

CHAPTER 6 - FOUNDATION DESIGN

600. DESIGN PROCEDURE. In this chapter information about the building site and the building structure are combined and used to determine the size of footings, reinforcing for the foundation, and the size and spacing of anchorage used to tie the unit to the foundation.

600-1. GENERAL

A. Foundation Appendices. The foundation design information in Appendices A, B, & C may be used to design new foundation systems or to verify the design of proposed or existing systems. Appendix A, Foundation Design Concepts, shows design concepts suitable for a variety of manufactured home types and site conditions. Appendix B, Foundation Design Load Tables, provides design requirements for anchorage of the manufactured home to the foundation and recommended footing sizes. Appendix C, Foundation Capacities Tables, provides design capacities for foundation uplift and withdrawal, based on the foundation type chosen (wood, concrete masonry or cast-in-place concrete).

B. Design Verification Sequence. The three Appendices (A, B, & C) are intended to be used in sequence.

1. Appendix A, Foundation Design Concepts, is used to identify acceptable foundation designs based on the manufactured home type and the site conditions.
2. Appendix B, Foundation Design Load Tables, is used to determine the required footing sizes and the required vertical and horizontal an-

chorage forces to be transferred to the foundation.

3. The required anchorage values are used in Appendix C, Foundation Capacities Tables, to determine the materials, dimensions, and construction details of the foundation.

C. Design Criteria and Design Loads.

The design criteria and loads are needed for the Foundation Design Load Tables (Appendix B).

1. Width of Unit. The measured width of the manufactured home, converted to a nominal width is needed.
2. Height of Unit. The unit is assumed 8'-0" tall from bottom of floor framing to eave at roof. Ceilings may be horizontal (flat) or cathedral sloped.
3. Design Loads. The design ground snow load, wind speed, seismic ground acceleration and seismic performance category are needed. Refer to Appendix H to determine the design load values.

D. Effective Footing Area (Aftg). The footings for the permanent foundation must be sized to prevent sinking or settlement of the manufactured home. Footing area is given the abbreviation (Aftg). The values for (Aftg) are given in square feet (sf) for pier footings and feet (ft) for wall footing width. Refer to Appendix D for the derivation of equations for the determination of effective footing areas.

E. Vertical Anchorage (Av). The manufactured home must be securely anchored to the foundation. One critical anchorage requirement is for the structure to resist uplift and overturning from wind activity in the transverse direction. This is vertical anchorage and it can be achieved at the chassis beams or along longitudinal wall locations, or both locations. It is given the abbreviation (Av), and the (Av) values are all given in pounds (lbs. per pier or lbs. per foot of foundation wall). Refer to Appendix D for the derivation of the equations for determination of required vertical anchorage force.

F. Horizontal Anchorage (Ah). Another critical anchorage requirement is for the manufactured home to resist horizontal sliding forces in both the transverse and longitudinal directions. Horizontal forces are a result of wind or seismic activity. Horizontal anchorage is given the abbreviation (Ah). The transverse or longitudinal direction relates to the direction of force application and to the orientation of the resistance elements, such as the transverse vertical X-bracing planes or the longitudinal walls of the unit respectively (see Figure 1-1). The values for (Ah) are given in pounds per foot (lbs./ft.). Refer to Appendix D for the derivation of equations for determination of required horizontal anchorage force.

G. Loads Included and Load Combinations. All applicable gravity loads (dead, occupancy and snow or minimum roof live) and all lateral loads (wind or seismic) have been considered in the development of the Foundation Design Load Tables of Appendix B. Chapter 4 gives a brief description of each load and Appendix D derives the equations upon which the magnitude of these loads is determined for any geographic location and unit Type. Appropriate load combinations have

been selected from ASCE 7-93 for allowable stress design as follows:

1. The load combination used for The Foundation Design Footing Tables (Appendix B, Part 1) is:

$$DL \text{ (heavy)} + LL \text{ (occupancy)} + LL \text{ (attic)} + SL \text{ (or min. roof LL)}.$$

2. The load combination used for The Foundation Design: Anchorage Tables (Appendix B, Part 2,3,4) is:

$$(\text{Wind or Seismic}^*) \pm DL \text{ (light)}$$

- * Heavy DL was used to calculate the roof and floor inertia forces only.

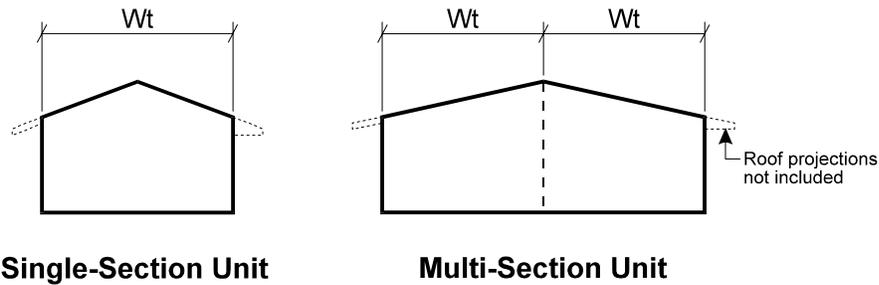
600-2 DETERMINATION OF BUILDING WIDTH

A. Building Width for Use of Appendix B Tables. The actual measured building width must be converted into the nominal building width for use in the Foundation Design Footing Tables and Anchorage Tables. The nominal building width should be calculated as follows:

1. To obtain the nominal building width for use in the Foundation Design: use the following information:

<u>Actual Building Width</u>	<u>Nominal Width</u>
11'-4" to 12'-0"	12'
13'-4" to 14'-0"	14'
15'-4" to 16'-0"	16'

2. The tables are based upon the width of each section as it is transported. A multi-section superstructure classified as a nominal 14-foot width could be 26'-8" to 28'-0" in actual width.



Unit Width Description

Figure 6 - 1

3. The nominal width to be used in the Foundation Design Load Tables should be recorded.

B. Width Illustration. If there is a question about which dimension is actually the width of the structure, see Figure 6-1. The width of the home is shown as W_t (nominal 12', 14', or 16'.)

600-3. DETERMINATION OF DESIGN GROUND SNOW LOAD. Verify the geographic location where the unit will be sited. Refer to the ground snow load map on pages H-11, H-12 and H-13, and read the pound per square foot (psf) isobar for the intended site. Note that a mandatory minimum roof live load may be greater than the roof snow load. Refer to section 402-2.A and C for further clarification.

600-4. DETERMINATION OF DESIGN WIND SPEED. Verify the geographic location where the unit will be sited. Refer to the wind speed map on page H-14 and read the MPH wind speed isobar for the intended site. Note that a minimum wind speed of 80 MPH is required by the *Minimum Property Standards*, even if the map isobar shows a smaller MPH value. Establish if the site is Inland or Coastal (section 402-3.B).

600-5. DETERMINATION OF DESIGN SEISMIC FACTORS.

A. Determine Design Seismic Ground Acceleration Values.

1. Verify the geographic location where the unit will be sited.
2. Refer to the two Ground Acceleration Contour Maps on pages H-15 and H-16 and read (A_a) from map 1 and (A_v) from map 2 for the isobar closest to the site.
3. The manufactured home is exempt from seismic requirements if the map value for (A_v) is less than 0.15; therefore, wind becomes the only lateral load design issue. If (A_v) is equal to or greater than 0.15 seismic provisions must be met (Section 402-4).

B. Determine the Required Seismic Performance Category.

1. A seismic hazard exposure group of (I) is assumed for single family residences.
2. The seismic value (A_v) and the Seismic Hazard Exposure Group (I)

are used to assign the manufactured home to a Seismic Performance Category. Refer to the Seismic Performance Category Table on page H-17, enter the Table with these two values and record either (C) or (D) as applicable. Note that if (C) is the correct Category, it is required to comply with the requirements for Category (A) and (B) as well as (C). If Category (D) is the correct Category, then the requirements for Category (A) through (D) must be met. These requirements, as they pertain to permanent foundations for manufactured housing are listed in Section H-300 as a reference. The Foundation Concepts illustrated in Appendix A can meet the intent of the foundation requirements of Section 9.7 of ASCE 7-93 for Seismic Performance Categories (A) through (D).

3. The manufacturer shall verify that the unit provides continuous load paths with adequate strength and stiffness to transfer all forces from the point of application to the point

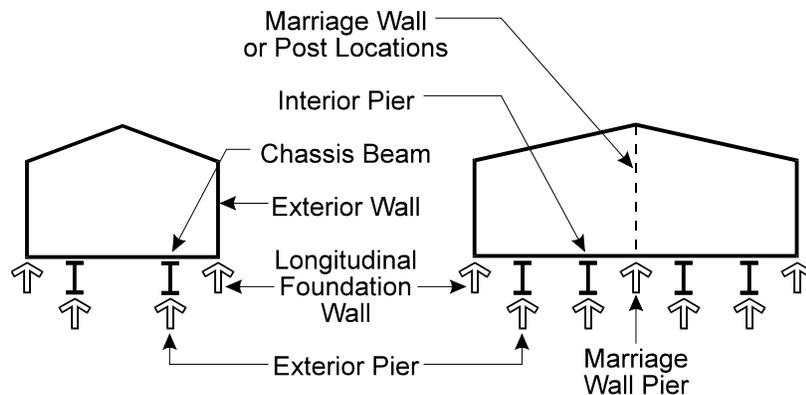
of resistance at the foundation. The design and detailing of the unit shall comply with Section 9.3.6 of ASCE 7-93 for the Seismic Performance Category assigned in step 2 above.

601. VERIFYING THE FOUNDATION DESIGN CONCEPT (APPENDIX A)

601-1. LOCATION OF FOUNDATION SUPPORTS

A. Definition of Support. Support is herein defined as the location where the gravity loads (dead, occupancy, snow, minimum roof live load) within and applied to the unit are transferred to the foundation system.

B. Illustration of Support Locations. The acceptable locations where foundation piers and walls support the unit are illustrated in Figure 6-2. Terms that appear throughout Appendices A, B and C are also defined. Some or all of the illustrated locations may be used, but symmetry of the support system must be maintained. Note that marriage walls may be continuous walls, or contain specifically located openings with posts at the ends of each



Definition of Terms and Possible Support Locations

Figure 6 - 2

opening.

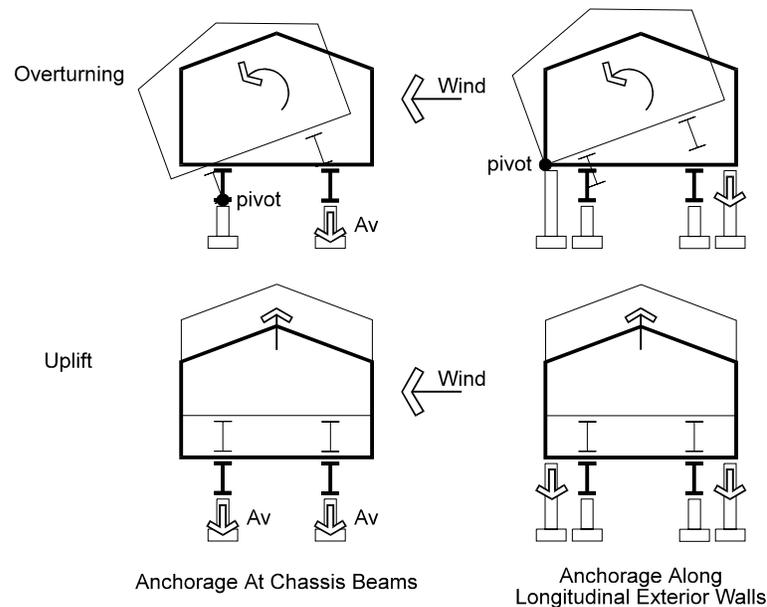
C. Determine the Location of Foundation Supports. Single-section or multi-section units are supported by equally spaced piers along their chassis beams, by exterior longitudinal walls or both. Multi-section units may possibly have additional equally spaced pier supports along a continuous marriage wall, and have piers placed according to post locations at the ends of specific marriage wall openings. Select one of the following unit support options:

Type C: Piers are equally spaced along the chassis beams for single-section units. Additional piers may exist below continuous marriage walls and under posts at the ends of openings within the marriage wall, that exist for multi-section units. If no support exists below the marriage

wall the unit is defined as a Type **Cnw**, and no openings can be permitted in the marriage wall. It must be a continuous wall, supported by the floor and chassis beam system.

Type E or I: A combination of longitudinal exterior walls and equally spaced piers under the chassis beams are used for single-section or multi-section units. The same discussion regarding continuous marriage walls and marriage walls with openings within them, as found under Type **C**, applies to Type **E** and **I**.

601-2 LOCATION OF VERTICAL ANCHORAGE (A_v) IN THE TRANSVERSE DIRECTION.



Overturning and Uplift Resistance Options

Figure 6 - 3

A. Definition of Vertical Anchorage.

Vertical anchorage exists in the transverse direction when a mechanical connection is made between the manufactured home unit and the foundation to resist wind related overturning and uplift forces. Overturning is the tendency for the unit to rotate about a pivot point either at the bearing point between chassis beam and support pier, or the bearing between the unit and the longitudinal exterior wall. This rotation lifts the unit off its other bearing points; therefore, requiring vertical anchorage (tie-down) to resist the force. Uplift of the unit occurs as wind passes over the roof surface, tending to lift the unit. Vertical anchorage resists this force. See Figure 6-3 for illustration of both of these effects in the transverse direction. Analysis for both effects in the transverse direction indicates that overturning forces are greater than uplift forces. Thus, Appendix B, Part 2 Vertical Anchorage Tables are based on overturning behavior with the knowledge that uplift forces will also be handled. Locations for this mechanical connection exist either along the chassis beams and/or along the exterior longitudinal walls. Vertical anchorage and gravity support may exist at the same locations, but other combinations of support and anchorage may exist. Connection types include anchor bolts, welds, or a broad range of framing anchors and fasteners common to the wood industry. A unit that merely sits on its foundation, does not constitute vertical anchorage of the unit. A physical connection of adequate capacity is required for vertical anchorage to exist.

B. Determine Locations of Vertical Anchorage (Av). The character of the foundation support Type selected in section 601-1.C must be reviewed for vertical anchorage capability. The manufactured home unit may be anchored by any of the methods described in section

601-2.A. Select one of the following vertical anchorage options:

Type C: Vertical anchorage is along the chassis beams only, and occurs at the equally spaced support piers for single-section units. Multi-section units may utilize the exterior chassis beams (2 ties) or all the chassis beams (4 ties) for vertical anchorage to the support piers.

Type C1: Vertical anchorage is typically provided by external straps which wrap over the top and down the sides of the unit. Short vertical ties, which attach directly to the home's exterior wall structure, are a possible alternate. These straps or ties attach to concrete "dead man" footings set at the appropriate depth below grade. The straps or ties are generally spaced to match support pier locations; however, variations are possible. These anchorage types are limited to single-section units. It is required that the first external straps or ties be a minimum of 2 feet in from each end of the unit with the remainder equally spaced.

Type E: Vertical anchorage is only along the exterior longitudinal walls for single-section units. Multi-section units may vertically anchor to exterior longitudinal walls (2 ties) or vertically anchor to exterior longitudinal walls and interior chassis beams at the equally spaced piers (4 ties).

Type I: Vertical anchorage is along the chassis beams only, and occurs at the equally spaced support piers for

single-section units. Type **I** vertical anchorage differs from Type **C** vertical anchorage only in its pivot point location for overturning. Multi-section units may utilize the exterior chassis beams (2 ties) or all of the chassis beams (4 ties) for vertical anchorage at the equally spaced support piers.

601-3. LOCATION OF HORIZONTAL ANCHORAGE (Ah)

A. Definition of Horizontal Anchorage.

Horizontal anchorage exists when a mechanical connection is made between the manufactured home unit and the foundation to resist sliding due to wind or seismic lateral forces. Sliding can occur in the transverse direction or the longitudinal direction, and both directions must independently be checked. Sliding involves horizontal movement in the transverse or longitudinal direction of the unit, and if the wind or seismic event is of large enough magnitude, these horizontal forces can result in the unit sliding off its foundation. Anchorage between unit and foundation to avoid this situation is accomplished in one of two ways: (1) utilizing bolts, welds or other acceptable means to connect the unit to foundation walls that are made of concrete masonry, treated wood or concrete, or (2) utilizing vertical X-bracing planes of galvanized rod or wire diagonal ties or straps between the top side of the steel chassis beams diagonally down to the top of the concrete footings.

B. Determine Locations of Horizontal Anchorage (Ah). Horizontal sliding must be resisted both in the transverse and longitudinal directions. Options for each direction are as follows:

1. Transverse Direction: Anchorage location options include 2, 4, or 6 transverse walls (shear walls) or a select number of vertical planes of X-bracing (trussing) with galvanized rods, wires or straps. Figure 6-4 illustrates these individual options for a single-section unit and Figure 6-5 illustrates one combination of these options, also for a single-section unit. Selection of transverse horizontal anchorage location option is not influenced by the selection of Type C, E or I unit for support or vertical anchorage in the transverse direction as done in sections 601-1 and 601-2.
2. Longitudinal Direction: Anchorage location options include either the two exterior longitudinal walls (for single or multi-section units) or the chassis beam lines (2 for single-section units, or 4 for multi-section units), where vertical planes of X-bracing with galvanized rods, wires or straps are possible. Illustration of the two choices is shown in Figure 6-6 for a single-section unit. Selection of longitudinal horizontal anchorage location option is not influenced by the selection of Type C, E or I unit for support or vertical anchorage in the transverse direction as done in sections 601-1 and 601-2.

601-4. FOUNDATION CONCEPT SELECTION. Whether designing a new permanent foundation or upgrading an existing foundation to a permanent foundation, confirmation of a foundation concept from Appendix A is required. The permanent foundation type is a function of the support option selected in sec-

tion 601-1.C and the vertical anchorage option selected in section 601-2.B. Note: The horizontal anchorage option is independent of these two issues and does not influence selection of foundation type.

A. Three Basic Foundation Types. A summary of the structural characteristics required for each type of permanent foundation system follows:

Type C: Support and vertical anchorage occurs at equally spaced points along the Chassis beam lines only. This is true for single-section or multi-section units.

Type E: Support occurs at the Exterior longitudinal foundation walls as well as at equally spaced points along the chassis beam lines. Vertical anchorage occurs continuously along the exterior longitudinal foundation walls for single-section or multi-section units (2 ties), or a combination of vertical anchorage can occur continuously along the exterior longitudinal foundation walls and along the equally spaced pier locations along interior chassis beams (4 ties).

Type I: Support occurs at the exterior longitudinal foundation walls as well as at equally spaced piers along the

chassis beam lines, just as for Type E, for single-section or multi-section units. Vertical anchorage occurs at the equally spaced piers along the chassis beam lines only for single-section or multi-section units (2 ties or 4 ties).

B. Illustration of Foundation Types and Concepts. Single-section foundation types and detailing concepts are illustrated in Figure 6-7 and Appendix A. Multi-section foundation types and detailing concepts are illustrated in Figure 6-8 and Appendix A. The meaning of the arrow orientation in both Figures is as follows:

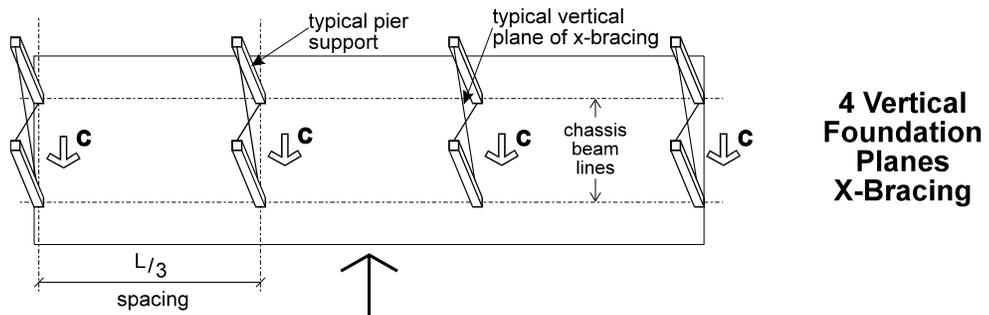
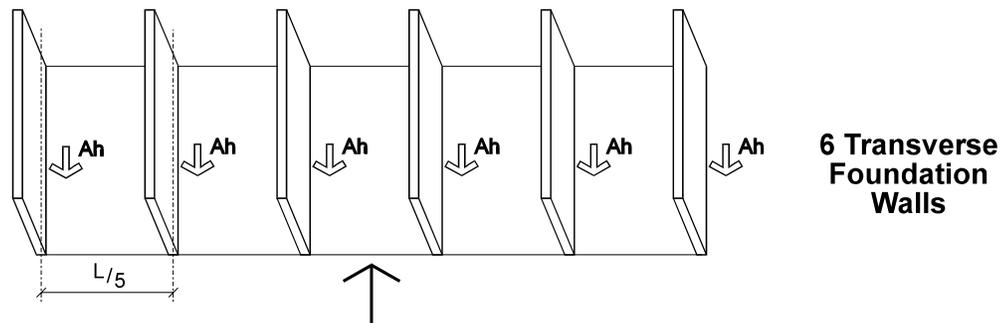
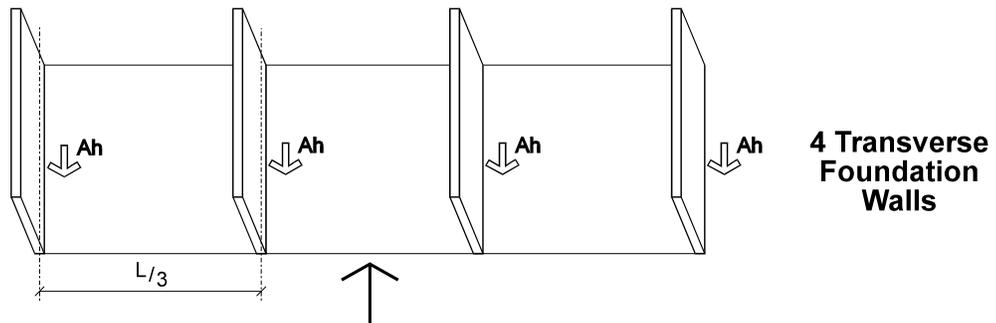
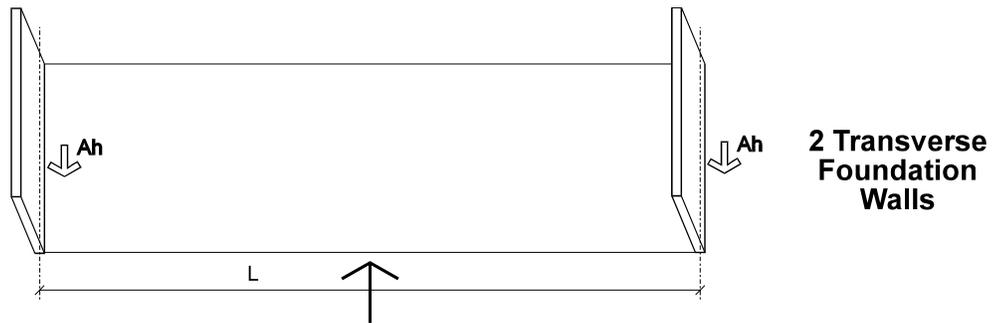
Symbols:  vertical anchorage (uplift and overturning)
 support (gravity)

Type C: concepts C2 to C4

Type E: concepts E1 and E8 (E2 omitted in this revision)

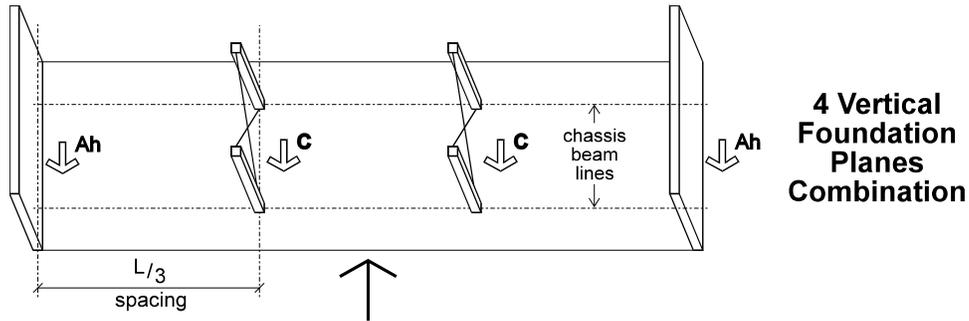
Type I: included here as possible future design concepts. None were currently submitted by manufacturers.

C. Determine Foundation Concept. Based on the foundation type selected, choose one of the several concept options below:



Sliding Resistance Options - Transverse Direction

Figure 6 - 4



Sliding Resistance - Combination Option - Transverse Direction

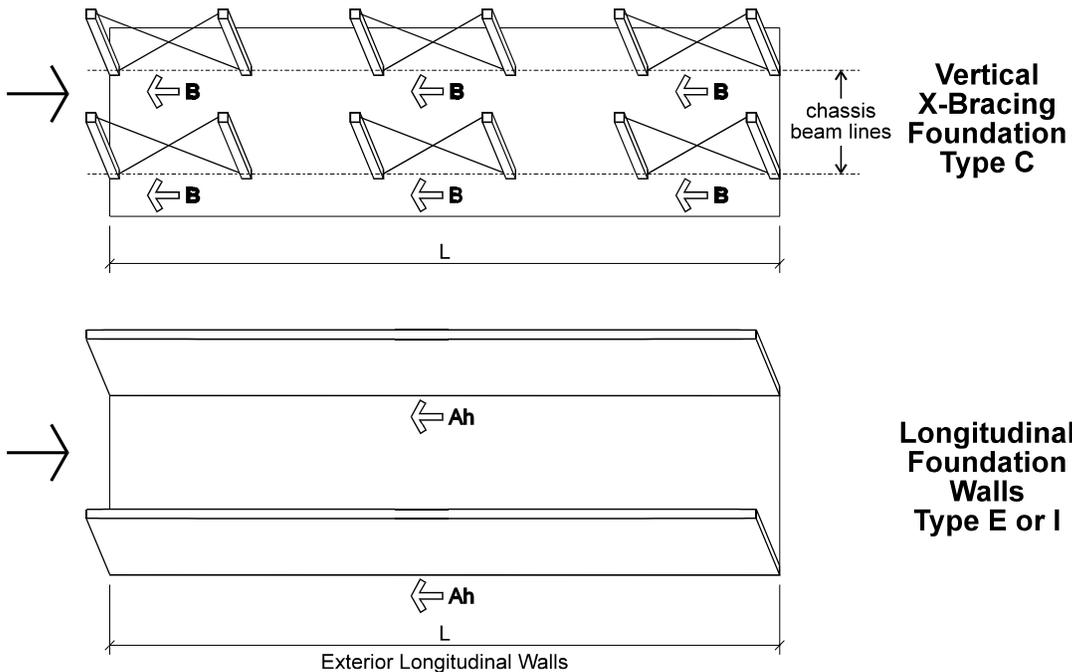
Figure 6 - 5

D. Additional Foundation Types and Concepts. Some combinations of support and vertical anchorage, other than the basic Types C, E and I. Should that be the case, select one of the concept options below:

Type **C1**: concept C1 (Single-section)

Type **E**: concept E3, E4 (single-section)
concept E3 (multi-section)
concept E5, E6, E7 (multi-section)

Type **Cnw**: concepts C2, C3, C4 (type Cnw stands for a Type C multi-section with no marriage wall)



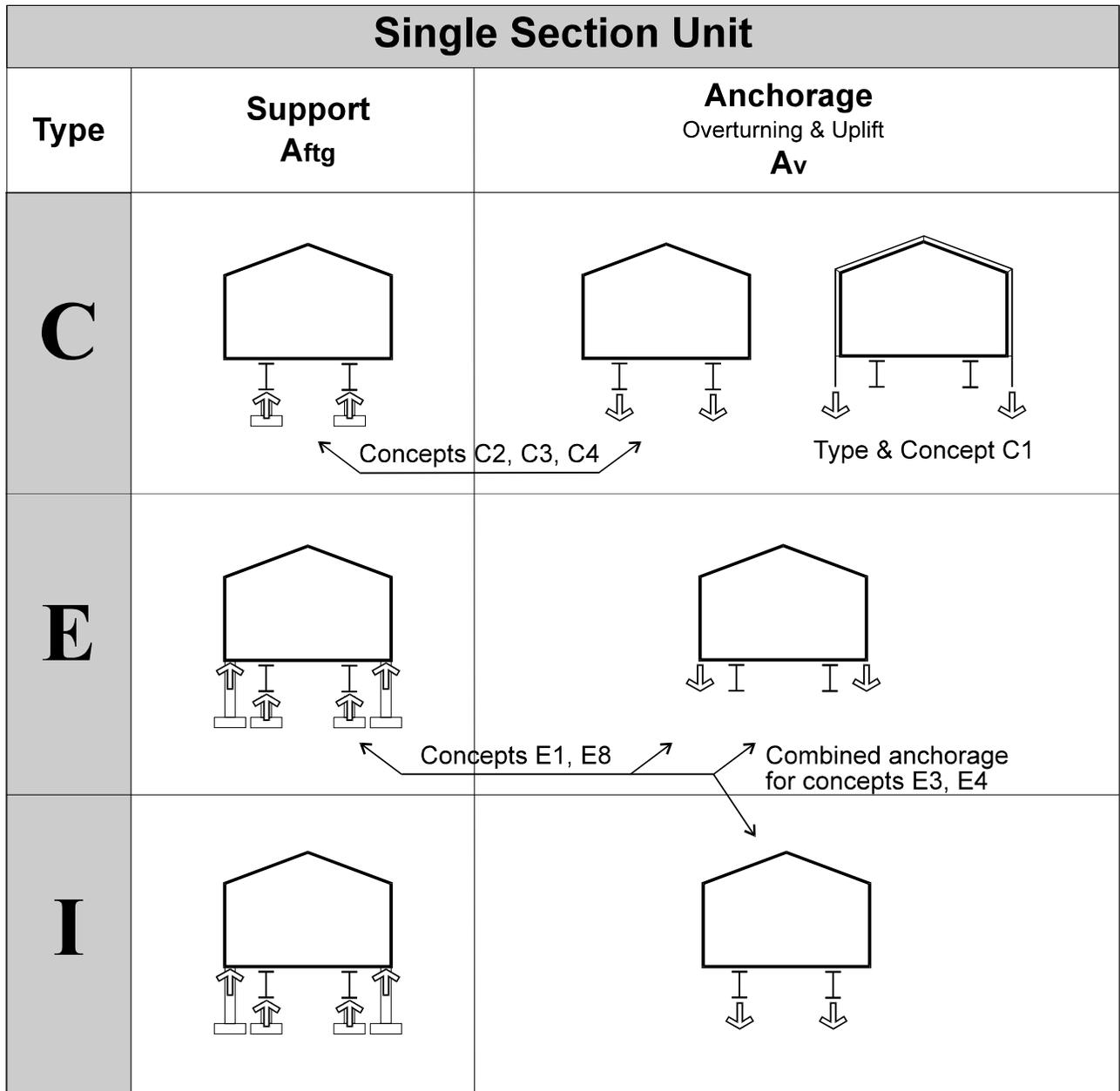
Sliding Resistance Options - Longitudinal Direction

Figure 6 - 6

602. USING THE FOUNDATION DESIGN TABLES (APPENDIX B)

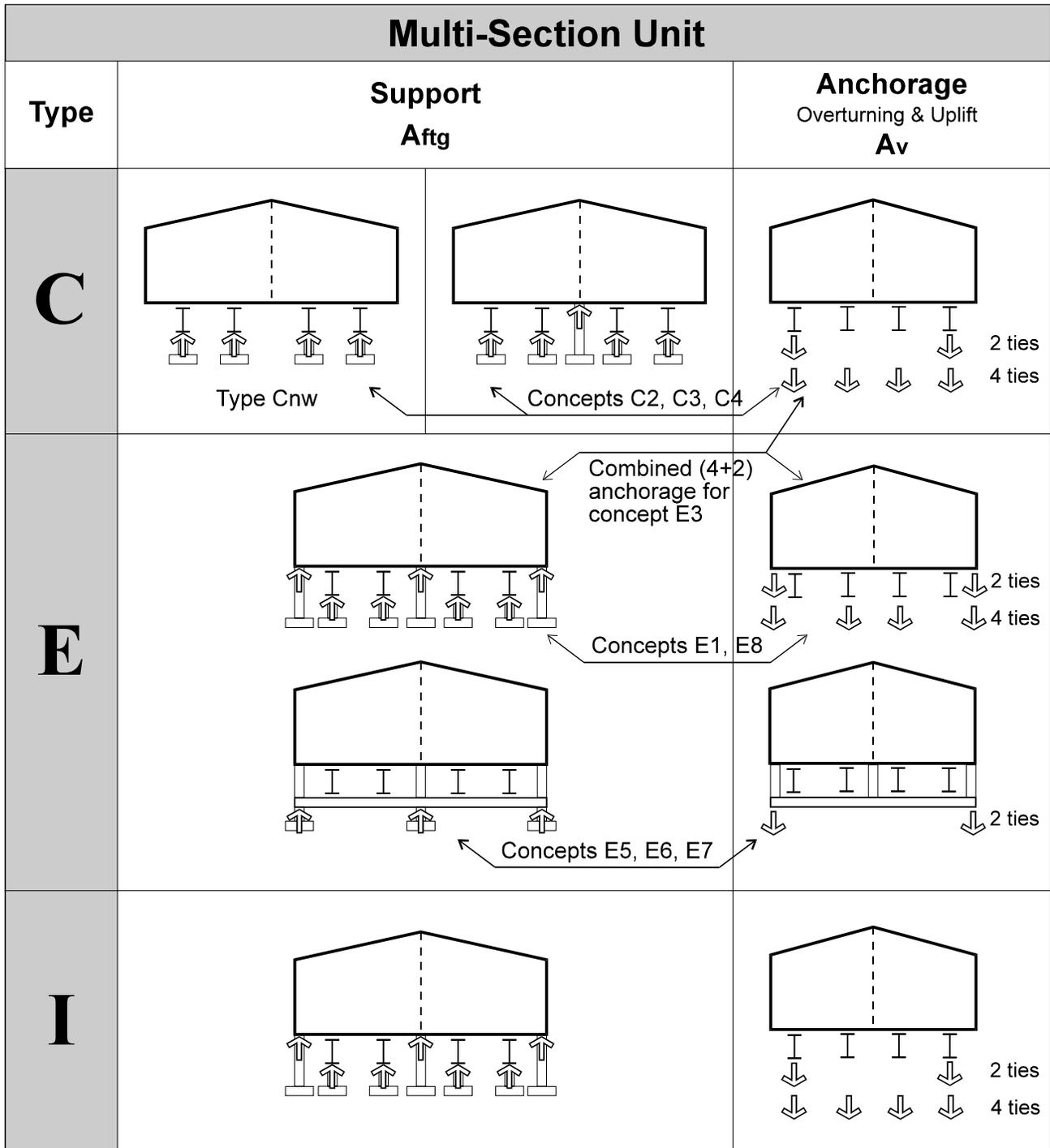
602-1. GENERAL. The Foundation Design Load Tables (Appendix B) are used to deter-

mine foundation footing sizes required, plus vertical and horizontal anchorage forces to be resisted for all the foundation types. This section gives step-by-step instructions for using the Foundation Design Load Tables.



Foundation Design Concepts: Single-Section Units

Figure 6 - 5



Foundation Design Concepts: Multi-Section Units

Figure 6 - 6

602-2. FOUNDATION VOCABULARY.

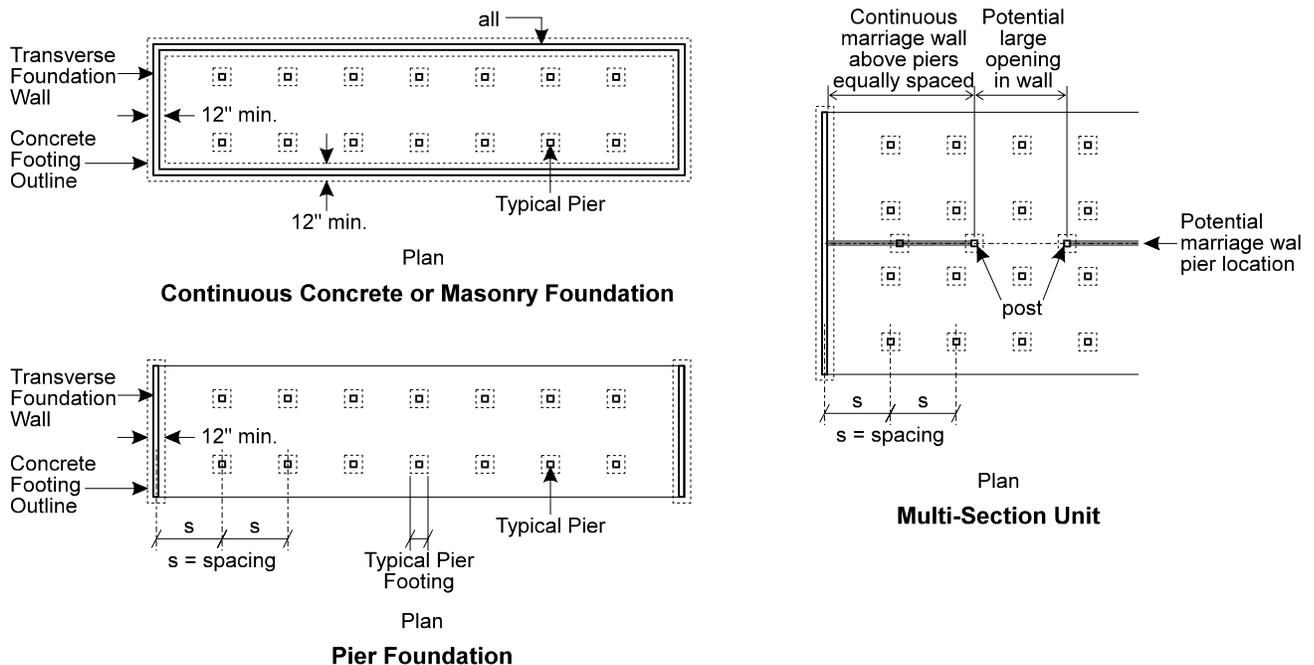
Figure 6-9 illustrates the following foundation terms.

A. Pier Foundations. The longitudinal variety of spacing of piers under the chassis beam lines as shown in the Foundation Design Load Tables is 4, 5, 6, 7, 8 and 10 feet. If pier spacings other than those shown are contemplated, use the next largest spacing (i.e. for 4.5 feet use 5 feet). Piers placed under continuous marriage walls are assumed equally spaced, while piers must be placed under posts that define the ends of a large opening in a marriage wall. These openings are assumed to range from 10 to 20 feet in 2 foot increments. All marriage wall piers are assumed to only participate in transferring gravity loads, thus they do not participate in resistance to overturning or sliding. Piers may be made of concrete, concrete masonry or steel. Reinforcing is required

for all concrete or masonry pier concepts in seismic regions with A_v greater than or equal to 0.3. The values shown in the Foundation Design Load Tables are values based on the pier spacing in pounds per pier (lbs) for (A_v), and square feet for (A_{ftg}), whether exterior, interior or marriage wall piers.

B. Transverse Foundation Walls.

Transverse foundation walls can occur at the exterior ends of a single-section or multi-section unit, as well as at selected interior locations along the length of the unit. A continuous concrete footing must exist under the transverse walls regardless of the wall material: concrete, concrete masonry or treated wood. Interior transverse foundation walls of concrete or masonry can: (1) box around the chassis beams and provide direct continuous connection to the floor structure of the unit, or (2) the wall can stop at the underside of the chassis



Foundation Terms

Figure 6 - 7

beams and utilize diagonal steel straps or diagonal wood ties to complete connection between the transverse wall and the unit's floor structure. Appendix A illustrates these approaches. Reinforcement will be required for most transverse wall concepts. The values shown in the Foundation Design Load Tables (Appendix B) for horizontal anchorage (**Ah**) are values based on pounds per lineal foot (lbs./ft.) of wall.

C. Longitudinal Foundation Walls. Longitudinal Structural foundation walls are provided for foundation Types **E** and **I**. A continuous concrete footing must exist under the longitudinal foundation walls regardless of the wall material: concrete, concrete masonry or treated wood. Reinforcement will be required for all longitudinal wall concepts. The values shown in the Foundation Design Load Tables (Appendix B) for: (1) vertical anchorage (**Av**) are values based on a continuous wall support in pounds per lineal foot (lbs./ft.) of wall, (2) horizontal anchorage (**Ah**) are values based on pounds per lineal foot (lbs./ft.) of wall and (3) footing width values are in feet (ft) for (**Aftg**).

602-3. REQUIRED FOOTING AREAS (Aftg) (APPENDIX B, PART 1)

A. General. The foundation must be capable of transmitting the total gravity load to the soil without exceeding the net allowable soil bearing pressure. The gravity loads consist of the unit dead weight, snow load or minimum roof live load, and occupancy live load. Bearing against the soil is accomplished with square concrete footings under piers and continuous linear concrete footings under walls. Compliance with this requirement should prevent excessive differential settlement.

B. Determine Design Ground Snow Load / Minimum Roof Live Load. This step has been done in section 600-3 and is required for single-section and multi-section units.

C. Occupancy Live Loads. The residential occupancy floor live load is 40 psf in all the model codes and has been used as the floor live load in the Tables of Appendix B, Part 1. Attic live load is assumed to be 10 psf.

D. Determine Net Allowable Soil Bearing Pressure. The maximum net allowable soil bearing pressure shall be based on a geotechnical investigation, a national model code presumptive value, or an assigned value by the local authority having jurisdiction, as described in Chapter 2. The Tables in this document assume a minimum of 1000 psf. The value for design should be recorded in the Owner's Site Acceptability Worksheet (Appendix E, question # 10 or #11).

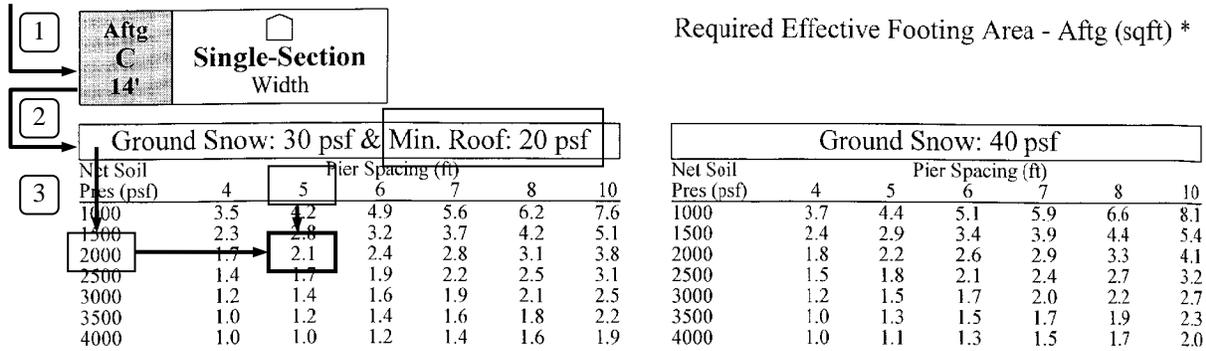
E. Determine (Aftg) Value from the Tables. Refer to Appendix B, Part 1 of the Foundation Design Load Tables. Several steps must be followed to arrive at the pier and/or wall footing sizes:

1. Select the correct Table based on the foundation type (**C**, **Cnw**, **E,I** or **E5**; single-section or multi-section) and the unit nominal width (12, 14 or 16 feet).
2. Enter the selected Table with the design ground snow load or minimum roof live load. This step is slightly different depending on unit Type as follows:

Type C (single-section or multi-section), Type Cnw, and Type E, I multi-section: Blocks of values

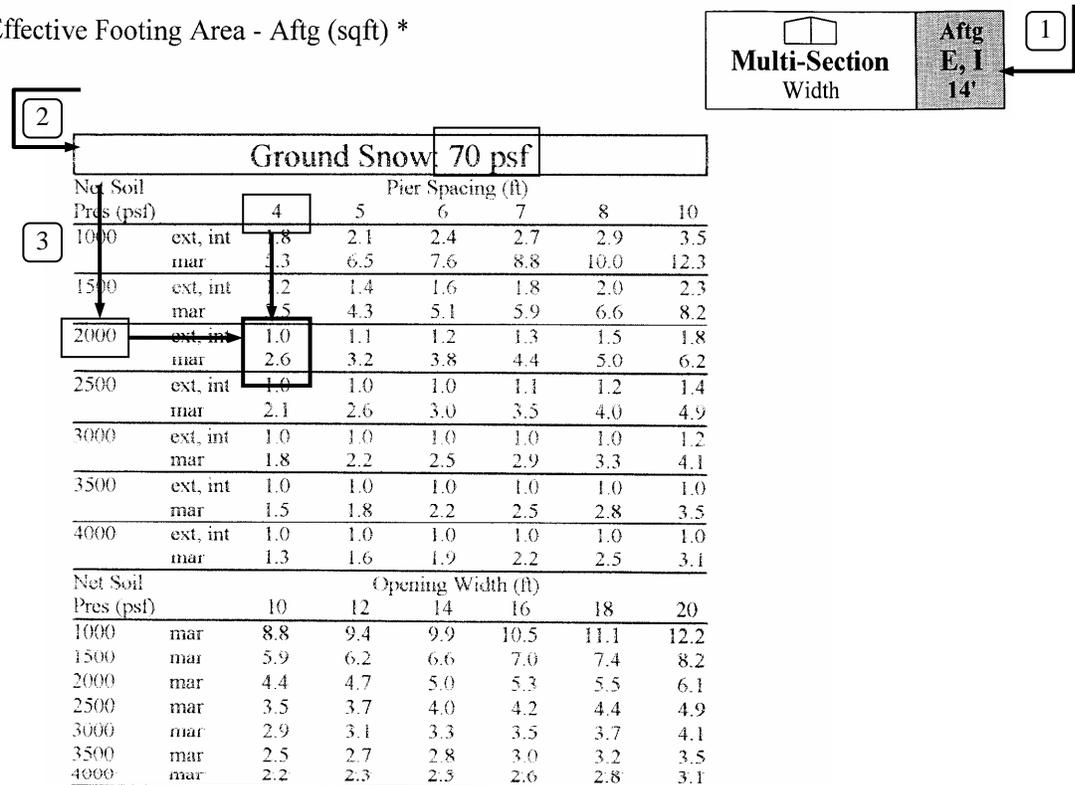
have headings for the various ground snow load and minimum roof live load magnitudes. Select

Example 1: Type: C - Single-Section Unit; Location: Tampa, FL.; Wt = 14 ft.; L = 60 ft.; Roof Slope: 2 in 12; 4 Transverse Shear Walls; Pier Spacing: 5 ft.; Pg = 0 psf.; Min. Roof LL = 20 psf.; V = 100 mph.; Coastal; Seismic $\underline{A}_v = 0.05$; $\underline{A}_a = 0.05$; Allowable Soil Pressure: 2000 psf.



Example 2: Type: E - Multi-Section Unit; Location: West Yellow Stone, MT.; Wt = 14 ft.; L = 60 ft.; Roof Slope: 2 in 12; 4 Transverse Walls; Pier Spacing: 5 ft; Pg = 70 psf.; V = 80 mph.; Inland; Seismic $\underline{A}_v = 0.40$; $\underline{A}_a = 0.40$; Allowable Soil Pressure: 2000 psf. Marriage wall opening width = 14'-0".

Required Effective Footing Area - Aftg (sqft) *



the correct ground snow load block of values.

Type **E** or **I** single-section: Snow load is included in the loading combination but is not required to move to the next step.

3. Select the row for the required net allowable soil bearing pressure and proceed horizontally until the desired, or manufacturer's recommended, pier spacing is located (see the Manufacturer's Worksheet in Appendix E, item #10 or #11). Read and record on the Design Worksheet (Appendix F) the required footing areas for interior and exterior pier footings and continuous marriage wall footings (as required).
4. When the marriage wall of a multi-section unit has a large opening, the lower portion of the block of values is also required. Re-use the net allowable soil bearing pressure and move horizontally until the selected opening width is found. Read the required effective footing area (Aftg) for the piers required at the ends of the opening. Record on the Design Worksheet (Appendix F).

Note: For Types **E** and **I**, the exterior wall footing is a minimum 1'-0" wide for single or multi-section units. Read the footnotes at the bottom of each table for special cases where for certain ground snow loads in combination with an allowable soil pressure of 1000 psf other minimum footing widths are required.

602-4. REQUIRED VERTICAL ANCHORAGE (A_v) IN THE TRANSVERSE DIRECTION (APPENDIX B, PART 2)

A. General. The foundation must provide enough structural capacity to resist uplift and overturning forces due to wind pressure and suction. These forces are resisted by connections to anchors at the piers or to anchors along the longitudinal foundation walls. Seismic inertia forces generated from the ground acceleration and the mass of roof and floor planes of the manufactured housing unit were **not** found to control over wind for overturning in the transverse direction, regardless of whether a single-section or multi-section unit was analyzed, and regardless of seismic, wind or snow zone.

B. Determine Design Wind Speed. This step has been done in section 600-4, and is required for single-section and multi-section units.

C. Determine (A_v) Value from the Tables. Refer to Appendix B, Part 2 of the Foundation Design Load Tables. Several steps must be followed to arrive at the Required Vertical Anchorage in the Transverse Direction:

1. Select the correct Table based on the foundation type (**C**, **C1**, **E** or **I** for single-section units and **C**, **E** or **I** for Multi-section units); 2 tie-downs or 4 tie-downs; 12, 14 or 16 foot nominal unit width).
2. Enter the selected Table and move down the wind speed column until the design wind speed magnitude (for Inland or Coastal region) is reached. Read horizontally across the row until the desired, or manu-

manufacturer recommended, pier spacing is reached.

3. Read (A_v) and record on the Design Worksheet (Appendix F) the value with its appropriate units as shown in the table. Steps 1 through 3 were described for Type C, C1 or I single-section units. For Type E single-section units or multi-section units with 2 tie-downs, values must be multiplied by the anticipated spacing of connections along the exterior longitudinal walls. For Type C or I multi-section units select the Table for 2 tie-downs or 4 tie-downs (whichever applies) and

proceed as above to find the correct value. For Type E multi-section units with 4 tie-downs read two values, first for interior pier locations, and second for exterior longitudinal wall locations.

D. Comparison With Home Manufacturer's Values (Optional). The value for (A_v) determined from the Tables must be compared to the value supplied by the manufacturer. The home manufacturer's uplift resistance value must be equal or greater than the vertical anchorage requirement from the Tables.

602-5.REQUIRED HORIZONTAL ANCHORAGE (A_h) IN THE TRANSVERSE DIRECTION (APPENDIX B, PART 3)

Example 1:

Required Vertical Anchorage - A_v (lbs)

Wind Speed (mph)	Pier Spacing (ft)						
	4	5	6	7	8	10	
Inland	80	960	1300	1450	1690	1930	2410
90	1370	1710	2060	2400	2740	3200	3660
100	1830	2280	2740	3200	3660	4570	
110	2330	2910	3500	4080	4660	5830	
Coastal	80	1120	1400	1680	1960	2240	2800
90	1570	1960	2360	2750	3140	3930	
100	2070	2590	3110	3630	4150	5180	
110	2630	3290	3940	4600	5260	6570	

Single-Section
Width

A_v
C
14'

1

Example 2:

Required Vertical Anchorage - A_v (lbs)

Wind Speed (mph)	Exterior (lbs/ft)	Interior Pier Spacing (ft)						
		4	5	6	7	8	10	
Inland	80	80	210	270	320	370	420	530
90	160	390	490	580	680	780	970	
100	230	590	730	880	1030	1170	1470	
110	320	810	1010	1210	1410	1610	2010	
Coastal	80	110	280	350	420	490	560	700
90	190	480	590	710	830	950	1190	
100	280	690	870	1040	1210	1390	1730	
110	370	930	1170	1400	1640	1870	2340	

A_v
E
14'
4

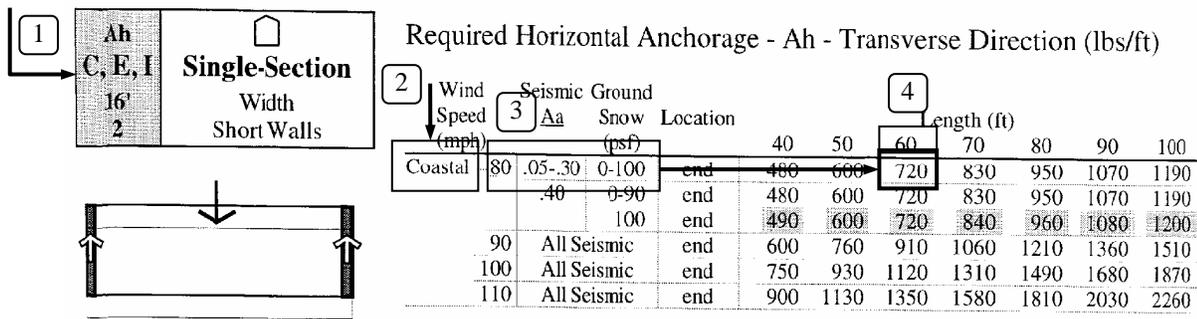
Multi-Section
Width
Tiedowns

1

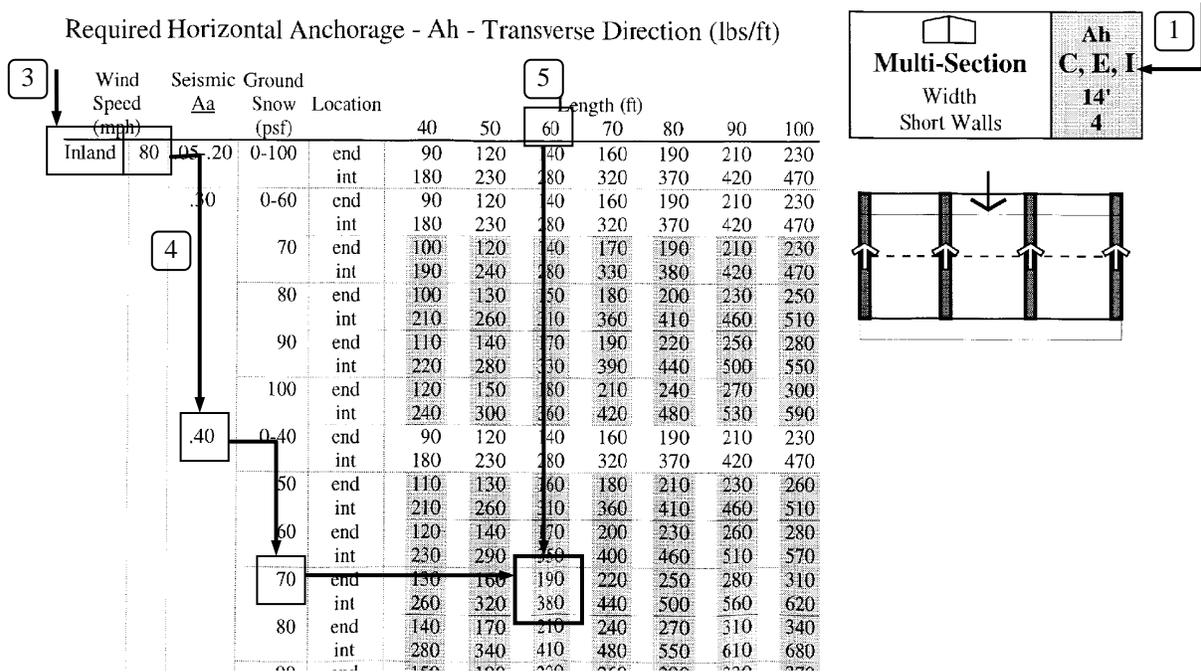
A. General. The attachment of the unit to the foundation must provide sufficient structural anchorage for the manufactured home to resist sliding forces due to wind pressures and suctions or seismic inertia forces, whichever controls. Analysis, based on the conservative load assumptions of this handbook, has shown

that in the transverse direction for single-section units and for multi-section units, it is necessary to check both wind and seismic to determine which force controls. These horizontal forces are resisted by connection of the unit to anchors along the exterior walls, plus any additional interior transverse walls; or by

Example 1:



Example 2:



connection of the unit to a combination of exterior and interior vertical planes of X-bracing at pier locations. Interior transverse walls may be either full height or short of the chassis beams and completed with some form of diagonal bracing. See illustration of options in Appendix C.

B. Determine Design Ground Snow Load. This step has been done in section 600-3 and is only required for multi-section units, where it may influence seismic values.

C. Determine Design Wind Speed. This step has been done in section 600-4, and is required for single-section and multi-section units.

D. Determine Design Seismic Ground Acceleration Values and Required Seismic Performance Category. This step has been done in section 600-5 and is required for single-section and multi-section units.

E. Determine Horizontal Anchorage (Ah) in the Transverse Direction from the Tables. Refer to Appendix B, Part 3 of the Foundation Design Load Tables. Several steps must be followed to arrive at the Required Horizontal Anchorage in the Transverse Direction:

1. Select the correct Table based on single-section or multi-section unit, nominal unit width of 12, 14 or 16 feet, and whether 2, 4, or 6 transverse walls (the handbook has limited the number of transverse walls to 6). Note that the foundation type does not influence the required horizontal anchorage force, thus the heading for all the Tables read: Type C, E or I.

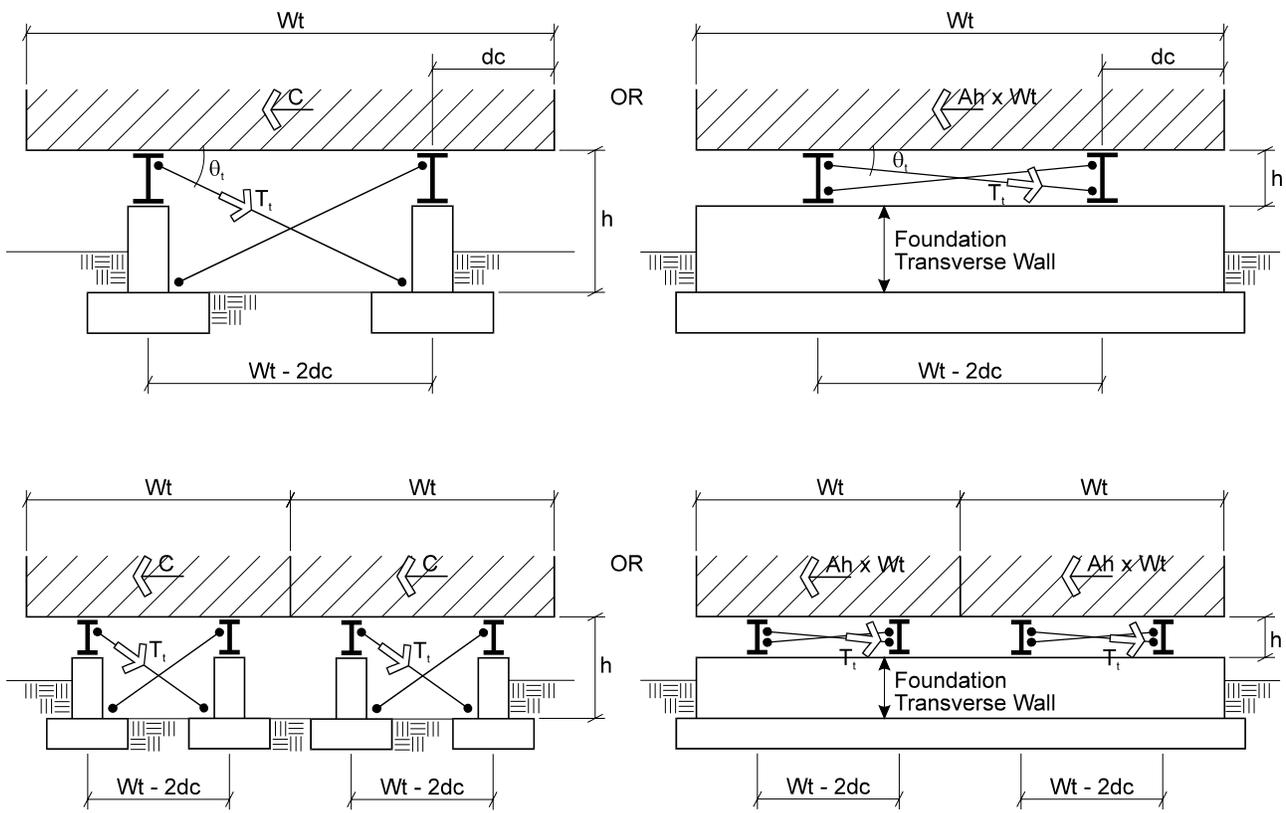
2. Enter the selected Table at the far left and move down either the Inland or Coastal wind speed column, as appropriate, until the required MPH value is reached. Slide to the next column to the right within the block of numbers covered by that wind speed.
3. Select the next smaller block of numbers based on the required seismic (Aa). Move to the right to the next column and locate the required ground snow load. The seismic (Aa) and ground snow load columns will in many cases include a range of values (i.e. .05-.30, or 0-100 psf respectively, which means that the group of values covers all values in that range). These column movements define a unique pair of rows of values taking into account wind and seismic lateral forces.
4. Move to the right until the column for the known unit length is reached. The intersection of that column and the already located rows represents the correct horizontal anchorage values (Ah) for design in (lbs./ft.). If the values are grayed, seismic controlled the magnitude of the values. In the case of two transverse walls, they will be located at the ends of the unit. The Location column in the Table will state **end**. If 4 or 6 transverse walls are selected, there will be two rows of values; one for **end** walls and one for **interior** walls.

help: **Choosing the number of transverse foundation walls.** As a

guide, increasing the number of transverse foundation walls reduces the force per anchor/connection and permits an increased spacing between anchors. Thus, the user should begin with the fewest number of transverse walls - two (2). Comparison of (Ah) with the horizontal anchorage capacities in Appendix C can be simultaneously verified during the completion of the Design Worksheet (Appendix F). A greater number of transverse foundation walls (4 or 6) may

be required. Multi-section units may be stable enough so that only two transverse foundation walls are required. Long, narrow single-section units, or units in windy or high seismic areas, may require more than two transverse walls.

F. Comparison with Manufacturer's Values (Optional). The value for the horizontal anchorage force required for design in the transverse direction must be compared to the value supplied by the manufacturer. The manufacturer's horizontal anchorage value must be



Multi-Section Units

$$\cos \theta_t = \frac{Wt - 2dc}{\sqrt{h^2 + (Wt - 2dc)^2}}$$

Horizontal Anchorage with X-bracing - Transverse Direction

Figure 6 - 8

equal to or greater than the horizontal anchorage requirements from the Tables. See the Manufacturer's Worksheet, item # 16(c) and example number 1 in Appendix G.

G. Horizontal Anchorage with Diagonal bracing atop transverse shear walls or complete Vertical X-Bracing planes. Diagonal members may be used to complete transverse walls that stop at the underside of the chassis beams, or complete X-bracing can be used in lieu of shear walls for transverse foundation walls. Refer to the Transverse Foundation Wall Concepts for Types C, E and I in Appendix A, and example number 2 in Appendix G.

1. *To use diagonal steel straps or wood diagonals to complete the transverse foundation walls.* The required Horizontal Anchorage Table value of (Ah) for single-section or multi-section units must be converted to a diagonal tension (T_t) to size the strap.
 - a. Multiply the required (Ah) by (Wt) to calculate the total horizontal force at the transverse wall under a pair of chassis beams. Note: two sets of diagonals, using this force, are required for multi-section units.
 - b. Divide this value by the cosine of the angle of the diagonal to arrive at the tension (T_t) in the diagonal. See Figure 6-10 for an illustration of this condition. The equation is as follows:

$$T_t = \frac{Ah \times Wt}{\cos\theta_t}$$

2. *To use Vertical X-Bracing Planes with steel straps or rods instead of transverse foundation walls.* This method is possible for Foundation Concepts **C1, C2, E1, E3 and E4** only. The required Horizontal Anchorage Table value of (Ah) must be modified as follows:

- a. Select the required (Ah) value from the Table for two (2) transverse foundation walls for single-section or multi-section units.
- b. Multiply (Ah) times (Wt), regardless if single-section or multi-section unit and then multiply that by 2. Finally divide that total by the unit length (L) to generate a horizontal force (H) in pounds per foot of unit length. The equation follows:

$$H \text{ (lbs./ft. of length)} = \frac{Ah \times Wt \times 2}{L}$$

- c. Multiply (H), horizontal force, by the spacing between vertical X-bracing planes to determine the horizontal force (C) to be resisted at each X-brace location. Thus, for multi-section units (C) is the applied force at both X-bracing locations in the vertical plane. This spacing should be some multiple of the pier spacing. The equation follows:
- $$C \text{ (lbs./X-brace)} = H \times \text{spacing}$$
- d. Divide (C), horizontal force, by the cosine of the angle of the diagonals as illustrated in Figure

6-10, to arrive at the required diagonal tension force in pounds. The equation follows:

$$T_t (\text{lbs./diagonal}) = \frac{C}{\cos\theta_t}$$

- e. Compare the required tension force (T_t) and the required horizontal force per X-brace (C) with the rated capacities supplied by the manufacturer in the Manufacturer's Worksheet, items #16(c and e). See Figures 6-4 and 6-5 for illustrations.

602-6 REQUIRED HORIZONTAL ANCHORAGE (A_h) IN THE LONGITUDINAL DIRECTION (APPENDIX B, PART 4).

A. General. The attachment of the unit to the foundation must provide sufficient structural anchorage for the manufactured home to resist sliding forces due to wind pressures and suctions, or seismic inertia forces, whichever controls. Analysis, based on the conservative assumptions used in this handbook, has shown that wind or seismic may control in the longitudinal direction for single-section or multi-section units, thus it is necessary to check both wind and seismic for all units. These horizontal forces are resisted by connection of the unit to anchors in the exterior longitudinal walls, or by connection of the unit to vertical planes of X-bracing under and along the chassis beams (between piers).

B. Determine Design Ground Snow Load. This step has been done in section 600-3 and is required for single-section or multi-section units.

C. Determine Design Wind Speed. This step has been done in section 600-4 and is required for single-section or multi-section units.

D. Determine Design Seismic Ground Acceleration Values and Required Seismic Performance Category. This step has been done in section 600-5 and is required for single-section or multi-section units.

E. Determine Design Horizontal Anchorage (A_h) in the Longitudinal Direction from the Tables. Refer to Appendix B, Part 4 of the Foundation Design Load Tables. Several steps must be followed to arrive at the Required Horizontal Anchorage in the Longitudinal Direction:

1. Select the correct Table based on single-section or multi-section unit and nominal unit width (W_t) of 12, 14 or 16 feet. Note that the foundation type does not influence the required horizontal anchorage force in the longitudinal direction, thus the heading for the Tables read: Type **C, E or I**.
2. Enter the selected Table and move down the left-most column until the required Seismic (A_a) value is reached. This defines a large block of values. Move to the right to the next column and locate the required ground snow load. This defines a smaller block of values. Move to the next column to the right and locate the inland or coastal block of values and lastly find the required wind speed within that same column. This now defines a single row of values that represents comparison of seismic and wind effects.

- Select the column which represents the length of the unit. The intersection of that column and the already determined row locates the required horizontal anchorage value (Ah) in the longitudinal direction along two lines; either the two exterior longitudinal walls for Type E or I or along the two exterior chassis beams for Type C.

suffice as shear walls in the longitudinal direction. See example number 1 in Appendix G. For Type C units, vertical X-bracing planes under and along the exterior chassis beam lines (between piers) are required. See Section 602-6.F for guidance.

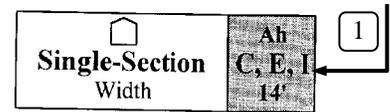
F. Horizontal Anchorage with X-bracing for the Longitudinal Direction. Diagonal members under and along the exterior chassis beams may also be used in lieu of exte-

Help: for Type E or I units, longitudinal exterior walls will exist, and will

Example 1:

Required Horizontal Anchorage - Ah - Longitudinal Direction (lbs/ft)

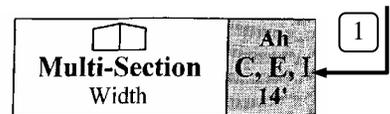
Seismic Ground Snow (psf)	Wind Speed (mph)		Length (ft)							
			40	50	60	70	80	90	100	
.05-.10	0-100	Inland	80	41	33	27	23	20	18	16
			90	52	41	35	30	26	23	21
			100	64	51	43	37	32	28	26
			110	77	62	52	44	39	34	31
		Coastal	80	45	36	30	26	23	20	18
			90	57	46	38	33	29	25	23
			100	71	56	47	40	35	31	28
			110	85	68	57	49	43	38	34



Example 2:

Required Horizontal Anchorage - Ah - Longitudinal Direction (lbs/ft)

Seismic Ground Snow (psf)	Wind Speed (mph)		Length (ft)						
			40	50	60	70	80	90	100
.40	0-30	Inland	80	100	92	92	92	92	92
			90	127	101	92	92	92	92
			100	156	125	104	92	92	92
			110	189	151	126	108	94	92
		Coastal	80	110	92	92	92	92	92
			90	139	112	93	92	92	92
			100	172	138	105	98	92	92
			110	208	167	139	119	104	93
		Inland	80-100	180	180	180	180	180	180
			110	189	180	180	180	180	180
			80-100	180	180	180	180	180	180
			110	208	180	180	180	180	180
		Coastal	80-100	180	180	180	180	180	180
			110	208	180	180	180	180	180
			80-110	202	202	202	202	202	202
			80-100	202	202	202	202	202	202
			110	208	202	202	202	202	202
			80	224	224	224	224	224	224
			70	247	247	247	247	247	247
			80	269	269	269	269	269	269
			90	291	291	291	291	291	291
			100	313	313	313	313	313	313



rior longitudinal shear walls. If galvanized steel diagonal members are used instead of full height exterior foundation walls, the required Horizontal Anchorage Table value of (Ah) must be modified as follows:

1. Select the required (Ah) value from the Tables in Part 4, Appendix B for single-section or multi-section units.
2. Multiply (Ah) times the manufactured home unit length (L) and divide by the selected number of X-brace locations (n) along one exterior chassis beam to generate the total horizontal force (B) to be resisted at each X-brace location along each chassis beam for single-section units, and along each exterior chassis beam for multi-section units. As an example, there are three (n = 3) X-brace locations along each chassis beam for the single-section unit in Figure 6-6. The equation follows:

$$B(\text{lbs./X-brace}) = \frac{Ah \times L}{n}$$

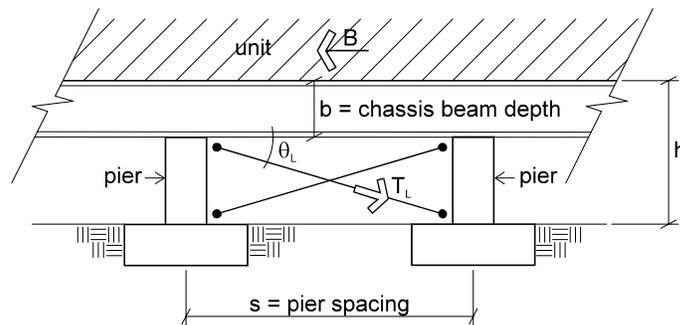
Note: For multi-section units using all four (4) chassis beam lines as vertical X-bracing lines, divide the above equation by 2 (see Fig.D-26 for an example).

3. Divide (B) by the cosine of the angle of the diagonals as illustrated in Figure 6-11, to arrive at the required diagonal tension force in pounds. The equation follows:

$$T_L (\text{lbs./diagonal}) = \frac{B}{\cos \theta_L}$$

4. Compare the required tension force (T_L) and the horizontal force to each X-brace (B) with the rated capacities supplied by the manufacturer in the Manufacturer's Worksheet, items #16(c and e), or supplied by another vendor.

603. USING THE FOUNDATION



Longitudinal Direction

$$\cos \theta_L = \frac{s}{\sqrt{(h-b)^2 + s^2}}$$

Horizontal Anchorage with X-bracing - Longitudinal Direction

Figure 6 - 9

CAPACITIES TABLES (APPENDIX C)

603-1. GENERAL. The Foundation Capacities Tables in Appendix C will be used to find the required size and depth of footings, the required sizes and spacing of anchors, and necessary reinforcement. There are three conditions that will be investigated: 1) Vertical Anchorage (uplift and overturning) requirements for longitudinal foundation walls and piers, 2) Horizontal Anchorage (sliding) in the transverse direction (for transverse foundation walls that function as shear walls), and 3) Horizontal Anchorage (sliding) in the longitudinal direction (for longitudinal foundation walls that function as shear walls).

603-2. REQUIRED VERTICAL ANCHORAGE: LONGITUDINAL FOUNDATION WALLS AND PIERS

A. Determining Footing Depth for Longitudinal Foundation Walls and Piers. This involves selecting sufficient counterweight of material dead loads (wall or pier, footing and soil) to resist the required uplift. The field officer determines how deep the footings must be placed. In frost-prone areas, the footing must at least be placed below the extreme frost depth below grade (map, page H-4). In windy or seismic areas, it may also be necessary to place the footing deeper in the soil than frost protection alone would require. Burying the footing deeper gives it greater withdrawal resistance--it is harder to pull it out of the soil.

B. Determine Required Withdrawal Resistance. It is necessary to compare the values obtained from the Foundation Design Load Table for (A_v) with Tables C-1 or C-2 of Appendix C.

1. *For longitudinal foundation walls,* compare the required value for (A_v) with the numbers in the columns in Table C-1 (for foundation Type E).
 - a. Find a number in the table that is greater than (A_v) . There may be several numbers that meet this criteria.
 - b. Any number that is greater than (A_v) means that the foundation type and footing width (found at the top of the column) can be used. The number (hw) in the column on the left indicates how deep the footing should be placed to resist the uplift and overturning force. Example calculations are included in Appendix C if alternate footing widths are desired.
2. *For isolated pier foundations and concrete tie-down blocks (Concept Type C1),* compare the value for the required (A_v) with the numbers in the columns in Table C-2 (for foundation Types C or I and type E with 4 tie downs).
 - a. Find a number in the table that is greater than (A_v) . There may be several numbers that meet this criteria.
 - b. Any number that is greater than (A_v) means that the width of the square footing (found at the top of the column) can be used. The number hw in the left-hand column indicates how deep the footing should be placed to provide adequate withdrawal resis-

tance. Example calculations are included in Appendix C if alternate footing widths are desired. The same Table C-2 can conservatively be used for concrete deadman footing sizes for concept Type C1.

C. Foundation System Verification.

The HUD field office should verify that the foundation system selected has sufficient depth to withstand uplift. Regardless of the required depth for uplift or overturning, the footing must always be placed below the extreme frost depth below grade.

D. Determine Required Anchorage and Reinforcement for Longitudinal Foundation Walls and Piers.

The field officer will now verify the kinds of anchorage (steel anchor bolts) and reinforcement (steel reinforcing bars) that will be needed to tie together the footing, wall or pier, and the unit itself. The field officer will refer to Table C-3: Vertical Anchor Capacity for Piers and Table C-4A or C-4B: Vertical Anchor Capacity for Longitudinal Foundation Walls (Appendix C).

1. For piers, use Table C-3.

- a. Compare the required value of (A_v) with the capacity numbers.
- b. Find a capacity number that is greater than the required value for (A_v). The number of anchor bolts is listed at the top of the column. The diameter of the anchor bolt is listed in the left column.
- c. Move to Table C-3A to find the reinforcing size, lap splice, and reinforcing-bar hook require-

ments, based on the anchor bolt diameter selected in Table C-3.

- d. Refer to the illustration next to Table C-2 for the required footing reinforcement.
- e. Refer to the Foundation Type C1 (Appendix A) Design Concept for the tie-down bar size.
- f. Sample calculations are included in Appendix C if alternate reinforcement sizes, spacings or material grades are desired.

2. For longitudinal foundation walls, start with Table C-4A for concrete or concrete masonry walls, or C-4B for a treated wood wall.

- a. Compare the required value for (A_v) with the numbers in the left hand column of Table C-4.
- b. Find a number that is greater than the required (A_v).
- c. Read across the column and find:
 - 1) For masonry and concrete foundations (Table C-4A):
 - (a) Anchor bolt size and spacing.
 - (b) From Table C-3A, reinforcing-bar size, lap splice, and hook length.
 - 2) For treated wood foundations (Table C-4B):

- (a) The required nailing.
 - (b) The minimum plywood nailer thickness.
 - (c) The required anchor bolt size and spacing.
- 3) Example calculations are included in Appendix C if alternate reinforcement sizes, spacings or material grades are desired.

603-3. REQUIRED HORIZONTAL ANCHORAGE: TRANSVERSE FOUNDATION WALLS

A. Horizontal Anchorage in the Transverse Direction. This involves connections to avoid sliding between the unit and its foundation. The field officer will compare the required value for (Ah) with Tables C-5 of Appendix C: Horizontal Anchor Capacity for Transverse or Longitudinal Foundation Walls. See example number 1 in Appendix G.

- 1. Compare the required value for (Ah) with the numbers in the left hand column of Table C-5A or C-5B.
- 2. Find a number that is greater than the required (Ah).
- 3. If none of the numbers is greater than (Ah), go back to Section 602-5.E and increase the number of transverse foundation walls until the required value of (Ah) is small enough to be used in the Horizontal Anchor Capacities Tables C-5A or C-5B.

4. The required anchorage for the transverse foundation wall can be read across the columns for:

a. *Masonry and Concrete Foundations* (Table C-5A):

- 1) Anchor bolt diameter.
- 2) Reinforcing bar size.
- 3) Anchor bolt spacing.
- 4) Based on the anchor bolt size, refer back to Table C-3A to obtain the following values:

- (a) Minimum lap splice.
- (b) Reinforcing bar hook.

b. *Treated Wood Foundations* (Table C-5B):

- 1) Required nailing.
- 2) Minimum plywood nailer thickness.
- 3) Anchor bolt diameter.
- 4) Anchor bolt spacing.

5. Example calculations are included in Appendix C if alternate reinforcement sizes, spacings or material grades are desired.

603-4 REQUIRED HORIZONTAL ANCHORAGE: LONGITUDINAL FOUNDATION WALLS

A. Horizontal Anchorage in the Longitudinal Direction. This involves connections

to avoid sliding between the unit and its foundation in the longitudinal direction. The field officer will check compliance with the required value for (Ah) in the longitudinal direction with Tables C-5 of Appendix C: Horizontal Anchor Capacity for Transverse or Longitudinal Foundation Walls. The process is identical with that of section 603-3 for transverse walls and will not be repeated here. See example number 1 in Appendix G.

603-5 DIAGONALS USED TO COMPLETE TRANSVERSE WALLS

A. Horizontal Anchorage. Determine the required horizontal anchorage force by multiplying the required (Ah) by the unit width (Wt). Reference section 602-5.G.1.a and Figure 6-10 for the required horizontal force (Ah) × (Wt).

1. Compare this value with the bottom number in the left hand column of Table C-5A. The capacity listed for 1/2" bolts at a 12" spacing is equal to the single-bolt capacity for horizontal anchorage of diagonals.
2. Divide (Ah) × (Wt) by the number in the table to determine the number of bolts required for diagonal anchorage.

603-6 REQUIRED VERTICAL X-BRACING PLANES IN THE TRANSVERSE AND/OR LONGITUDINAL DIRECTIONS IN PLACE OF TRANSVERSE WALLS

A. Horizontal Anchorage with Diagonal Members. This involves connection of the ends of the diagonal straps to the unit and to the foundation. The HUD Field Office will

compare the required horizontal anchorage value at each diagonal with Table C-5A of Appendix C to verify adequacy of connection between diagonal and footing. See example number 2 in Appendix G.

1. *Transverse Direction.* Use the horizontal anchorage force (C) per diagonal found in section 602-5.G.2.c and Figure 6-10.
 - a. Compare the value for (C) with the bottom number in the left hand column of Table C-5A. The capacity listed for 1/2" bolts at a 12" spacing is equal to the single-bolt capacity for anchorage of diagonals.
 - b. Divide (C) by the number in the table to determine the number of bolts required for diagonal anchorage.
 - c. Refer back to Table C-3A, to obtain the following values:
 - 1) Minimum lap splice.
 - 2) Reinforcing bar hook.
2. *Longitudinal Direction.* Use the horizontal anchorage force (B) per diagonal found in section 602-6.F and Figure 6-11..
 - a. Repeat steps (a.) to (c.) as for the transverse direction, using (B) instead of (C).

603-7. CONCLUSION. Values for the verification of the manufactured home foundation have now been obtained.