TEK 14-9: ENGINEERED CONCRETE MASONRY WAREHOUSE WALLS (1977)

Introduction

Warehouses and similar buildings, such as manufacturing plants, machine shops, grocery stores, etc. which have relatively long and high one-story walls, offer considerable opportunities for the use of engineered concrete masonry walls. Such walls may be used as non-load bearing infill walls in a structural frame or they may be utilized as load bearing walls, carrying all of the vertical and lateral loads to the foundation. As will be illustrated in this TEK, engineered concrete masonry walls are very versatile and can be designed to safely carry wind and other live and dead loads under a variety of support conditions which are often encountered in the design of warehouse walls.

Design

Lateral Loads. Where the warehouse roof loads are carried entirely by the structural frame, the warehouse walls will only be required to support lateral loads due to wind pressure or earthquake forces. Where the total wall height is less than 30 feet, the wind pressure is often given by the formula

$p = 0.0033V^2$

where p is wind pressure in pounds per square foot and V is the peak gust velocity in miles per hour. For ordinary rectangular buildings, the wind pressure on the windward wall is 80% p and on the leeward wall, the suction is 20% p. With respect to earthquake forces, a typical building code provision in seismic regions calls for a lateral design load of 20% of the dead weight of the wall. Usually this will be less than the wind load on exterior walls. For specific lateral design loads, one should refer to the applicable local building code or the American National Standard A58.1-1972, "Building Code Requirements for Minimum Design Loads in Buildings."

An engineered concrete masonry wall can be designed to resist lateral loads in the horizontal and vertical spans, depending on its height and the length between structural supports (beams, girders, columns, pilasters, etc). Where a wall is supported on more than two sides, Figure 1 can be used to determine the approximate wind load distributed to horizontal and vertical supports. Vertical Loads. Where the dead and live loads of the warehouse roof are directly superimposed on the walls, the walls must be capable of supporting such vertical loads as well as the lateral loads discussed previously.

Design Tables

Nonreinforced Walls. Maximum wall spans for engineered nonreinforced hollow concrete masonry walls subjected to uniformly distributed wind loads are given in Tables 1, 2 and 3. Table 1 covers simply supported walls which span vertically; Table 2 pertains to simply supported walls which span horizontally; and Table 3 is applicable to walls which are simply supported on all four sides. Design stresses utilized in developing these tables are based on those given in the NCMA “Specification for the Design and Construction of Load-Bearing Concrete Masonry" for architectural or engineering inspected nonreinforced construction. **In computing the values given in Table 1 and 3, the effect of wall weight has been neglected**. Assumed section modulii (based on net mortar bedded areas) were: 46 in. ^{3} for 6-in. walls; 80 in. ^{3} for 8-in. walls; 118 in. ^{3} for 10-in. walls; and 159 in.3 for 12-in. walls.

Design tables for nonreinforced concrete masonry walls subject to vertical loads, and combined vertical and lateral loading are contained in "Nonreinforced Concrete Masonry Design Tables," NCMA—1971 .

TABLE 1. Maximum Vertical Spans (feet) for Hollow Nonreinforced Concrete Masonry Walls Subjected to Uniformly Distributed Wind Load, w (psf)*

Wind Load, w (psf)→		10		15		20		25		30	
Mortar Type →		M,S	N	M.S	N	M,S	N	M.S	N	M,S	N
Nominal Wall Thickness (in.)	6	9.6	8.1	7.8	6.6	6.8	5.7	6.1	5.1	5.5	4.7
	8	12.7	10.7	10.4	8.7	9.0	7.5	8.0	6.7	7.3	6.1
	10	15.4	12.9	12.6	10.6	10.9	9.1	9.8	8.2	8.9	7.5
	12	17.9	15.0	14.6	12.3	12.7	10.6	11.3	9.5	10.3	8.7

*Walls simply supported at top and bottom.

TABLE 2. Maximum Horizontal Spans (feet) for Hollow Nonreinforced Concrete Masonry Walls Subjected to Uniformly Distributed Wind Load, w (psf)*

Wind Load, w (psf)→		10		15		20		25		30	
Mortar Type →		M.S	N	M.S	N	M.S	N	M.S	N	M.S	N
Nominal Wall Thickness (in.)	6	13.6	11.4	11.1	9.3	9.7	8.1	8.6	7.2	7.8	6.6
	8	18.0	15.1	14.7	12.3	12.7	10.6	11.4	9.5	10.3	8.7
	10	21.9	18.3	17.8	14.9	15.5	12.9	13.8	11.6	12.6	10.6
	12	25.4	21.2	20.7	17.3	18.0	15.0	16.1	13.4	14.6	12.2

*Walls simply supported at each end.

TABLE 3. Maximum Horizontal Spans (feet) for Hollow Nonreinforced Concrete Masonry Walls Subjected to Uniformly Distributed Wind Load, w (psf)**

Wall Thickness→		6"								8"							
Lateral Load→		15 psf		20 psf		25 psf		30 psf		15 psf		20 psf		25 psf		30 psf	
Mortar Type→		M.S	N	M.S	N	M.S	N	M.S	N	M.S	N	M.S	N	M.S	N	M.S	N
WALL HEIGHT, FT.	8	19	9.6	10.2	8.1	8.8	7.3	7.9	6.7	*	*	*	13.6	*	10.0	12.2	8.8
	10	11.5	9.3	9.7	8.3	8.8	7.7	8.1	7.3	*	13.2	14.5	10.8	11.6	9.5	10.5	8.8
	12	11.2	9.7	9.9	8.9	9.2	8.2	8.8	7.8	15.8	12.5	12.9	10.8	11.4	9.8	10.6	9.2
	14	11.5	10.2	10.5	9.4	9.8	8.7	9.2	8.1	14.7	12.5	12.9	11.2	11.6	10.4	11.1	9.8
	16	12.0	10.7	10.9	9.8	9.9	9.1	9.6	8.5	14.9	12.8	13.1	11.7	12.3	10.9	11.5	10.2
	18	12.6	11.0	11.2	10.1	10.8	9.5	10.2	9.2	14.9	13.5	13.7	12.1	12.8	11.3	12.1	10.8
	20	13.0	11.6	12.0	10.6	11.0	10.0	10.6	9.6	15.6	14.0	14.2	12.6	13.0	11.8	12.2	11.0
	22	13.6	12.1	12.1	11.2	11.7	10.5	11.0	9.9	16.2	14.3	14.7	13.0	13.8	12.1	13.2	11.7
	24	13.9	12.5	12.7	11.8	12.0	11.0	11.5	10.8	16.8	14.9	15.4	13.7	14.4	12.7	13.2	12.4

Wall Thickness→		10"								12"							
Lateral Load→		15 psf		20 psf		25 psf		30 psf		15 psf		20 psf		25 psf		30 psf	
Mortar Type→		M.S	N	M.S	N	M.S	N	M.S	N	M.S	N	M.S	N	M.S	N	M.S	N
WALL HEIGHT, FT	8	*	*	*	*	*	*	*	12.8	*	*	*	*	*	*	*	*
	10	*	*	*	15.0	22.0	11.9	14.2	10.7	*	*	*	*	*	17.8	*	13.2
	12	*	22.8	22.8	13.1	14.3	11.5	12.8	10.7	*	*	*	16.8	21.0	13.7	15.8	12.4
	14	20.6	15.1	15.6	13.0	13.9	11.6	12.7	11.1	*	19.2	20.6	15.1	16.5	13.4	14.8	12.2
	16	18.4	14.9	15.5	13.3	14.1	12.3	13.3	11.7	24.0	17.6	18.2	15.0	16.2	13.6	14.7	12.8
	18	17.8	15.3	15.7	13.9	14.6	13.0	13.7	12.1	21.2	17.5	18.0	15.3	16.2	14.2	14.9	13.3
	20	18.0	15.8	16.2	14.4	15.0	13.4	14.2	12.6	21.0	17.4	18.0	15.8	16.4	14.6	15.6	14.0
	22	18.3	16.3	16.5	14.9	15.6	13.9	14.7	13.2	20.9	17.8	18.3	16.5	17.2	15.4	16.1	14.5
	24	19.0	16.8	17.3	15.1	16.1	14.4	15.1	13.7	21.1	18.5	19.0	16.8	17.5	15.8	16.8	14.9

*Unlimited
**Walls simply supported on four sides

Reinforced Walls. Tables 4 and 5 contain maximum vertical and horizontal spans, respectively, for reinforced concrete masonry walls subjected to uniformly distributed wind loads. Design stresses uutilized in these tables are also based on those given in the NCMA “Specification for the Design and Construction of Load Bearing Concrete Masonry“ for inspected reinforced concrete masonry construction. Other design assumptions used in calculating the span values are noted in the tables.

Allowable vertical loads and combined vertical and lateral loads for reinforced concrete masonry walls are contained in “Reinforced Concrete Masonry Design Tables,“ NCMA-1971.

Partially Reinforced Walls . Design tables and information for partially reinforced concrete masonry walls is discussed in TEK 63.

Design Examples. For the following three different lateral support conditions, select exterior nonfood bearing concrete masonry walls (non-reinforced or reinforced) for a one-story warehouse building where the design wind load (w) is equal to 20 psf.

(1) Lateral supports at top and bottom of wall; wall height equal to 12 feet.
From Table 1: 12-in. nonreinforced wall (type M or S mortar)
From Table 4: 6-in. reinforced wall with No. 5 bars spaced 48" o.c. or 8-in. reinforced wall with No. 4 bars spaced 48" o.c.

(2) Lateral supports (columns or pilasters) spaced 15 feet o.c. horizontally.
From Table 2: 10-in. nonreinforced wall (type M or S mortar); or 12-in. nonreinforced wall (type N mortar).
From Table 5: 8-in. reinforced wall with bond beams (32" o.c.) containing 2-No. 4 bars

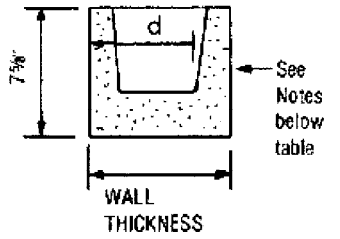
(3) Lateral supports on four sides—12 feet apart vertically and 20 feet apart horizontally.
From Table 3: 10-in. nonreinforced wall (M or S mortar).

TABLE 4. Maximum Vertical Spans (feet) for Hollow Reinforced Concrete Masonry Walls Subjected to Uniformly Distributed Wind Load, w (psf)*

Nominal Wall Thickness (in.)	Vertical Reinforcement	Wind Load, w (psf)				
		10	15	20	25	30
6	No. 4 @ 48"	15.2	12.4	10.7	9.6	8.8
	No. 5 @ 48"	18.8	15.4	13.3	11.9	10.9
	No. 6 @ 48"	22.2	18.1	15.7	14.0	12.8
	No. 5 @ 24"	25.2	20.6	17.8	15.9	14.6
	No. 6 @ 24"	26.7	21.8	18.9	16.9	15.4
8	No. 4 @ 48"	17.8	14.5	12.6	11.2	10.3
	No. 5 @ 48"	22.1	18.0	15.6	14.0	12.7
	No. 6 @ 48"	26.0	21.3	18.4	16.5	15.0
	No. 5 @ 24"	30.7	25.0	21.7	19.4	17.7
	No. 6 @ 24"	34.4	28.1	24.4	21.8	19.9
10	No. 4 @ 48"	20.0	16.4	14.2	12.7	11.6
	No. 5 @ 48"	24.9	20.3	17.6	15.7	14.4
	No. 6 @ 48"	29.4	24.0	20.8	18.6	17.0
	No. 5 @ 24"	34.6	28.3	24.5	21.9	20.0
	No. 6 @ 24"	40.9	33.4	29.0	25.9	23.6
12	No. 4 @ 48"	22.1	18.0	15.6	14.0	12.8
	No. 5 @ 48"	27.4	22.4	19.4	17.4	15.8
	No. 6 @ 48"	32.4	26.5	22.9	20.5	18.7
	No. 5 @ 24"	38.2	31.2	27.0	24.2	22.1
	No. 6 @ 24"	45.2	36.9	32.0	28.6	26.1

*Design assumptions: (1) Vertical reinforcement located on centerline of wall; (2) f'_m = 1500 × 1.33 = 1995 psi; (3) f_s = 20,000 × 1.33 = 26,667 psi; (4) total area of steel in wall is not less than 0.002 times the cross-sectional area of wall (not more than ½ of which is used in either direction).

TABLE 5. Maximum Horizontal Spans (feet) for Hollow Reinforced Concrete Masonry Walls Subjected to Uniformly Distributed Wind Load, w (psf)



DESIGN FACTORS:

$f_m' = 1500 \times 1.33 = 1995$ psi

$f_a = 0.33\ f_m' = 665$ psi

$f_s = 20{,}000 \times 1.33 = 26{,}667$ psi

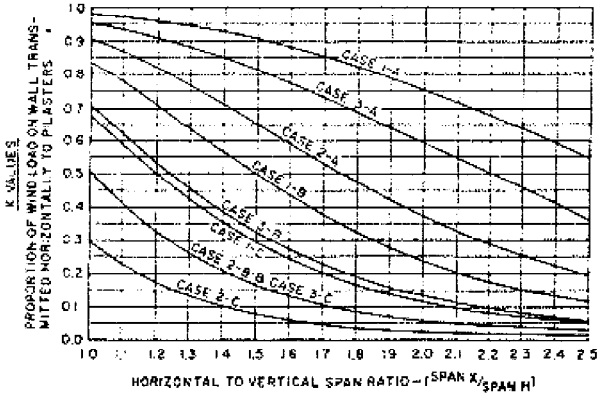
$v = 1.1\sqrt{f_m'} = 43$ psi; $u = 160\ (1.33) = 213$ psi

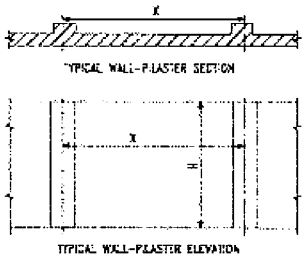
$n = 19.33$

NOMINAL WALL THICKNESS	BOND BEAM SPACING	REINF. PER BOND BEAM	WIND LOAD w (psf)				
			10	15	20	25	30
6"	24" o.c.	1—No. 4	15.8	12.9	11.2	10.0	9.1
		1—No. 5	16.8	13.7	11.9	10.6	9.7
		1—No. 6	17.6	14.4	12.5	11.1	10.2
8"	32" o.c.	2—No. 4	22.2	18.1	15.7	14.0	12.8
		2—No. 5	24.0	19.6	17.1	15.2	13.8
		2—No. 6	25.3	20.7	17.9	16.0	14.6
10"	40" o.c.	2—No. 4	25.6*	20.9*	18.1*	16.2*	14.8*
		2—No. 5	28.5	23.3	20.1	18.0	16.4
		2—No. 6	30.2	24.7	21.4	19.1	17.5
12"	40" o.c.	2—No. 4	29.2*	23.8*	20.6	18.5	16.9
		2—No. 5	35.0	28.6	24.8	22.2	20.2
		2—No. 6	37.3	30.4	26.4	23.6	21.5

*Maximum wall length limited by allowable steel stress.

Notes: Assumed d values; for 6" wall, d = 2.8"; for 8" wall, d = 5"; for 10" wall, d = 7"; for 12" wall, d = 9". Where bond beam contains two reinforcing bars, only one bar used in computing resisting moment.





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
B. supported top and bottom
C. fixed at bottom, supported at top

Figure 1—Approximate Wind Load Distribution to Horizontal and Vertical Supports