{ psf})(18 \text{ ft}^2)}{12} \times 12 \text{ in./ft}$$
$$= 5897 \text{ in.-lb/ft } (2186 \text{ N} \bullet \text{m/m})$$

The flexural tensile stress in the horizontal span, f_t, is:

$$f_t = \frac{M}{S} = \frac{5897 \text{ in.-lb/ft}}{159.9 \text{ in.}^3\text{/ft}} = 37 \text{ psi } (0.26 \text{ MPa})$$

The allowable tensile stress for hollow units, Type N mortar, tension parallel to bed joints, was determined to be 50.5 psi (0.35 MPa). Since the calculated tensile stress is less than the allowable, the design meets the code criteria.

In the vertical span, the wall described above carries 9% (1 - 0.91) of the wind load. Since the wall is free at the top and fixed at the base, the maximum moment is:

$$M = \frac{wH^2}{2} = \frac{0.09(20 \text{ psf})(12 \text{ ft}^2)}{2} \times 12 \text{ in./ft}$$
$$= 1560 \text{ in.-lb/ft } (578 \text{ N} \bullet \text{m/m})$$

The flexural tensile stress in the vertical span is:

$$f_t = \frac{M}{S} = \frac{1560 \text{ in.-lb/ft}}{159.9 \text{ in.}^3\text{/ft}} = 10 \text{ psi } (0.07 \text{ MPa})$$

This value can be reduced by the dead load stress on the wall at the point of maximum moment. Assuming that the wall weighs 50 lb/ft^2 (2394 N/m^2):

$$\frac{50 \text{ lb/ft}^2(12 \text{ ft})}{36 \text{ in.}^2\text{/ft}} = 17 \text{ psi compression } (0.12 \text{ MPa})$$

This results in a net axial compressive stress of 7 psi (48.3 Pa).

PILASTERS

A pilaster is a thickened wall section or vertical support built contiguous with and forming a part of the masonry wall. Pilasters are often used to stiffen masonry walls and to provide all or part of the lateral support. They may be built of hollow or solid units (manufactured in one or two pieces), grouted hollow units or reinforced hollow units. Pilasters function primarily as flexural members when used only for lateral support although they can also be used to support vertical compressive loads.

When designing pilasters, the lateral loads transmitted to the pilasters by the adjacent wall panels must be determined. Figure 1 can be used to approximate the proportion of wind load which is transmitted horizontally to pilasters and to calculate the approximate wind load carried by a pilaster.

The formulas given in Figure 2 can be used to calculate the maximum moment and shear on a pilaster after w_p and the support conditions for the pilaster have been determined.

Consider the design described in the previous design example. From Figure 1, it was determined that for Case 1-A with span ratio of 1.5, approximately 91% of the wind load is transmitted in the horizontal span. If the pilasters in the above example are assumed to be fixed at the bottom and simply supported at the top, the maximum moment and shear values are as follows:

$$M_{max} = \frac{w_p H^2}{8} = \frac{(328 \text{ lb/ft})(12 \text{ ft})^2}{8}$$
$$= 5900 \text{ ft-lb} = 70.8 \text{ in.-kip } (8 \text{ kN} \bullet \text{m})$$

$$V_{max} = \frac{5w_p H}{8} = \frac{5(328)(12)}{8} = 2460 \text{ lb } (10.9 \text{ kN})$$

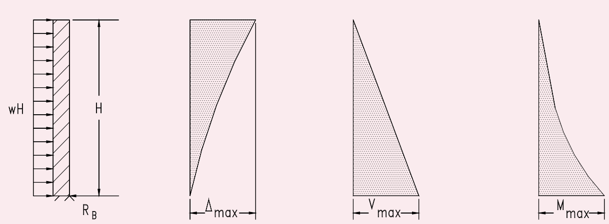
The pilaster, therefore, should be designed to provide an allowable moment and shear resistance equal to or greater than the above values.

NOTATION:

A_n = net cross-sectional area of masonry, in.^{2}/ft (m^2/m)
f_t = flexural tension in masonry, psi (MPa)
H = height of wall, ft (m)
K = proportion of wind load transmitted horizontally to pilasters or cross walls
M = moment, in.-lb/ft (N•m/m)
S = section modulus, in.^{3}/ft (m^3/m)
V_{max} = maximum shear, lb/ft (N/m)
w = uniformly distributed wind load, psf (Pa)
w_d = design wind load on wall, psf (Pa)
w_p = uniform lateral load which approximates the actual wind load transmitted by the walls to the pilasters or cross walls, lb/ft of height (N/m)
X = horizontal span of wall, from center to center of pilasters or cross walls, ft (m)

REFERENCES

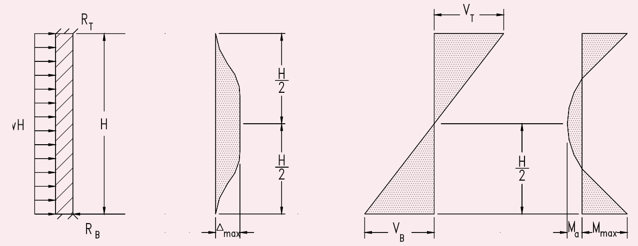
1. *Building Code Requirements for Masonry Structures*, ACI 530-92/ASCE 5-92/TMS 402-92. Reported by the Masonry Standards Joint Committee, 1992.



Deflection Shear Mo-ment

$V_{max} = wH$ $M_{max} = wH^2/2$ (12 in./ft)

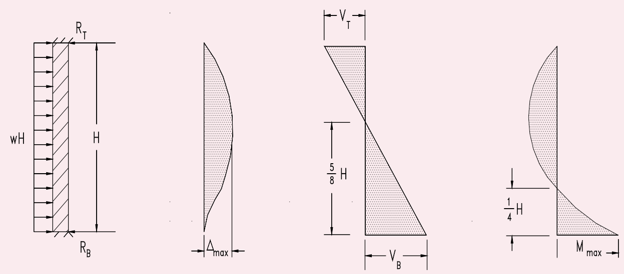
A. Free at top, fixed at bottom



Deflection Shear Moment

$V_{max} = wH/2$ $M_{max} = wH^2/12$ (12 in./ft)

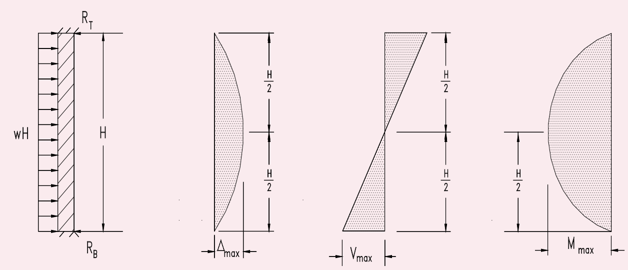
B. Fixed at top and bottom



Deflection Shear Moment

$V_{max} = 5wH/8$ $M_{max} = wH^2/8$ (12 in./ft)

C. Simply supported at top, fixed at bottom



Deflection Shear Moment

$V_{max} = wH/2$ $M_{max} = wH^2/8$ (12 in./ft)

D. Simply supported at top and bottom

Figure 2—Formulas For Maximum Moment and Shear on Walls and Pilasters Subjected To Uniform Lateral Loads