APPENDIX C
FOUNDATION CAPACITIES TABLES

C-100. USE OF FOUNDATION CAPACITIES TABLES.

C-100.1. GENERAL. The Foundation Capacities Tables provide foundation design capacities and dimensions for three conditions of foundation design.

A. Withdrawal Resistance. The ability of a foundation wall or pier plus its respective footing to resist uplift and overturning. See Tables C-1 & C-2.

B. Vertical Anchor Capacity. The required size and spacing of anchors to tie the superstructure to the foundation to meet the required uplift or overturning in the transverse direction. See Tables C-3 & C-4 (a & b).

C. Horizontal Anchor Capacity. The required size and spacing of anchors to tie the superstructure to the foundation to resist sliding in the transverse and longitudinal directions - Horizontal Anchor Capacity Table, Table C--5.

C-100.2. CONNECTIONS of the foundation to the manufactured home is dependent on the rated capacity of the manufacturer's connection designs.

C-200. WITHDRAWAL RESISTANCE CAPACITY TABLES.

There are two tables providing the withdrawal resistance (uplift and overturning) for different designs of foundation walls and piers on spread footings at different depths.

C-200.1. LONGITUDINAL FOUNDATION WALLS. The "Withdrawal Resistance for Longitudinal Foundation Walls - Table C-1" is used for manufactured homes anchored to longitudinal foundation walls, specifically system type E. The table provides a footing width and depth below grade to prevent uplift.

Example: Determine the withdrawal resistance of a 6" reinforced concrete wall with a height (hw) of 3'- 4" and with a 6"x16" footing. Repeat for a 6"CMU wall grouted solid, then grouted at 48" o.c., and lastly for an all-weather wood foundation.

Solution: Start with the concrete wall: wall weight: (0.5')×(3.33')×150 pcf = 250 plf; reinforced concrete footing weight: (6"×16"÷144in.sq./sq.ft.)×150pcf = 100 plf; rectangular soil wedge wt: (3.33'-1')×((16"×6")÷(2"×12"))×120pcf = 116 plf. The total withdrawal resistance is the sum of the wall, footing and soil block weight, which is 250+100+116 = 466 plf. This matches the tabled value. The solid grouted CMU wall: wall wt.: (3.33')× (63 psf) = 210 plf, 16" footing and 5" soil wedge calculations are the same as above. The total withdrawal is the sum = 210 + 100 + 116 = 426 plf, just as found in the Table. The partially grouted CMU wall: wall wt.: (3.33)×(45psf) = 150 plf, 16" footing and 5" soil wedge are the same. The total withdrawal is the sum = 150+100+116 = 366 plf, just as found in the table. Lastly, for the all-weather wood foundation: wood stud wall wt.: 2"x6" plate = 2.1 plf; (3)-2"x4" plates = 3×1.3 plf = 3.9 plf; 2"x4"@ 16" o.c. = 1.0 psf × 3.33' = 3.33plf; 1/2"plywood = 1.5psf × 3.33' = 5.0

plf. Wood sum = 2.1+3.9+3.33+5.0 = 14.3 plf; footing weight is the same as caculated before. Soil weight is based on a 6" wide wedge: (3.33')×(16-4)÷(2×12)×pcf = 140 plf. Total withdrawal = 14.3+100+140 = 254 plf, just as in the Table.

C-200.2. PIER FOUNDATIONS. The "Withdrawal Resistance for Piers - Table C-2" is used for manufactured homes anchored to piers; specifically system Types **C**, **I**, and Type **E** when interior piers are used for anchorage. This table also applies to the concrete tie-down block for type **C1** foundations.

Example: Determine the withdrawal resistance of a 3 foot square footing with an 8"x16" solid grouted CMU pier of a height (hp) of 3'-4". Grade exists 12 inches down from the top of the pier.

Solution: Assume the following material weights: 8"CMU = 84 psf; soil = 120 pcf; and concrete = 150 pcf. Pier weight = (84psf) × (16/12) × (3.33') = 373 lbs. Footing weight = (150pcf)×(8/12)×(3'×3') = 900 lbs. Assume footing perimeter creates a conservative shear plane. Soil above footing also counted to resist withdrawal. Soil Weight = (120pcf)×(3.33'-1')×(3^2 - (8)×(16)/144) = 2267 lbs. Total withdrawal resistance is the sum of the pier + footing + soil = 3541 lbs. This magnitude matches the value found in the Table C-2.

C-200.3. FOOTING DEPTH. The bottom of the footings must be below the maximum frost depth for the area where the home is located.

Example: The average depth of frost penetration is 35 inches. Assume that the required footing depth to resist withdrawal (Av) is hw = 2 feet. The depth of the base of the footing is 24"-12"+6"=18". This is less than 35". The depth of hw must be increased to 41" in order for the base of the footing to be at 35"--the required depth to prevent frost damage & also satisfy withdrawal requirements (41"-12"+6"=35").

C-300. VERTICAL ANCHOR CAPACITY TABLES provide the required anchor and reinforcing size and spacing to tie the superstructure to the foundation wall or piers. As in section C-200.1 above, there are two Vertical Anchorage Capacity Tables, one for longitudinal foundation walls and one for piers.

C-300.1. PIERS. The "Vertical Anchor Capacity for Piers - Table C-3" is used for manufactured homes anchored to piers to prevent uplift specifically system Types **C**, **I**, and Type **E** when interior piers are used for anchorage (multi-section E's).

Example: Anchor bolts are assumed to be made from A36 rod stock and of embedment length sufficient to fully develop the allowable tensile capacity ($0.6\times F_y$) of the diameter of rod used. A 1/2"diameter anchor bolt has the following capacity: $(0.6\times 36{,}000\text{psi})\times(\pi \times 0.5^2/4)$ = 4,240 psi, as noted in the Table. The capacity of any substituted grade of steel can easily be calculated if the yield point and diameter are known.

C-300.2. LONGITUDINAL CONCRETE/MASONRY FOUNDATION WALLS. The "Vertical Anchorage Capacity for Longitudinal Foundation Walls - Table C--4A" is used for manufactured homes anchored to a continuous Reinforced concrete or reinforced concrete masonry foundation wall, specifically system Type **E**.

Example: Determine the anchorage capacity per foot of foundation wall if 1/2" diameter an-

chor bolts are spaced 3'-4" o.c. and attach to a continuous treated wood mud sill 1-1/2" thick. Standard washers are used under the nut and bear into the mud sill perpendicular to grain.

Solution: Determine the bearing area of a standard washer with O.D. = 1.375" and I.D. = 0.5625": $A_{brg} = \pi \times (1.375^2 - 0.5625^2) \div 4 = 1.237^{\text{sq. in.}}$. The capacity in bearing multiplied by a bearing area factor $C_b = 1.25$. Thus, the bearing capacity = $1.237 \times 1.25 \times 565$ psi = 873 lbs./ bolt. The capacity for a given spacing of bolts is found by division of that spacing. Thus, for a 3'-4" bolt spacing: 873 ÷ 3.33' = 262 plf, which is the same as in the Table.

Use of an oversized washer (for a 5/8" dia. bolt) produces a larger capacity per bolt. The O.D. = 1.75" and the I.D. = 0.6875", thus the net bearing area : $A_{brg} = \pi \times (1.75^2 - 0.6875^2) \div 4 = 2.03^{\text{sq. in.}}$. The vertical anchor capacity at the same same spacing = $2.03 \times 1.25 \times 565$ psi ÷ 3.33' = 431 plf, which is the same as in the Table.

C-300.3. LONGITUDINAL TREATED WOOD FOUNDATION WALLS. The "Vertical Anchorage Capacity for Longitudinal Foundation Walls - Table C-4B" is used for manufactured homes anchored to a continuous treated wood foundation wall, specifically system Type **E**. Vertical anchorage capacities are based on the use of standard washers over 1/2" dia. bolts. Plywood thickness, nail size and spacing are selected so as to provide equal or greater capacity than the standard washer in bearing. The APA Plywood Diaphragm Guide was used to select plywood, and nailing requirements for the Table.

Example: A 1/2" dia. bolt spaced at 3'-4" o.c. provides a vertical anchor capacity of 262 lbs./ft. This is the same capacity as found in Table C-4A for a standard washer in bearing, and its calculation is illustrated above. The APA Table - *Recommended Shear for Horizontal APA Panel Diaphrapms* requires for a shear of 320 plf > 262 plf: 8d COM nails @ 4" o.c. and uses 3/8" APA rated sheathing.

C-400. HORIZONTAL ANCHOR CAPACITY TABLES FOR TRANSVERSE AND LONGITUDINAL FOUNDATION WALLS

(Table C-5A & C-5B) are used for all types of manufactured homes: homes on continuous foundations - Type **E**; homes on piers - Types **C** and **I**.

C-400.1. ASSUMPTIONS. Along with the notes at the bottom of the tables the following assumptions are made:

A. The horizontal sliding forces are resisted totally by transverse foundation shear walls in the transverse direction and by longitudinal foundation shear walls in the longitudinal direction. An appropriate number of vertical X-bracing planes can be substituted for shear walls to resist sliding in the transverse or longitudinal direction. See sections 602-5.G and 602-6.F.

B. The roof/ceiling and floor of the superstructure are adequate as diaphragms, transferring wind load to the transverse and longitudinal foundation shear walls.

C. A home supported by piers does not provide adequate horizontal sliding resistance unless the piers and footings have been engineered to withstand lateral loads.

C-400.2. TABLES FOR HORIZONTAL ANCHOR CAPACITY. There are two Tables (C-5A & C-5B) for the Horizontal Anchor Capacity for Transverse or Longitudinal Walls.

A. Concrete or Masonry Walls. Table C-5A is based on the capacity of the anchor bolt in a properly designed concrete or masonry foundation system. Horizontal shear capacity for a specific spacing of anchor bolts is based on bearing of the anchor bolt against concrete or grout: $F_{brg} = 0.35 \times f_c' = 0.35 \times 2500psi = 875psi$.

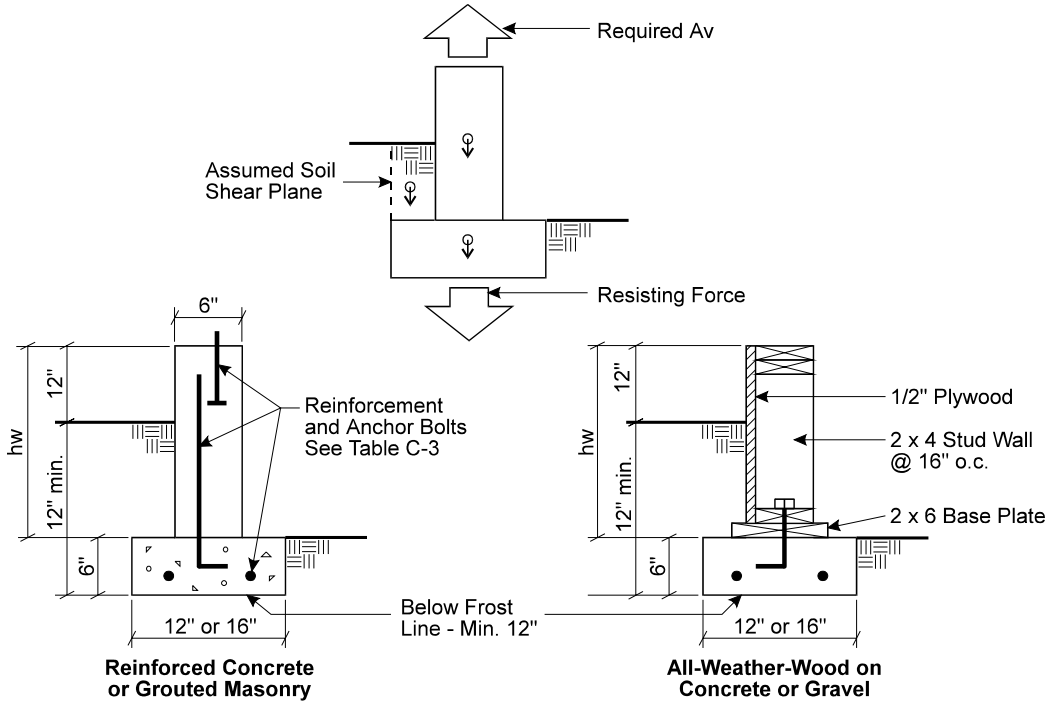
Example: Horizontal capacity per anchor bolt bearing = 875 psi × 1/2" dia. × 4" min. embed. = 1750 lb/bolt, rounded to 1800 lb/bolt. (Note: shear of the bolt did not control since it calculated to be 2830 lb/bolt, assuming A36 rod stock). Thus for 3 foot spacing: 1800 ÷ 3' = 600 plf, as shown in the Table.

B. Wood Foundation Walls. Table C-5B is based on the capacity of the anchor connection to a treated wood wall which is attached to a concrete footing. Horizontal shear capacity is controlled by bearing of wood parallel to grain against the anchor bolt, and then the spacing of those bolts. A 1600 psi end grain bearing allowable stress was assumed, since it would cover most typical species. Thus, the capacity per bolt = 1/2" dia. × 1.5" × 1600 psi = 1200 lb. The APA Plywood Diaphragm Guide was used to select plywood, and nailing requirements for the Table.

Example: For a 1/2" dia. bolt spaced at 3'- 4", the horizontal capacity is: 1200 lb. ÷ 3.33' = 360 plf as shown in the Table. The APA Table - *Recommended Shear for Horizontal APA Panel Diaphrapms* requires for a shear of 360 plf: 8d COM nails @ 4" o.c. and uses 15/32" APA rated sheathing, just as shown in the Table.

C. Anchorage For Diagonal Steel Members To Complete Transverse Foundation Walls Used As Shear Walls. The number of anchor bolts required to anchor the diagonal steel members to the foundation wall can be found by dividing the capacity value for a bolt spaced at 12 inches into the required Ah.

Table C-1
Withdrawal Resistance[1]
Longitudinal Continuous Foundations[2, 3]
(In pounds per linear foot of wall)



hw	Reinforced Concrete		Masonry-Fully Grouted 6" CMU		Masonry-Grouted @ 48" o.c.		All-Weather Wood w/ Conc. Footing	
	Footing Width		Footing Width		Footing Width		Footing Width	
	12"	16"	12"	16"	12"	16"	12"	16"
2'-0"	255	300	231	276	195	240	126	171
2'-8"	325	383	293	351	245	303	154	212
3'-4"	395	466	355	426	295	366	182	254
4'-0"	465	550	417	502	345	430	211	296
4'-8"	535	633	479	577	395	493	240	337

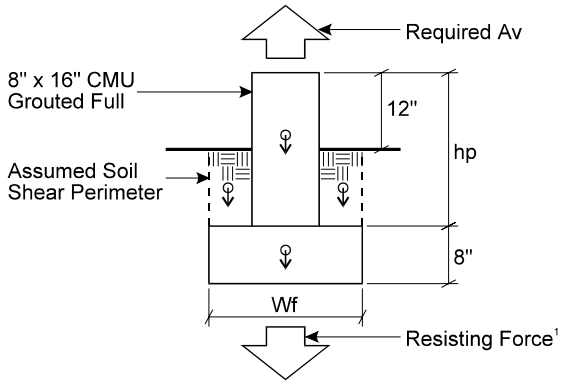
[1] Potential resistance to withdrawal is the maximum uplift resistance which can be provided by the foundations shown. It is computed by adding the weights of building materials and soil over the top of the footing, plus the footing weight. To fully develop this potential, adequate connections to the footing and superstructure must be provided. Material weights used: concrete (nlwt) = 150 psf; 6"solid grouted CMU = 63 psf; 6" CMU grouted @ 48"o.c. = 45psf; grout wt assumed = 140 pcf; CMU units nlwt; wood = 35 pcf; soil = 120 pcf.

[2] Foundations must be designed for bearing pressure, gravity loads, and uplift loads in addition to meeting the anchorage requirements tabulated in the Foundation Design Tables.

[3] Values shown in this table could be increased by widening the footing, provided the system is designed for the increased load, or by a more detailed analysis of the shearing strength of the soil overburden.

Table C-2
Withdrawal[1] Resistance For Piers[2, 3]
(In pounds per pier)

Hp Depth	Width of Square Footing: Wf			
	1'-0"[4]	2'-0"	3'-0"	4'-0"[4]
2'-0"	279	997	2097	3755
2'-8"	361	1322	2824	5049
3'-4"	442	1643	3541	6325
4'-0"	525	1967	4267	7617
4'-8"	607	2292	4994	8911



[1] Potential resistance to withdrawal is the maximum uplift resistance which can be provided by the foundations shown. It is computed by adding the weights of building materials and soil over the top of the footing, plus the footing weight. To fully develop this potential, adequate connections to the footing and superstructure must be provided. Material weights used: concrete (nlwt) = 150 psf; nlwt 8"CMU = 84 psf grouted solid; grout (nlwt) = 140 pcf; soil = 120 pcf.

[2] Foundations must be designed for lateral soil pressure, bearing pressure, gravity loads, and uplift loads, in addition to meeting the anchorage requirements tabulated in the Foundation Design Tables. The bottom of the footing must also be below the maximum depth of frost penetration.

[3] Values shown in this table could be increased by widening the footing, providing the wall system is designed for the increased load, or by a more detailed analysis of the shear strength of the soil overburden.

[4] Assumes 8" x 8" pier for the 1'-0" square footing, and 16" x 16" pier for the 4'-0" square footing.

Table C-3
Vertical Anchor Capacity For Piers[1, 2]
(In pounds)

Anchor Bolt Dia.	Capacity Per Number Of Bolts	
	1	2
1/2"	4240	8480
5/8"	6620	13240

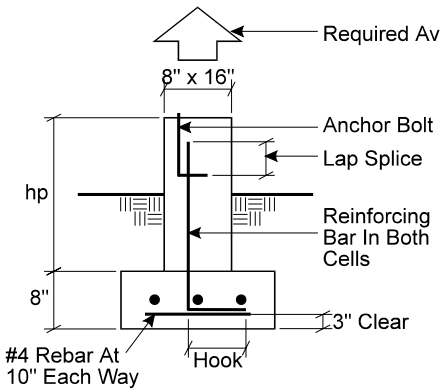


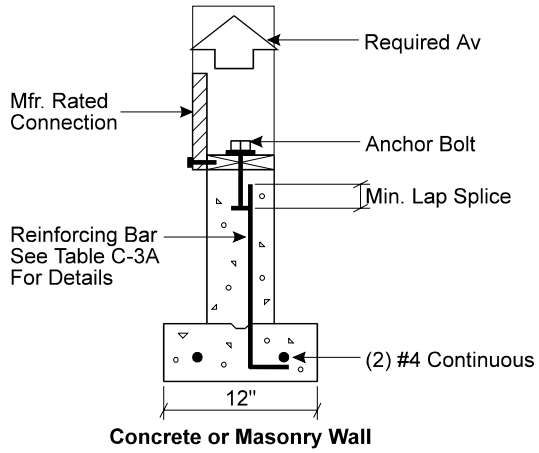
Table C-3A

Anchor Bolt Dia.	Vertical Rebar	Minimum Lap Splice	Rebar Hook
1/2"	# 4	16"	6"
5/8"	# 5	20"	7"

[1] The vertical anchor capacity is based upon the working capacity of ASTM A-36 rod stock anchor bolts in 2500 psi concrete or grout. To fully develop this capacity, anchor bolts must be properly lapped with the pier's vertical reinforcement.

[2] The capacity is based on f_c = 2500 psi; F_y = 36,000 psi.

Table C-4A
Vertical Anchor Capacity For Longitudinal Foundation Wall[1]
(In pounds per linear foot of wall)



Vertical Capacity[5] lbs./ft.		Required Anchorage[2, 3]		
Standard Washer	Over-Sized Washer	Anchor Bolt	Rebar[4]	Spacing[5]
146	239	1/2”	# 4	6’-0”max.
164	270	↓	↓	5’-4”
187	307			4’-8”
218	359			4’-0”
262	431			3’-4”
327	538			2’-8”
437	718	↓	↓	2’-0”

[1] Compare with required Av for Type E units.
[2] Values are based on vertical capacity per foot of wall.
[3] Assuming 1 1/2” thick sill plate, 3/4” edge distance for wood or composite nailer plates or 20 diameter end distance for plywood sheathing; APA rated, properly seasoned wood; Group III woods, not permanently loaded, and a 25% length of bearing factor increase.
[4] It is assumed that a reinforcing bar of the same diameter and spacing as the anchor is adequately embedded in the footing and lapped with the anchor.
[5] Spacing and capacity is based on allowable compression of wood perpendicular to grain for F_c = 565 psi and washer as define below:

Standard washer: 1 3/8” O.D. and 0.5625” I.D. washer (for 1/2” ϕ bolt)
Over-sized washer: 1 3/4” O.D. and 0.6875” I.D. washer (for 5/8” ϕ bolt) placed under the standard washer.

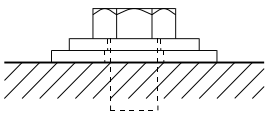
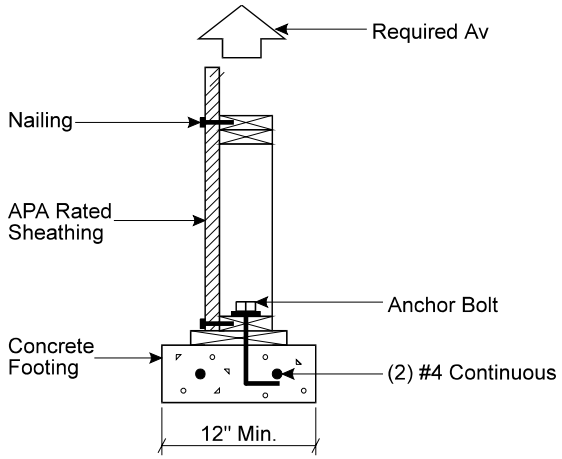


Table C-4B
Vertical Anchor Capacity For Longitudinal Foundation Wall[1, 2]

(In pounds per linear foot of wall)



Treated Wood Wall

Vertical Capacity lbs./ft.	Required Nailing[4, 5] (Edge Spacing, in.)	Min. Plywood Thickness	Required Anchorage[2, 3]	
Standard Washer			Anchor Bolt Diameter	Bolt Spacing[6]
146	6d @ 6" o.c.	3/8"	1/2"	6'-0"max.
164	↓	↓	↓	5'-4"
187	↓	↓	↓	4'-8"
218	8d @ 6" o.c.	↓	↓	4'-0"
262	8d @ 4" o.c.	↓	↓	3'-4"
327	8d @ 4" o.c.	15/32"	↓	2'-8"
437	10d @ 2 1/2" o.c.	↓	↓	2'-0"
***				

*** For required Av greater than 437 lbs./ft., consider using a different foundation material or utilize an engineered design with a higher capacity.

[1] Compare with required Av for Type E units.

[2] In the case of a treated wood foundation wall, the wood wall and its connections must be designed to transfer the anchor load to a concrete footing. This table does not apply to treated wood foundation walls on gravel bases.

[3] Values are based on vertical capacity per foot of wall.

[4] Assuming 1 1/2" thick sill plate, 3/4" edge distance for wood or composite nailer plates or 20 diameter end distance for plywood sheathing; APA rated, properly seasoned wood; Group III woods, not permanently loaded, and a 25% length of bearing factor increase.

[5] Nailing schedule in this table is intended to secure the superstructure to the foundation only, and not to provide required edge fastening for plywood siding or sheathing.

[6] Spacing and capacity is based on allowable compression of wood perpendicular to grain for F_c = 565 psi and standard washer = 1 3/8" O.D. and 9/16" I.D. washer (for 1/2" ϕ bolt).

Table C-5A
Horizontal Anchor Capacity For Transverse or Longitudinal Shear Walls[1]
(In pounds per foot of wall)

Concrete or Masonry

Horizontal Capacity[2] lbs./ft.	Required Anchorage[5]		
	Anchor Bolt[4]	Rebar	Spacing[6]
300	1/2”	#4	72” o.c. max.
600	↓	↓	36” o.c.
675			32” o.c.
900			24” o.c.
1350			16” o.c.
1800			12” o.c.
***			
See Table C-3A For Rebar Details			

*** For required Ah greater than 1800 lbs./ft., consider using an engineered design with a higher capacity.

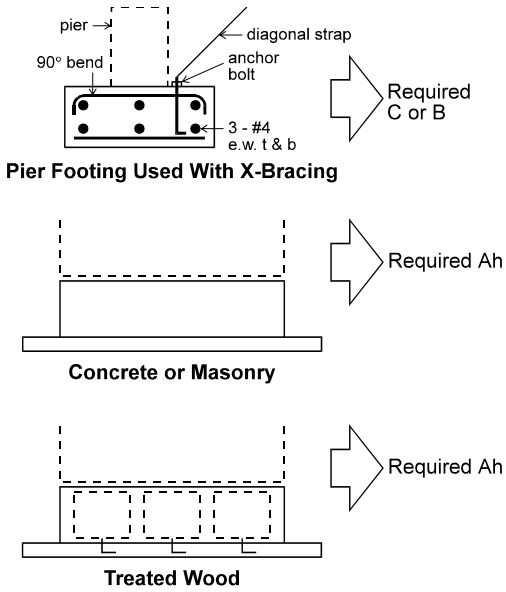


Table C-5B

Treated Wood

Horizontal Capacity[2] lbs./ft.	Required Nailing[3, 4] (Edge Spacing, in.)	Min. Plywood[4] Nailer Thickness	Required Anchorage	
			Anchor Bolt Diameter	Bolt Spacing[7]
300	8d @ 4” o.c.	7/16”	1/2”	4’-0” max.
360	8d @ 4” o.c.	15/32”	↓	3’-4”
449	10d @ 4” o.c.	15/32”		2’-8”
600	10d @ 3” o.c.	19/32”		2’-0”

[1] Compare capacity with required Ah in transverse or longitudinal direction.
[2] Values are based on horizontal load per foot of wall. Select Ah for pier spacing of 4 feet for use with this table.
[3] Assuming 1 1/2” thick sill plate, 3/4” edge distance for wood or composite nailer plates or 20 diameter end distance for plywood sheathing; APA rated, properly seasoned wood; Group III woods, not permanently loaded.
[4] Nailing schedule in this table is intended to secure the superstructure to the foundation only, and not to provide required edge fastening for plywood siding or sheathing.
[5] It is assumed that a reinforcing bar of the same diameter as the anchor is adequately embedded in the footing and lapped with the anchor. In the case of a treated wood foundation wall, the wood wall and its connections must be designed to transfer the anchor load to a concrete footing. This table does not apply to treated wood foundation walls on gravel bases.
[6] Spacing based on bearing capacity of bolt against concrete/grout.
[7] Spacing based on capacity of anchor bolt in bearing against the wood plate. (see also #5.)