INTRODUCTORY COMMENTS

Preface

This Handbook is a guide for those approving manufactured homes on permanent foundations -- HUD Field Offices involved in the approval process and manufacturers and site owners who are seeking approval.

There are two acceptable methods for owners or developers to use in seeking HUD Approval: (1) Furnish foundation drawings and design calculations prepared and sealed by a licensed professional for foundation concepts shown in Appendix A and other foundation concepts not covered in the Handbook. The design criteria and requirements of Chapters 1-7 of the Handbook shall be followed in Method (1) and does not require the submittal of Appendix F (Appendix F instructions in paragraph 103 do not apply to Method 1.) Or (2) Furnish the Design Worksheet (Appendix F) prepared by a licensed professional in accordance with the Handbook. Method (2) does not require design calculations. Methods (1) & (2) both require submittals of Appendix E. See Table i - 1 on page ii.

The Foundation Concepts (Appendix A) are considered permanent foundations. Permanent foundations are those that have been engineered for safety and long-term satisfactory performance. These foundations were also designed specifically for use with manufactured homes. The Handbook contains construction recommendations that assure the home, the foundation and the site are all compatible. Because these recommendations are based on estimated conditions, it is important to have complete information for each manufactured home and its site.

Manufacturer-Supplied Information

Information about the home must be provided by the manufacturer. To simplify the approval process, the manufacturer may wish to prepare a Manufacturer's Worksheet for each standard foundation system. The Manufacturer's Worksheet is in Appendix E.

Owner-Supplied Information

Information about the building site must be provided by the owner. The size of the foundation, the depth of the footings, and the anchorage requirements depends on the building's site. This information should be submitted on the Owner's Site Acceptance Worksheet (Appendix E).

Handbook: Site Conditions

Chapters 2 and 3 of the Handbook contain recommendations for site preparation. They also point out unusual site conditions that may call for additional geotechnical engineering reports, such as sloping sites and problem soils. This documentation must also be submitted if problem sites are found.

Handbook: Foundation Design Concepts

Companies building manufactured homes have assisted in the preparation of this handbook by providing foundation design concepts appropriate for manufactured housing. This information was assembled and used as the basis for the Foundation Design Concepts in Appendix A.

The Handbook provides information about three basic foundation types and six alternative types. Appendix A shows which foundation designs can be used on sites with special requirements, such as windy sites.

Handbook: Design Verification

The Handbook's format is arranged for a licensed professional to progress through a series of logical steps designated to lead to approval. The HUD Field Office at their prerogative may review the Design Worksheet.

Technical assistance to determine acceptability of individual designs of permanent foundation systems should be obtained from a licensed professional engineer.

TITLE	Method (1)	Method (2)
Foundation Drawings (Prepared & Sealed by Licensed Professional)	Yes	No
Design Calculations (Prepared & Sealed by Licensed Professional)	Yes	No
Design Criteria Chapters 1-7	Yes	Yes
Appendix A - Foundation Concepts	Yes	Yes
Other Foundation Concepts	Yes	No
Appendix E (Owner's Site Acceptability & Manufacturer's Worksheets)	Yes	Yes
Appendix F Design Worksheet (Prepared & Sealed by Licensed Professional)	No	Yes

Table i - 1

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LIST OF ACRONYMS

ANSI........American National Standards Institute
APA.........American Plywood Association
ASCE.......American Society of Civil Engineers
ASTM ......American Society of Testing Materials
BOCA ......Building Officials and Code Administrators International
CABO ......Council of American Building Officials
ELF..........Equivalent Lateral Force
FEMA ......Federal Emergency Management Agency
HUD ........U.S. Department of Housing and Urban Development
ICBO........International Conference of Building Officials
MHCSS....Manufactured Home Construction and Safety Standards
MPS.........Minimum Property Standards
NBSIR .....National Bureau of Standards Institute for Research
NCSBCS..National Conference of States on Building Codes and Standards, Inc.
NEHRP....National Earthquake Hazard Reduction Program
NIST ....National Institute of Standards and Technology
SBCCI......Southern Building Code Congress International

CHAPTER 1 - GENERAL INFORMATION

100. APPLICATION

100-1. GENERAL. Manufactured homes, as addressed by this handbook, are manufactured in accordance with 24 CFR Chapter XX, Part 3280, *Manufactured Home Construction and Safety Standards* (MHCSS), and are sited on a permanent foundation in accordance with *Handbook 4145.1, REV-2, Change 1, Feb. 14, 1992*, Architectural Processing and Inspections for Home Mortgage Insurance, paragraph 3-4.

A. Description of Manufactured Unit. Designs and approval for foundations in this manual are based on the following assumptions about the manufactured home:

1. Transportable in one or more sections.
2. Between 11'-4" and 16'-0" in width in transport mode.
3. Minimum 400 sf. in area for a single section unit.
4. Exterior wall height of 7'-6" or 8'-0" from top of wall to foundation.
5. Built on permanent chassis with minimum distance between main chassis beams of:

Mfg. Home Width	Beam Spacing
12' nom.	6'-3"
14' nom.	6'-10"
16' nom.	8'-0"

Note: Smaller beam spacing will require design by a professional engineer.

6. Chassis beams 10" deep for 12' and 14' nominal unit widths, and 12" deep for 16' nominal unit width.
7. Roof slope varies from a minimum 1/2:12 to a maximum 4.4:12 (20°).
8. Set on permanent foundation of piers, or of continuous, cast-in-place concrete, concrete-block masonry, all-weather wood, or other approved systems.
9. Double width units are assumed connected to behave structurally as a single box.

B. Chassis Removal. The chassis of a manufactured home, under the *Federal Manufactured Housing and Construction safety Standards*, is not permitted to be removed. Accordingly, foundations in this manual are designed for manufactured homes that DO NOT HAVE THEIR CHASSIS REMOVED.

C. Definition of Permanent Foundation. Permanent foundations must be constructed of durable materials; i.e. concrete, mortared masonry, or treated wood - and be site-built. It shall have attachment points to anchor and stabilize the manufactured home to transfer all loads, herein defined, to the underlying soil or rock. The permanent foundations shall be structurally developed in accordance with this document or be structurally designed by a licensed professional engineer for the following:

1. Vertical stability:

    a. Rated anchorage capacity to prevent uplift and overturning due to wind or seismic forces, whichever controls. Screw-in soil anchors are not considered a permanent anchorage.

    b. Footing size to prevent overloading the soil-bearing capacity and avoids soil settlement. Footing shall be reinforced concrete to be considered permanent.

    c. Base of footing below maximum frost-penetration depth.

    d. Encloses a basement of crawl space with a continuous wall (whether bearing or non-bearing) that separates the basement of crawl space from the backfill, and keeps out vermin and water.

2. Lateral stability. Rated anchorage capacity to prevent sliding due to wind or seismic forces, whichever controls, in the transverse and longitudinal directions.

100-2. DEFINITIONS. These are terms used throughout the Handbook and the Design Worksheet. Additional terms are used in Appendix D, where the derivation of equations is shown. These terms are defined in Appendix D, and illustrated in Figure 6-2.

Anchorage: Connection between superstructure and foundation, by means of welds, bolts, and various light gage metal plates. Anchorage does not refer to any type of soil anchor.

Chassis: The structural system running beneath the manufactured home. Example: Pair of steel beams.

Exterior Foundation Wall: Foundation walls placed directly below the exterior perimeter walls of the unit. These walls may, or may not, be structurally used as bearing walls under gravity loads, and/or used as shear walls under horizontal loads. If these walls are not used structurally they are called non-bearing walls or skirt walls.

Exterior Piers: Piers inside the exterior walls, needed to support the chassis beams nearest the longitudinal foundation walls.

Foundation Types:

Type C: Foundation system supported and anchored at chassis only, to equally spaced piers.

Type E: Foundation system supported at chassis and exterior wall but anchored for uplift and overturning at exterior wall only.

Type I: Foundation system supported at chassis and exterior wall but anchored for uplift and overturning at exterior piers only.

Interior Piers: Piers nearest the marriage wall and supporting the chassis in multi-section units.

Longitudinal Foundation Walls: Two walls beneath the long dimension of the unit (in its transport mode) which are structurally used as foundation shear walls that resist applied wind or seismic forces from the superstructure's shear walls in the longitudinal direction.

Longitudinal Direction: Direction of horizontal wind or seismic forces applied parallel to long dimension of unit. See Figure 1-1.

Marriage Wall: The wall where two single-section units are structurally joined to form a multi-section unit. The marriage wall may contain openings that permit interior spaces to expand to two units wide.

Marriage Wall Piers: Piers placed beneath a continuous marriage wall in multi-section homes are assumed to be equally spaced. Piers are also placed at the ends of openings, beneath the posts that transfer concentrated loads from the roof.

Superstructure Shear walls*:* Vertical elements (usually walls) of the superstructure's lateral load resistance system. These vertical elements structurally transfer horizontal wind or seimsic forces, applied to the roof and floor planes of the unit, to the foundation system.

Transverse Foundation Walls: Walls across the short dimension of the unit which are structurally designed to function as foundation shear walls that resist horizontal applied wind or seismic forces from the superstructure's shear walls in the transverse direction.

Transverse Direction: Direction of horizontal wind or seismic forces applied perpendicular to long dimension of unit. See Figure 1-1.

Aa: The seismic coefficient representing the effective peak acceleration as determined by the seismic map 1.

Av: The seismic coefficient representing the effective peak velocity-related acceleration as determined by the seismic map 2.

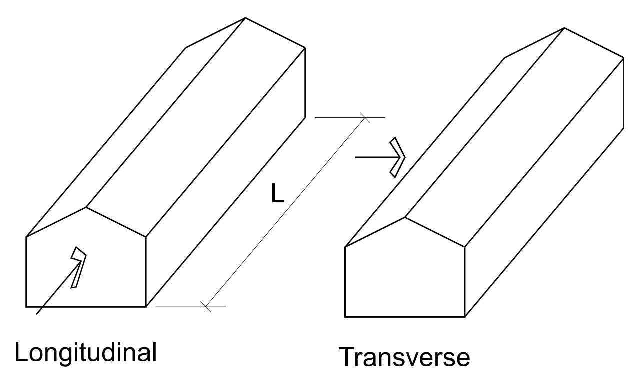


Figure 1 - 1

Av: Vertical anchorage force requirement for the unit; (Pier load in lbs. or wall load in lbs./LF). Example; Anchorage force to prevent uplift and overturning in the transverse direction of applied wind or seismic forces.

Ah: Horizontal anchorage force requirement (lbs./ft.). Example; Anchorage force to keep unit from sliding in the transverse and longitudinal directions of applied wind or seismic forces.

Aftg: Foundation footing size for the isolated unit pier spread footing area (sq. ft.) & continuous wall footing width (ft.).

hn: The height of the manufactured unit exterior wall.

hp: The depth at which a pier footing must be placed to prevent it from pulling out of the soil (ft.).

hw: The depth at which a continuous foundation wall must be placed to prevent it from pulling out of the soil (ft.).

L: Length of manufactured home (ft.).

W: Actual self (dead load) weight of the unit (lbs.).

w: The distributed weight of the unit (lbs./ft). W/L = w; therefore weight per foot of length.

Wt: Actual measured width of the unit (ft.) between superstructure walls, excluding roof projections. A single-section unit has one width measurement (Wt). A double-section unit is composed of 2 single-section widths (2Wt).

100-3. LICENSED PROFESSIONALS. Those using this handbook are referred to using licensed professionals when design considerations require additional information or when a particular site, foundation system, or superstructure (manufactured home) falls outside the design assumptions and parameters of the handbook. As used herein, the term Geotechnical Engineer is a professional engineer registered under the appropriate laws of the State to practice in the field of Geotechnical Engineering. The term Structural Engineer is a professional or structural engineer registered under the appropriate laws of the State to practice in the field of Structural Engineering . And the term Architect is a professional architect registered under the appropriate laws of the State to practice Architecture.

101. LOCAL CODES AND STANDARDS

101-1. NEW CONSTRUCTION. This handbook has been developed for use at all new permanent manufactured home sites, communities, and set-ups.

101-2. EXISTING CONSTRUCTION. The practices recommended in the Handbook are not intended to be applied retroactively to existing sites unless the authority in the jurisdiction considers such application essential for safety and health of occupants. Upgrade of existing anchorages and footings shall meet the intent of the definition of permanent foundation stated herein.

101-3. RESPONSIBILITY. This handbook does not relieve the installer of responsibility for compliance with local ordinances, codes, and regulations established by authorities having jurisdiction.

101-4. OTHER FOUNDATION DESIGNS. Manufacturers of home designs not covered by this handbook or recommending a foundation system not included in this handbook shall submit drawings and structural calculations prepared and sealed by a licensed professional to the owner.

102. REFERENCED STANDARDS

102-1. CODES GOVERNING SUBSURFACE INVESTIGATION

A. HUD *Minimum Property Standards for Housing 1994 Ed.* Handbook 4910.1; Final Rule-24 CFR Part 200.926 contain provisions that apply to permanent foundation installations recommended in this handbook.

B. Engineering Report. If adverse site conditions are discovered, specific recommendations by a Geotechnical Engineer shall be included with the Design Worksheet (Appendix F).

102-2. CODES GOVERNING BUILDINGS AND SITES

A. Seismic, Wind and Snow Loads for each type of structure were computed based on ASCE 7-93: *Minimum Design Loads for Buildings and Other Structures*. Minimum wind and minimum roof live load were based on *MPS*

HUD Document 4910.1, Appendix K, art. 200.926e (a) & (c).

B. Grading, Drainage and Fill. The HUD *Land-Planning Data Sheet*s (79g), Handbooks 4140.3 and 4145.1, should be used for grading, drainage and fill specifications.

C. Manufactured Homes on Elevated Foundations should follow standards in *Manufactured Home Installation in Flood Hazard Areas, FEMA 85/September 1985*.

D. Additions to CABO *One and Two Family Dwelling Code, 1992 Ed*. (including 1993 Amendments) that apply to construction in this manual are found in CABO, Appendix C -- Section C-101, C-102, C-201, C-301, C-302, C-303, C-304, C-305, C-306, C-307, C-401, C-501, C-502, C-503, C-504, C-505, C-506, C-507, C-600, C-601, C-602, C-603, C-604, C-605.

E. Rural Housing Service (RHS) Formerly Rural Housing and Community Development Service, formerly Farmers Home Administration (FmHA). Provisions for the approval of direct loans for manufactured homes on permanent foundations are contained in Subpart A of Part 1944: Section 502 Rural Housing Loan Policies and Authorizations and for guaranteed loans in Subpart D of Part 1980: Rural Housing Loans. The provisions for acceptable site development, installation and set-up are contained in Subpart A of Part 1924 Exhibit J: Manufactured Home Sites, Rental Projects and Subdivisions. These Agency instructions are available in any RHS field office.

F. Superstructure HUD Code - *Federal Manufactured Home Construction and Safety Standards Oct. 25, 1994*. The structural design of the superstructure of the manufactured home has been assumed to be in conformance with HUD Code Section 3280.305 and .306 (a)(2) which anticipates the manufactured unit to make provision for the support and anchoring system forces required by this document.

103. GENERAL PROCEDURE

103-1. SUBMISSIONS. Three worksheets must be filled out before evaluation of the foundation system can begin, the "Owner’s Site Acceptability Worksheet and Manufacturer's Worksheet" in Appendix E, and the "Design Worksheet" in Appendix F. Refer to Table i - 1 in the Introductory Comments, which indicates requirements and submissions.

103-2. BEGINNING THE APPROVAL PROCESS. If the worksheets in Appendices E and F have been filled out, the approval process can begin. See Chapter 2, "Site Acceptability Criteria" and the Design Worksheet, Appendix F. Persons using the handbook should fill out the Design Worksheets while progressing through the chapters in the Handbook. Questions on the Design Worksheet are tied to sections of the Handbook and the section numbers are noted on the Worksheet.

CHAPTER 2 - SITE ACCEPTABILITY CRITERIA

200. GENERAL. Before approval of the site can begin, preliminary information about the site must be provided. Information to be provided appears in Appendix E.

201. SITE SUITABILITY. Site conditions can determine whether a given foundation design will be suitable for the manufactured home. Problem soils, flood-prone building sites, sloping sites, and ground-water level can affect decisions about foundation design. An investigation of the problem site by a qualified geotechnical engineer is recommended to assure that site conditions will not adversely affect foundation performance.

201-1. EXISTING GRADE ELEVATION(S) must be provided using a level and known benchmarks if any of the following are true:

A. The elevation is to be altered by grading or fill; or

B. The site is near a flood zone (e.g. lakes, rivers, streams, or coastal areas); or

C. The site is or will be incorporated in subdivisions and communities.

201-2. FLOOD-PRONE SITES. Building sites near lakes, rivers, streams and oceans are likely flood-prone areas. Information about whether the site is flood-prone should be obtained from FEMA Flood Maps. Determine whether the building site is in a flood zone. Refer also to the map showing distribution of great floods in the United States, page H-3.

A. Sites in Flood Zones. If the building site is within a flood zone, the finish grade of the building site must be located above the 100-year return frequency flood elevation, and in accordance with *HUD Handbooks 4135.1 REV.2* and *4145.1*.

B. Elevated Homes within flood zones can be built on specially-designed elevated foundations.

1. Refer to *Manufactured Home Installation in Flood-Hazard Areas*, FEMA-85 / Sept. 1985.

2. Homes built on elevated foundations must comply with requirements of the National Flood Insurance Program to qualify for flood insurance. (N.F.I.P.)

201-3. FROST PENETRATION DEPTH. Verify the frost penetration depth with local building code department. Refer to the Maximum Annual Frost Penetration map on page H-4. The base of the foundation footing must be below the maximum frost penetration depth. Foundations in permafrost must be designed by an engineer registered in Alaska.

201-4. GROUND WATER TABLE ELEVATION. Water table elevations vary from season to season and/or by locations. Building structures, streets, paved areas, and utilities shall be located or engineered to minimize the adverse effects of a high water table.

A. Subdivisions. A subsurface investigation by a Geotechnical Engineer is required to determine water table elevation.

1. Developed portions of a site which can be adversely affected by a potentially high ground water table shall be drained where possible (based on recommendations by Geotechnical Engineer) by subsurface drainage facilities adequate for the disposal of excess ground water or by provision of surface drainage and surface ponds.

2. A Geotechnical Engineering Report shall be submitted in subdivision applications.

B. Exceptions. For individually-sited homes, the water table elevation may be based on local records if available; otherwise, determine by subsurface investigation.

202. SOIL BEARING CAPACITY

202-1. GENERAL. Soil conditions typically vary with depth. Subsurface investigations to a minimum recommended depth below the footing depth by a Geotechnical Engineer, using appropriate laboratory tests, are recommended to identify soil type and bearing capacity.

202-2. REQUIRED SUBSURFACE INVESTIGATION. For subdivisions and communities, a subsurface investigation is required.

A. Preliminary Design. Other sources may be consulted for presumptive bearing pressures for preliminary design purposes.

1. Allowable bearing pressures based on national model codes:

   a. BOCA - Basic National Building Code

   b. SBCC - Standard Building Code

   c. ICBO - Uniform Building Code

   d. CABO - One and Two Family Dwelling Code

2. Local authority having jurisdiction

3. Soil Conservation District

4. United States Geological Survey

5. Soil Conservation Service of the U.S. Dept. of Agriculture

6. Highway Department

7. Utility Company Records

B. Exceptions. For individually-sited homes, the bearing capacity may be determined based on local building codes, unless the site is located in an area of known or suspected adverse soil conditions (as defined in Section 203), then a subsurface investigation may be required.

203. PROBLEM SOIL AND SITE CONDITIONS

203-1. ORGANIC SOILS

A. Soil Identification. If any of the following soil types is identified at the proposed site by a Geotechnical Engineer (or soil conservation maps), removal of the problem soil type and replacement with an engineered fill is permitted if submitted and approved by a Geotechnical Engineer.

1. *Loess*. Deposits of windblown organic silts. Susceptible to moisture and frost action and excessive settlement.

2. *Peat*. River or water deposits of organic matter and silts, susceptible to excessive settlement.

3. *Topsoil*. Top organic layer of soil, susceptible to excessive settlement.

4. *Others* (As defined by Geotechnical Engineer). Refer to overview map of expansive soils, Appendix F.

203-2. UNSTABLE CLAYS have potential for large movements.

A. Conditions Causing Instability:

1. Expansive characteristics

2. Highly plastic characteristics

3. High compressibility

4. Other conditions as noted by Geotechnical Engineer.

B. Foundations for Unstable Clays. The presence of unstable clays indicates that special foundation treatment as recommended by a Geotechnical Engineer be included in the approval plan.

203-3. SLOPING SITES

A. General. There is the potential for slope instability and soil movement if the following conditions occur:

1. Loading on the slope by fill, home, or foundation.

2. Removal of lateral supports by construction.

3. Inherent characteristics of soil material and slope geometry.

4. Changes in the water content of the soil.

5. Refer to overview map of landslide problems on pages H-6 and H-7, and National Academy of Sciences Report *Reducing Losses from Landsliding in the United States.*

B. Local Records. Refer to local Geotechnical records and ordinances for guidance.

C. Identification. Subsurface investigation by a Geotechnical Engineer is recommended for sloping sites. This is the primary method of determining slope instability.

203-4. SUBSIDENCE

A. General. Subsidence refers to the potential for lowering or collapse of the land surface. Its causes are:

1. Dissolving of soluble materials below the surface to form cavities.

2. Underground mining.

3. Withdrawal of gas, oil, and water from subterranean cavities

4. Other causes as noted by Geotechnical Engineer.

B. Identification. Areas where subsidence occurs can be identified by local geological records or by subsurface investigation by a Geotechnical Engineer. Refer to the maps showing cave locations and coal field locations on pages H-8 and H-9, NBSIR 81-2215 *Construction of Housing in Mine Subsidence Areas,* and National Academy of Sciences Report *Mitigating Losses from Land Subsidence in the United States*.

C. Stipulations. Construction on the site should be determined by a Geotechnical Engineer.

203-5. TERMITE HAZARD. Refer to the map on page H-10 for locations and intensity of termite infestation. Wood selection and treatment, and wood members in close proximity to the ground shall be in accordance with CABO *One & Two Family Dwelling Code* (all provisions listed in section R-309) or with local ordinances.

CHAPTER 3 - SITE PREPARATION

300. GENERAL. Site preparation must conform to referenced standards in Chapter 1.

301. DRAINAGE

301-1. RAIN DIVERSION. Provide the best available routing of run-off water to assure that buildings or other important facilities will not be endangered by the path of a major emergency flood run-off which would occur if the site storm drainage system is exceeded.

301-2. SITE-PLAN. Arrange structures on sites to retain natural drainage patterns (*MPS* HUD Document 4910.1, Chapter 3).

301-3. ROOF DRAINAGE. Control roof drainage by use of gutters and downspouts. Route away from foundation walls.

302. SITE-GRADING

302-1. GENERAL. Site-grading plan must be approved by HUD, according to the *Land Planning Data Sheet 79g* and *HUD Handbook 4145.1* (Appendix 8). Site grading and drainage must be performed to provide diversion of surface water away from the foundation and off the site, to prevent standing water. Design the new slope to tie in with natural grading.

302-2. RECOMMENDED TESTS. Obtain soil analysis, bearing tests, or special foundation design where soil stability is questionable.

303. FILL

303-1. GENERAL. Bearing for footings or foundations on engineered fill is permitted where determined acceptable by HUD Field Office and Geotechnical Engineer.

303-2. FILL SPECIFICATIONS. Fill must be engineered fill, (to 90% compaction, Modified Proctor Test, ASTM D1557) free of organic material such as weeds, or grasses, or other organic matter.

303-3. ENGINEERED FILL. Engineered fill shall have a minimum load bearing capacity as recommended by a Geotechnical Engineer. Use HUD *Land Planning Data Sheet 79g* for preparation requirements.

304. FINISH GRADE ELEVATION. The finish grade must be in accordance with *HUD Handbook 4145.1*, paragraph 3-4.A.6).

CHAPTER 4 - DESIGN LOADS FOR PERMANENT FOUNDATIONS

400. GENERAL.

Design and construction must insure that the load bearing portion of the home's foundation will remain stable and maintain its capacity to transmit all imposed loads to the ground.

400-1. FOUNDATION DESIGNER. The foundation designer must be aware of the structural limitations of the home to accommodate differential foundation movement. This is especially important with differential soil settlement or movement of problem soils.

400-2. REFERENCED STANDARDS. All structural design shall be based on generally accepted engineering practice. All loads shall be in accordance with ASCE 7-93, except as shown otherwise in this manual. Local codes must be reviewed for requirements that may be more stringent than ASCE 7-93.

400-3. DESIGN STANDARDS. Foundation design criteria is based on foundation criteria for conventional housing as defined in the *Minimum Property Standards*, and is not based on the *Manufactured Home Construction and Safety Standards* (Part 3280). Foundation Design Load Tables, Appendix B, were developed based on average ASCE *Minimum Design Dead Loads*. See Table 4-1 below. (See Derivation of Foundation Design Load Tables, Appendix D.)

401. BUILDING STRUCTURE AND SIZE.

Information must be provided by the manufacturer to assist in determining the suitability of a manufactured home for a particular site and foundation system. The inspector shall do a preliminary check to verify that all information has been prepared by the manufacturer. (The Manufacturer's Worksheet can be found in Appendix E, page E-3.)

402. DESIGN LOADS

402-1. DEAD LOADS

A. Computation of Forces. Two design dead load values are used in this guide. The values are based on typical materials used in construction of homes.

1. The lightest combination of loads is used for computation of horizontal

Range of Dead Loads Covered by This Guide (Average pounds per lineal foot (plf) of home length ± 5%)						
Nominal unit width:	**12 feet**		**14 feet**		**16 feet**	
Dead load:	light	heavy	light	heavy	light	heavy
Single-Section Type C, E, I	260	380	290	425	320	470
Multi-Section Note: Refer to the "Manufacturer's Worksheet" Appendix E for unit type.	500	715	560	805	615	895

Table 4 - 1

and vertical anchorage forces for wind related overturning and sliding stability.

2. The heaviest combination of loads is used for computation of: (1) footing bearing area and (2) equivalent lateral inertia forces applied at roof and floor levels for seismic related overturning and sliding stability.

B. Dead Load Values. The design light and heavy dead load values are shown in Table 4-1 for manufactured home type and nominal unit width.

C. Distributed Weight Calculation. The manufacturer shall provide the total weight (W) and the length (L) of the manufactured housing unit, including mechanical equipment. These values are used to convert the weight (W) into the distributed value of pounds per lineal foot (w). Use the following formula to make this conversion:

$$w = \frac{W}{L}$$

Where: L = length of home (Mfr. Wksht. #3)
W = total weight (Mfr. Wksht. #8)

D. Distributed Weight Comparison. The distributed home weight (w) shall be compared with the average calculated values in Table 4-1.

1. If the manufacturer's distributed value (w) is less than the light load or greater than the heavy load, the structural engineer will be required to design the foundation system and anchoring system. Proceed no further until an approved system, certified by a licensed structural engineer, has been provided. DO NOT USE THE TABLES. The tables are based on estimated conditions. Once outside those limits, the results will not be valid.

2. If the manufacturer's value falls within the light and heavy load limits (± 5%), USE THE TABLES IN THIS MANUAL and proceed with the verification process.

E. Other Dead Loads. Manufactured home partitions and other known loads caused by special installations such as stationary equipment, i.e. water heater, furnace, etc., shall be included to arrive at applicable dead loads.

402-2. SNOW LOAD

A. General. Ground snow loads are based on values from ASCE 7-93. The Ground Snow Load map on pages H-11, H-12, H-13, shall be used to determine a ground snow load value (Pg) for the manufactured home location. For areas where ground snow load values are not shown, consult local weather data or governing code authority. Ground snow loads (Pg) are converted to roof design snow loads (Ps) by multiplication on 0.7 × Pg. See Appendix D for derivation. The tables in Appendix B use Pg values from the map. Roof snow loads are assumed to be horizontally projected over the roof area.

B. Heavy Snow Loads. If the ground snow load value (Pg) exceeds 100 psf, consult a licensed structural engineer for footing design.

C. Minimum Roof Live Load. Roofs shall be designed for a minimum horizontally projected live load in accordance with *MPS* HUD

Document 4910.1, Appendix K, art.200.926e. The load magnitude is related to roof slope as follows: greater than 3 in 12: 15 psf; less than or equal to 3 in 12: 20 psf. The larger magnitude, between the design roof snow load and the minimum roof live load, shall be used for design. Note that a 20 psf ground snow load (Pg) corresponds closely to a 15 psf minimum roof live load (i.e. $0.7 \times 20 = 14$ psf rounded to 15 psf) and a 30 psf ground snow load corresponds closely to a 20 psf minimum roof live load (i.e. $0.7 \times 30 = 21$ psf rounded to 20 psf in the Foundation Design Load Tables).

402-3. WIND LOAD

A. General. Wind loads must be based on values from ASCE 7-93. The Basic wind speed map on page H-14 must be used to determine the basic wind speed (v) for the manufactured home location. Refer to Appendix D for factors influencing wind load. Map values below 80 mph shall conform to the minimum wind speed of 80 mph in accordance with *MPS* HUD Document 4910.1, Appendix K, art. 200.926e.

NOTE: Tornadoes have not been considered in the development of the basic wind speed map, and resistance to such conditions is not included in this manual.

B. Coastal or Inland Sites. Coastal regions include any locations within 100 miles of the Atlantic Ocean or Gulf of Mexico hurricane coastlines. All other locations are to be considered Inland regions. Exposure Category C has been assumed regardless of Coastal or Inland location in accordance with *MPS* HUD Document 4910.1, Appendix K, art. 200.926e.

C. Severe Wind and Design Pressures. In hurricane zones, or where severe wind pressures occur, foundations and anchoring for manufactured homes will require special treatment.

1. Foundations may be required to resist greater uplift and overturning than values shown in this manual.

2. Heavier, more deeply buried foundations may be required than values shown in the tables. It may be necessary to provide additional foundation shear walls and/or specially designed cantilever piers.

3. Home-to-foundation connections must be strengthened.

4. Refer to *Mobile Home Anchoring Systems and Related Construction and An Engineering Analysis: Mobile Homes in Windstorms*, Institute for Disaster Research in Lubbock, Texas.

D. Design Verification. The field office must verify the existence of engineered drawings showing connection and anchorage details. The connection details shall be engineered to resist wind speeds at the building site.

E. High Wind Design. For high wind areas, foundation designs must be those that are suited to both high wind and other site conditions, such as seismic or soil conditions.

402-4. SEISMIC LOADS

A. General. Seismic design loads and requirements are based on criteria and values from ASCE 7-93, which are taken from the NEHRP *Recommended Provisions for the Development of Seismic Regulations for New Buildings* (NEHRP 1991). The two seismic maps on pages H-15 and H-16 shall be used to determine the seismic values Aa and Av for the manufactured home location (county). Seismic values of Aa and Av that equal or exceed 0.3 shall conform to the special requirements of seismic performance category C and D (cited on page H-17) as they apply to foundation design and detailing. When Av values from the map on page H-16 are less than 0.15, the seismic provisions of ASCE 7-93 need not be considered, and anchorage design is then based on wind considerations alone. In seismic areas where Av and/or Aa ≥ 0.3, foundations must be designed by a professional engineer licensed in the applicable state.

B. Design Verification. The design concept proposed in question 10 of the "Manufacturer's Worksheet", found in Appendix E, should be compared with information in the Foundation Design Concept Tables (Appendix A) to determine whether the foundation is potentially suitable for location in a seismic zone.

C. Characteristic Differences between Wind and Seismic Loading.

1. Wind loads subject the exterior building envelope to pressures and suctions on each wall or roof surface. Thus, exposed surface area is important. Seismic loads are generated by the ground's acceleration being transferred to the foundation, according to the site soil characteristics (S) and then the building's structural system characteristics (R). This modified acceleration excites the building mass, which generates the inertia forces ($F = m \times a$) at each level (i.e. floor and roof). Thus, the entire building participates in the creation of seismic force, while only the exterior envelope participates in wind load generation.

2. Wind loading is usually long duration with short duration gusting that usually creates slow stress reversals, while seismic events are of short duration, creating accelerations that generate rapid oscillations in all directions with sudden stress reversals.

3. The slow structural response from wind loading permits frictional resistance from gravity loads to be considered for sliding resistance between superstructure and foundation. The simultaneous horizontal and vertical acceleration during a seismic event, generally negates the frictional resistance from gravity loads. Thus, friction is ignored as a potential resistance between superstructure and foundation for seismic loading. Even when wind loads exceed seismic loads, positive connections between superstructure and foundation are required for areas with Av equal to or greater than 0.15.

D. Seismic / Wind Force Comparisons. Overturning and sliding anchorage forces found in the Foundation Design Load Tables of Appendix B are based on the largest lateral forces from a consideration of wind and equivalent lateral seismic inertia forces. The results were as follows:

1. Wind controls for single or multi-section units subjected to (1) overturning from lateral forces in the transverse direction (perpendicular to

long dimension of unit) and (2) uplift forces in the vertical direction. Both conditions require vertical anchorage.

2. Wind or seismic may control for single or multi-section units subjected to sliding in the transverse and/or longitudinal direction. Values in the tables of Part 3 and 4 of Appendix B are grayed if seismic controls.

CHAPTER 5 - FOUNDATION REQUIREMENTS

500. GENERAL.

This section outlines general material and quality standards for all foundations in this manual.

501. EXCAVATION

501-1. FOOTING DEPTH. Excavation for footings or foundation walls shall extend below depth of soil subjected to seasonal or characteristic volume change to undisturbed soil that provides adequate bearing. Select the greatest depth required by any of the provisions below, reference Figure 5-1.

A. Maximum Frost Penetration Depth. The bottom of footings shall extend at least to the depth indicated on the map on page H-4.

B. Alternate Seasonal Wetting and Drying. This is especially important with expansive soils. If expansive soils exist, consult a geotechnical engineer to obtain required footing depth.

C. Footing Depth. The footings shall be deep enough to provide required uplift capacity. (This value may need to be determined for high wind areas after the calculations needed to determine footing bearing have been completed.)

502. FOUNDATION MATERIALS.

Footings and foundations shall be constructed of solid materials such as masonry, concrete, or treated wood, based on the Foundation Design Concept Selection (Appendix A) and Foundation Capacity Tables. (Appendix C) (For masonry and concrete refer to CABO R-302.2, R-304.1 and R-304.3; for wood refer to CABO R-302.1 and R-304.5.)

503. STRUCTURAL REQUIREMENTS

503-1. FOUNDATION REQUIREMENTS. All exterior walls, marriage walls, marriage wall posts, columns and piers, must be supported on an acceptable foundation system that must be of sufficient design to support safely the loads imposed, as determined from the character of the soil.

A. Height Above Grade. Foundation walls shall extend at least 8" above the finished grade adjacent to the foundation at all points. See Figure 5-1.

B. Minimum Foundation Wall and Wall Footing Thickness. For masonry or concrete construction, the minimum foundation wall will be 6 inches. The minimum reinforced concrete footing thickness will be 6 inches or 1-1/2 times the length of the footing projection from the foundation wall, whichever is greater.

503-2. PIER AND COLUMN FOOTING REQUIREMENTS. Footings for pier foundations shall be reinforced concrete and should be placed level on firm undisturbed soil of adequate bearing capacity and below the frost penetration depth. They can also be placed on engineered, compacted fill, approved by a licensed geotechnical engineer.

A. Unusual Conditions. Where unusual conditions exist, the spacing of piers and pier size and the load bearing capacity of the soil shall be determined specifically for such conditions.

B. Minimum Pier and Pier Footing Thickness. The minimum thickness for a pier is 8 inches. The minimum thickness for pier footings is 8 inches or 1-1/2 times the length of the footing projection from the pier, whichever is greater.

503-3. FOOTING REINFORCING (HORIZONTAL). Reinforce footings when the projection on each side of the wall, pier, or column exceeds 2/3 of the footing thickness, or when required because of soil conditions.

503-4. MASONRY PIERS AND WALLS. All masonry piers and walls shall have mortared bed and head joints. Reinforcing and grouting shall be in accordance with the foundation concept selected from Appendix A and designed in Appendix C.

503-5. CRAWL SPACE REQUIREMENTS (Basementless spaces)

A. Height Requirement. Ground level must be at least 18 inches below bottom of wood floor joists and 12 inches below bottom of chassis beam. Where it is necessary to provide access for maintenance and repair of mechanical equipment located in the under floor space, the ground level in the affected area shall not be less than 2 feet below wood floor joists. (Refer to CABO, Section R-309.) See Figure 5-1.

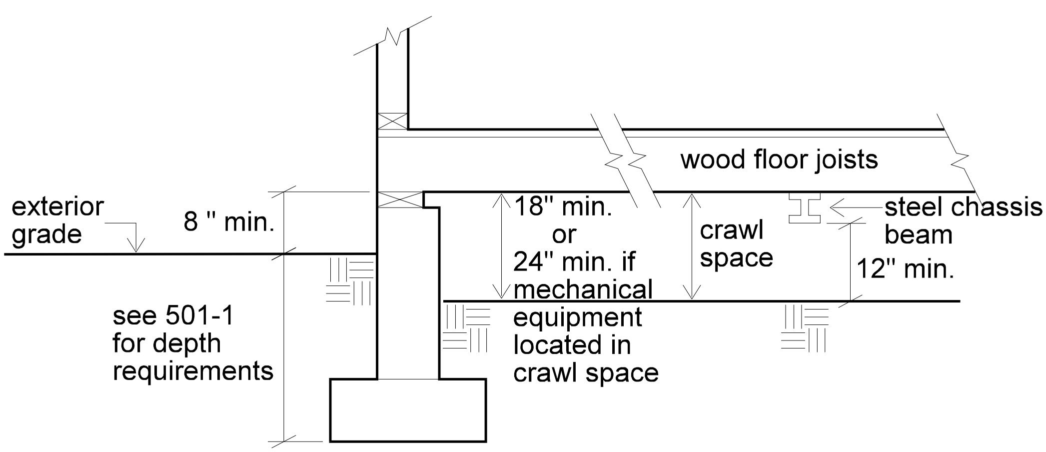
B. Interior vs. Exterior Ground Level. The interior ground level must be above the outside finish grade unless:

1. Adequate gravity drainage to a positive out fall is provided, or

2. The permeability of the soil and the location of the water table is such that water will not collect in the crawl space, or

3. Drain tile and automatic sump pump system are provided.

C. Openings. Locations of crawl space openings and ventilation openings should be on long foundation walls. Avoid any openings on short foundation walls. Sill plates or other structural members should not be randomly cut to accommodate openings. Continuity of structural



Minimum Clearances and Footing Depth

Figure 5 - 1

members must be maintained.

503-6. FOUNDATION WALLS FOR BASEMENTS. The design and reinforcing of basement walls is **NOT** in the scope of this document. Refer to local codes and ordinances for guidance. Refer also to CABO, Section R-304: "Foundation Walls." Design the unit's foundation based on soil conditions present at the site.

503-7. BACK FILL. Material used for back fill must be clean and free of wood scraps or other deleterious substances and must be placed carefully against walls.

503-8. S**TEEL BEAMS AND COLUMNS**. The analysis and design of steel transverse girders, steel longitudinal girders potentially used under marriage walls to reduce the number of steel pipe columns within a basement, and the steel pipe columns themselves are **NOT** within the scope of this document for system Types **E5**, **E6** and **E7**

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 anchorage 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 (heavy) + LL (occupancy) +
   LL (attic) + SL (or min. roof LL).

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

   (Wind or Seismic*) ± DL (light)

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

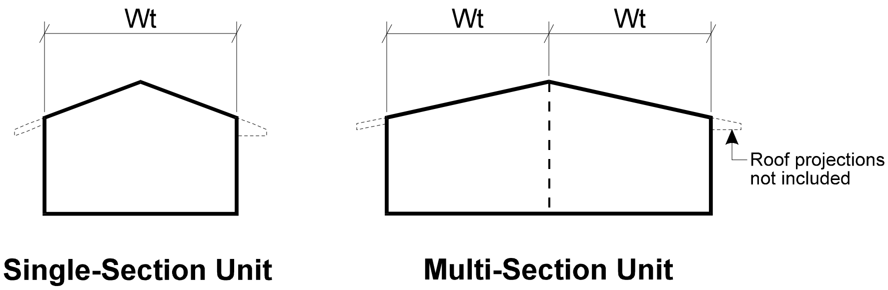
600-2 DETERMINATION OF BUILDING WIDTH

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:

Actual Building Width	Nominal Width
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 Wt (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 (Aa) from map 1 and (Av) from map 2 for the isobar closest to the site.

3. The manufactured home is exempt from seismic requirements if the map value for (Av) is less than 0.15; therefore, wind becomes the only lateral load design issue. If (Av) 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 (Av) 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).

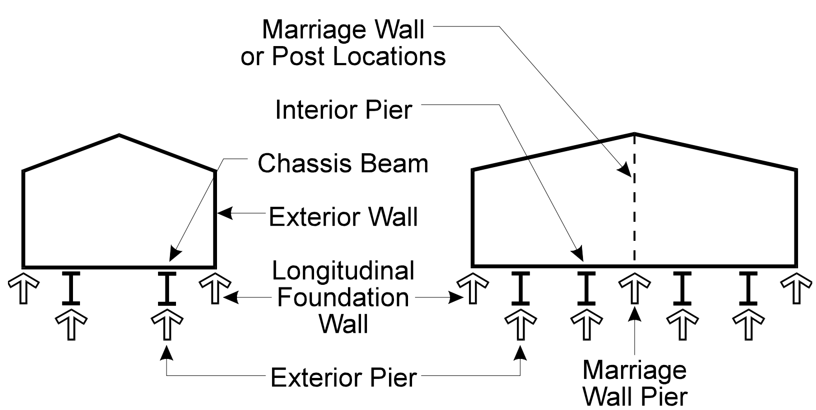
3. The manufacturer shall verify that the unit provides continuous load paths with adequate strength and stiffness to transfer all forces from the point of application to the point of resistance at the foundation. The design and detailing of the unit shall comply with Section 9.3.6 of ASCE 7-93 for the 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



Definition of Terms and Possible Support Locations

Figure 6 - 2

that marriage walls may be continuous walls, or contain specifically located openings with posts at the ends of each opening.

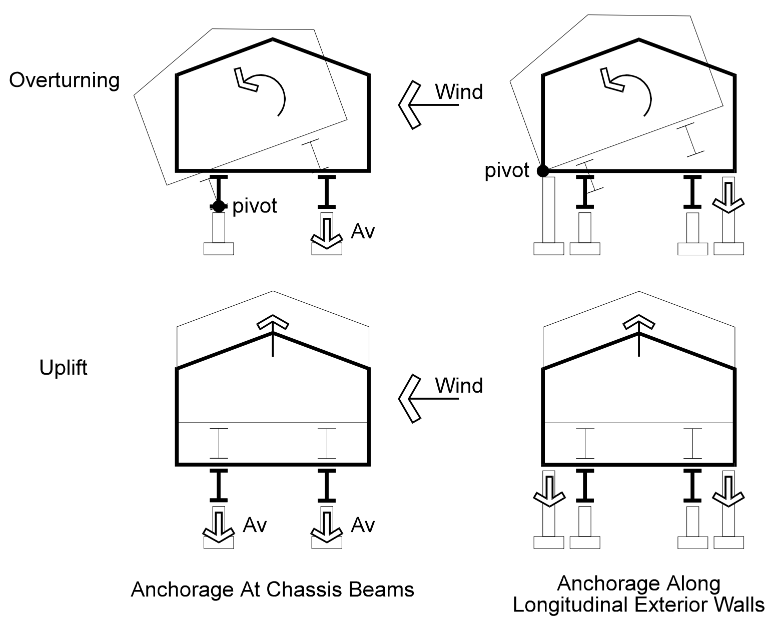
C. Determine the Location of Foundation Supports. Single-section or multi-section units are supported by equally spaced piers along their chassis beams, by exterior longitudinal walls or both. Multi-section units may possibly have additional equally spaced pier supports along a continuous marriage wall, 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 continous 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 (Av) IN THE TRANSVERSE DIRECTION.

A. Definition of Vertical Anchorage.



Overturning and Uplift Resistance Options

Figure 6 - 3

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 section 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 **C**hassis beam lines only. This is true for single-section or multi-section units.

Type **E**: Support occurs at the **E**xterior 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:

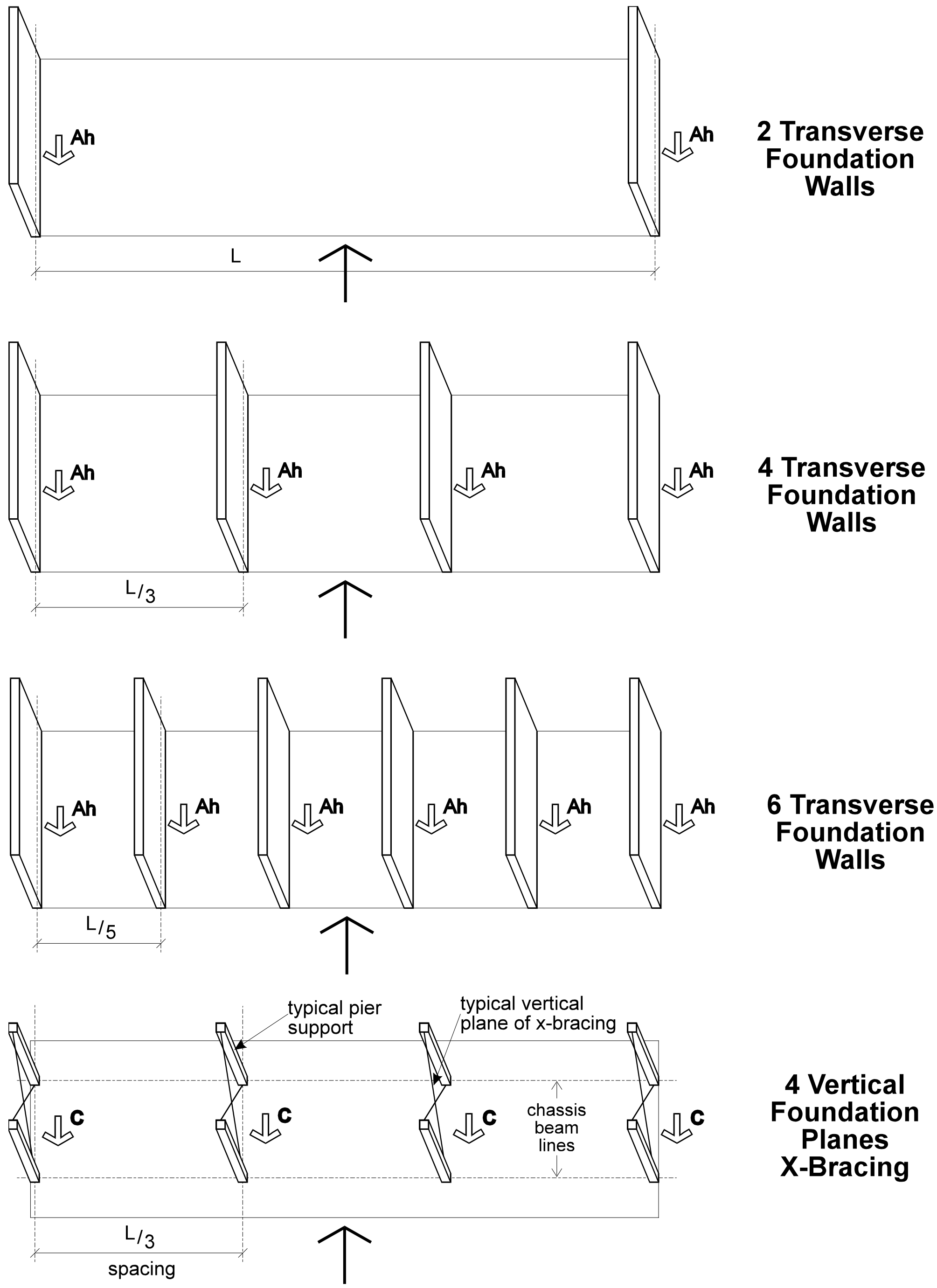
Symbols: ⇩ vertical anchorage (uplift and overturning)
⇧ support (gravity)

Type **C**: concepts C2 to C4

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

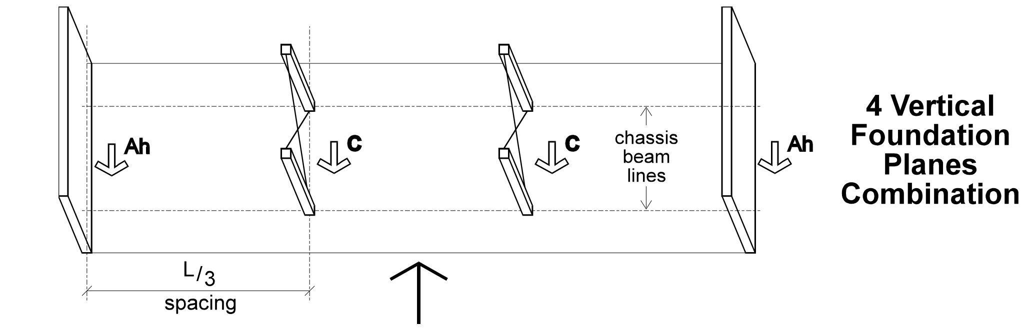
Type **I**: included here as possible future design concepts. None were currently submitted by manufacturers.

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

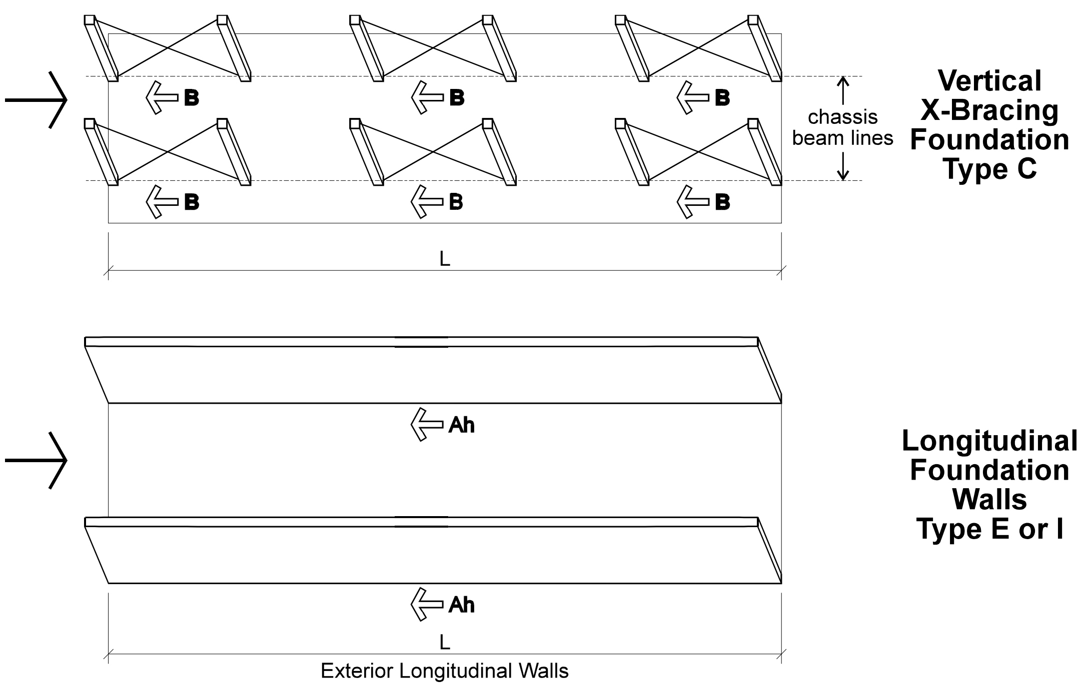
Figure 6 - 5

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



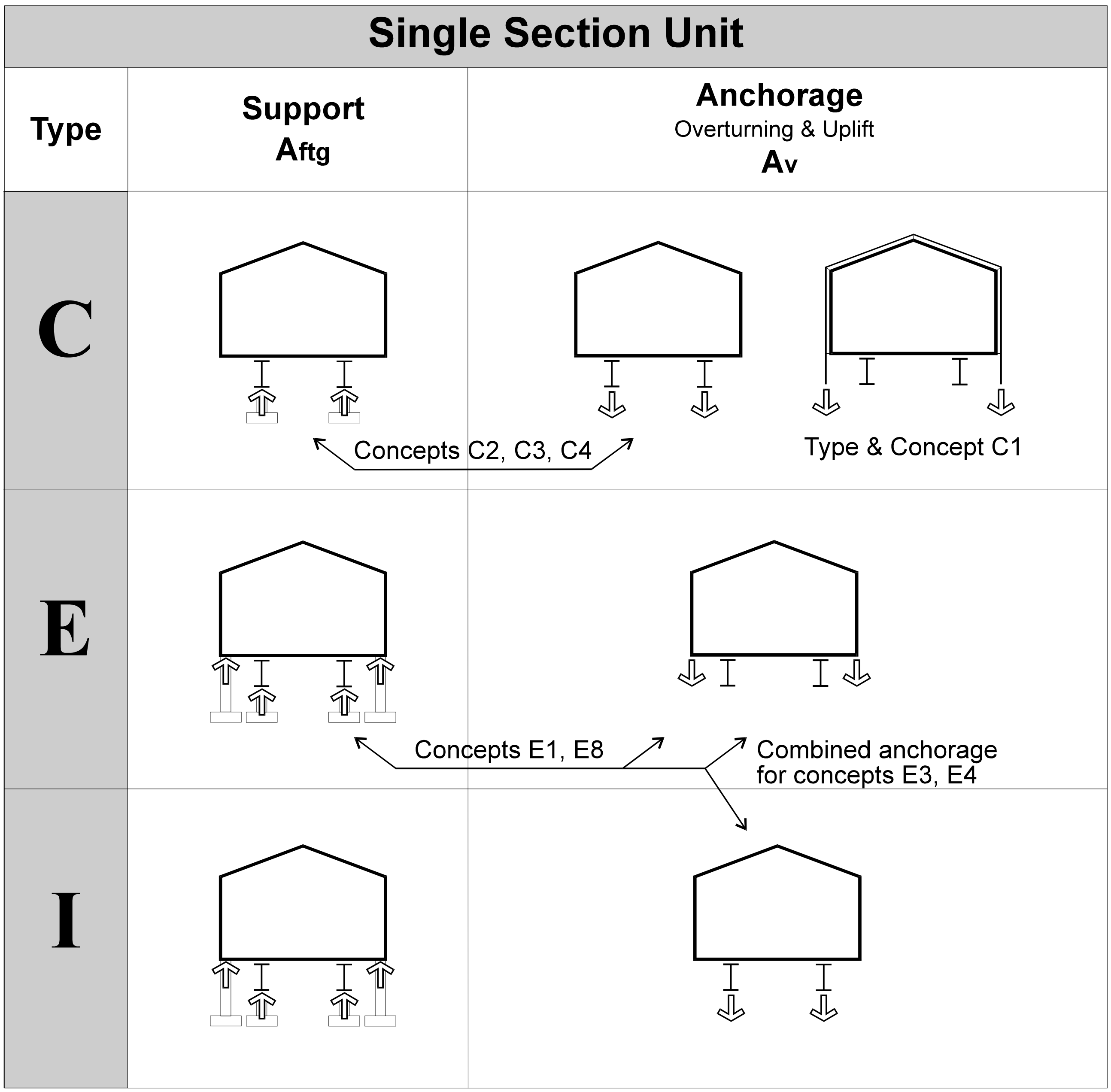
Sliding Resistance Options - Longitudinal Direction

Figure 6 - 6

with no marriage wall)

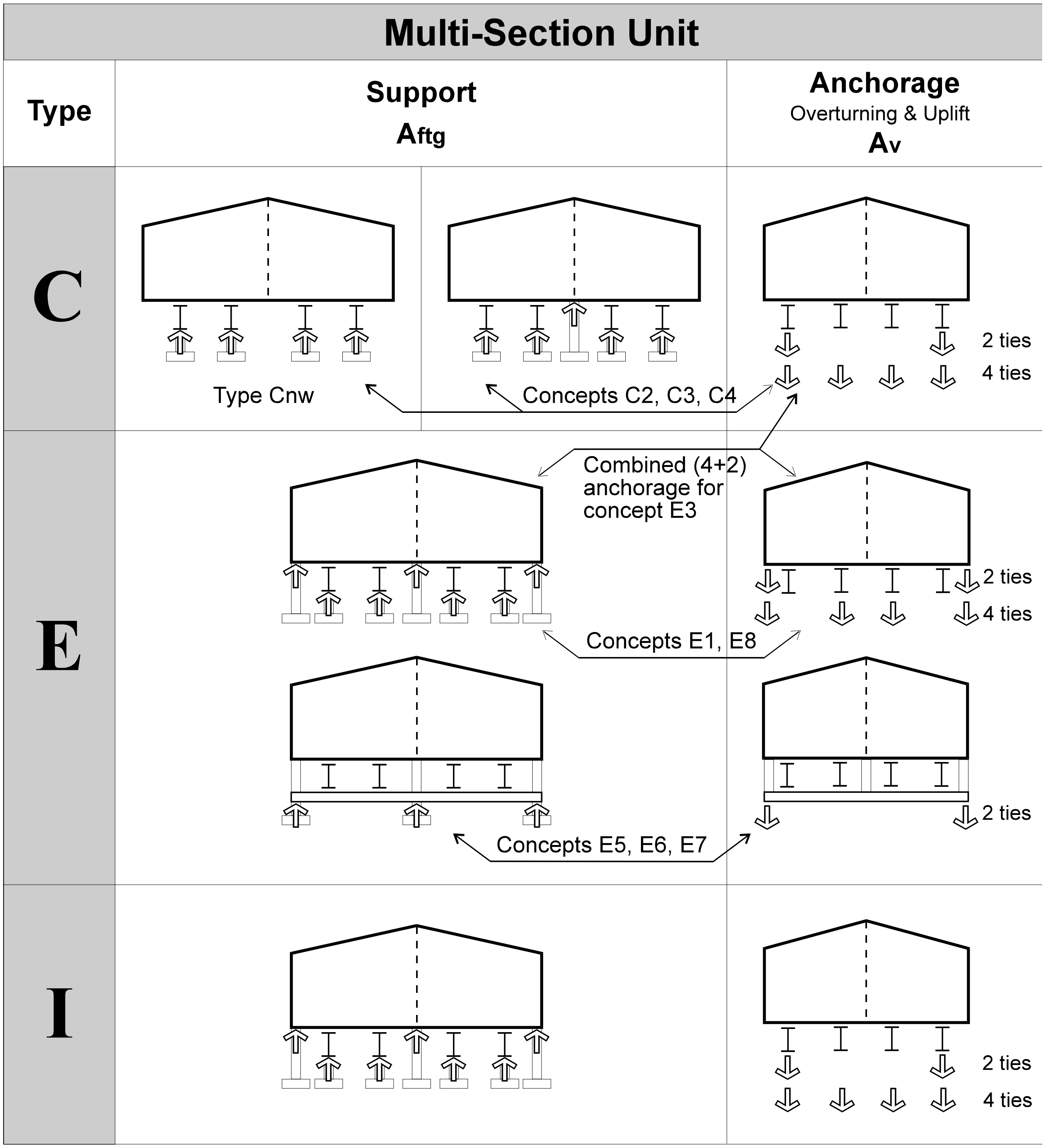
602. USING THE FOUNDATION DESIGN TABLES (APPENDIX B)

602-1. GENERAL. The Foundation Design Load Tables (Appendix B) are used to determine 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 Concepts: Single-Section Units

Figure 6 - 5



Foundation Design Concepts: Multi-Section Units

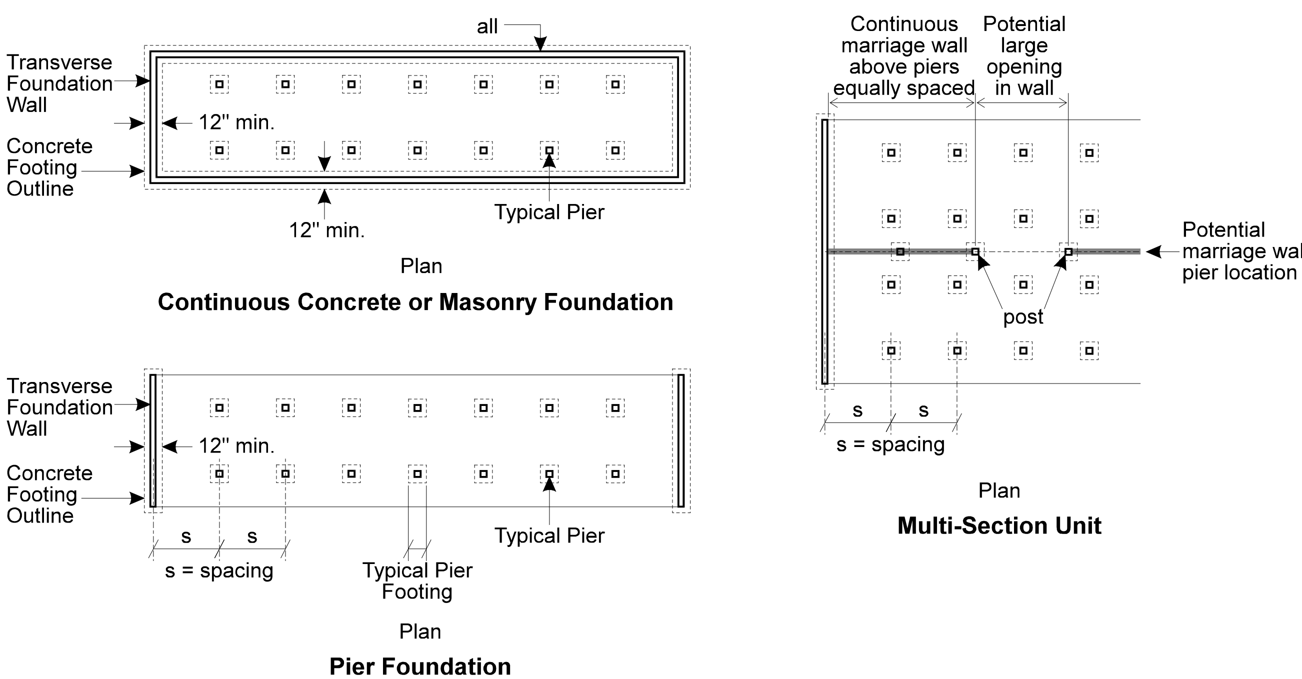
Figure 6 - 6

Foundation Design Load Tables.

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 Av 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 (**Av**), and square feet for (**Aftg**), 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



Foundation Terms

Figure 6 - 7

structure of the unit, or (2) the wall can stop at the underside of the chassis 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 linear 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 the correct

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 <u>Av</u> = 0.05; <u>Aa</u> = 0.05; Allowable Soil Pressure: 2000 psf.

1 — **Aftg C 14'** | **Single-Section** Width

Required Effective Footing Area - Aftg (sqft) *

2 — Ground Snow: 30 psf & Min. Roof: 20 psf

3 — Pier Spacing (ft): 5

Net Soil Pres (psf)	Pier Spacing (ft) 4	5	6	7	8	10
1000	3.5	4.2	4.9	5.6	6.2	7.6
1500	2.3	2.8	3.2	3.7	4.2	5.1
2000	1.7	2.1	2.4	2.8	3.1	3.8
2500	1.4	1.7	1.9	2.2	2.5	3.1
3000	1.2	1.4	1.6	1.9	2.1	2.5
3500	1.0	1.2	1.4	1.6	1.8	2.2
4000	1.0	1.0	1.2	1.4	1.6	1.9

Ground Snow: 40 psf

Net Soil Pres (psf)	Pier Spacing (ft) 4	5	6	7	8	10
1000	3.7	4.4	5.1	5.9	6.6	8.1
1500	2.4	2.9	3.4	3.9	4.4	5.4
2000	1.8	2.2	2.6	2.9	3.3	4.1
2500	1.5	1.8	2.1	2.4	2.7	3.2
3000	1.2	1.5	1.7	2.0	2.2	2.7
3500	1.0	1.3	1.5	1.7	1.9	2.3
4000	1.0	1.1	1.3	1.5	1.7	2.0

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 <u>Av</u> = 0.40; <u>Aa</u> = 0.40; Allowable Soil Pressure: 2000 psf. Marriage wall opening width = 14'-0".

Required Effective Footing Area - Aftg (sqft) *

Multi-Section Width | **Aftg E, I 14'** — 1

2 — Ground Snow: 70 psf

3 — Pier Spacing (ft): 4

Net Soil Pres (psf)		Pier Spacing (ft) 4	5	6	7	8	10
1000	ext, int	1.8	2.1	2.4	2.7	2.9	3.5
	mar	[illegible].3	6.5	7.6	8.8	10.0	12.3
1500	ext, int	1.2	1.4	1.6	1.8	2.0	2.3
	mar	[illegible].5	4.3	5.1	5.9	6.6	8.2
2000	ext, int	1.0	1.1	1.2	1.3	1.5	1.8
	mar	2.6	3.2	3.8	4.4	5.0	6.2
2500	ext, int	1.0	1.0	1.0	1.1	1.2	1.4
	mar	2.1	2.6	3.0	3.5	4.0	4.9
3000	ext, int	1.0	1.0	1.0	1.0	1.0	1.2
	mar	1.8	2.2	2.5	2.9	3.3	4.1
3500	ext, int	1.0	1.0	1.0	1.0	1.0	1.0
	mar	1.5	1.8	2.2	2.5	2.8	3.5
4000	ext, int	1.0	1.0	1.0	1.0	1.0	1.0
	mar	1.3	1.6	1.9	2.2	2.5	3.1

Net Soil Pres (psf)		Opening Width (ft) 10	12	14	16	18	20
1000	mar	8.8	9.4	9.9	10.5	11.1	12.2
1500	mar	5.9	6.2	6.6	7.0	7.4	8.2
2000	mar	4.4	4.7	5.0	5.3	5.5	6.1
2500	mar	3.5	3.7	4.0	4.2	4.4	4.9
3000	mar	2.9	3.1	3.3	3.5	3.7	4.1
3500	mar	2.5	2.7	2.8	3.0	3.2	3.5
4000	mar	2.2	2.3	2.5	2.6	2.8	3.1

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 (Av) 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 (Av) 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 manufacturer recommended, pier spacing is reached.

3. Read (**Av**) 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 (**Av**) 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 (Ah) IN THE TRANSVERSE DIRECTION (APPENDIX B, PART 3)

Example 1:

Required Vertical Anchorage - Av (lbs)

Wind Speed (mph)		Pier Spacing (ft) 4	5	6	7	8	10
Inland	80	960	1200	1450	1690	1930	2410
	90	1370	1710	2060	2400	2740	3430
	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

1 Single-Section Width — Av C 14'

2

Example 2:

1 Av E 14' 4 — Multi-Section Width Tiedowns

Required Vertical Anchorage - Av (lbs)

2

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. 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 connection of the unit to

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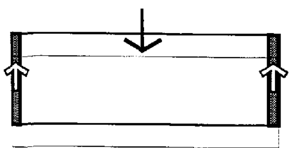
Example 1:

1 → Ah | C, E, I | 16' | 2 — **Single-Section** Width Short Walls



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

2 — 3 — 4

Wind Speed (mph)	Seismic Aa	Ground Snow (psf)	Location	40	50	60	70	80	90	100
Coastal 80	.05-.30	0-100	end	480	600	720	830	950	1070	1190
	.40	0-90	end	480	600	720	830	950	1070	1190
		100	end	490	600	720	840	960	1080	1200
90	All Seismic		end	600	760	910	1060	1210	1360	1510
100	All Seismic		end	750	930	1120	1310	1490	1680	1870
110	All Seismic		end	900	1130	1350	1580	1810	2030	2260

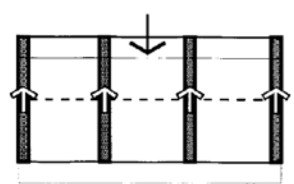
Example 2:

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

3 — 4 — 5

Wind Speed (mph)	Seismic Aa	Ground Snow (psf)	Location	40	50	60	70	80	90	100
Inland 80	.05-.20	0-100	end	90	120	140	160	190	210	230
			int	180	230	280	320	370	420	470
	.30	0-60	end	90	120	140	160	190	210	230
			int	180	230	280	320	370	420	470
		70	end	100	120	140	170	190	210	230
			int	190	240	280	330	380	420	470
		80	end	100	130	150	180	200	230	250
			int	210	260	310	360	410	460	510
		90	end	110	140	170	190	220	250	280
			int	220	280	330	390	440	500	550
		100	end	120	150	180	210	240	270	300
			int	240	300	360	420	480	530	590
	.40	0-40	end	90	120	140	160	190	210	230
			int	180	230	280	320	370	420	470
		50	end	110	130	160	180	210	230	260
			int	210	260	310	360	410	460	510
		60	end	120	140	170	200	230	260	280
			int	230	290	350	400	460	510	570
		70	end	130	160	190	220	250	280	310
			int	260	320	380	440	500	560	620
		80	end	140	170	210	240	270	310	340
			int	280	340	410	480	550	610	680

Multi-Section Width Short Walls — Ah | C, E, I | 14' | 4 ← 1



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**.

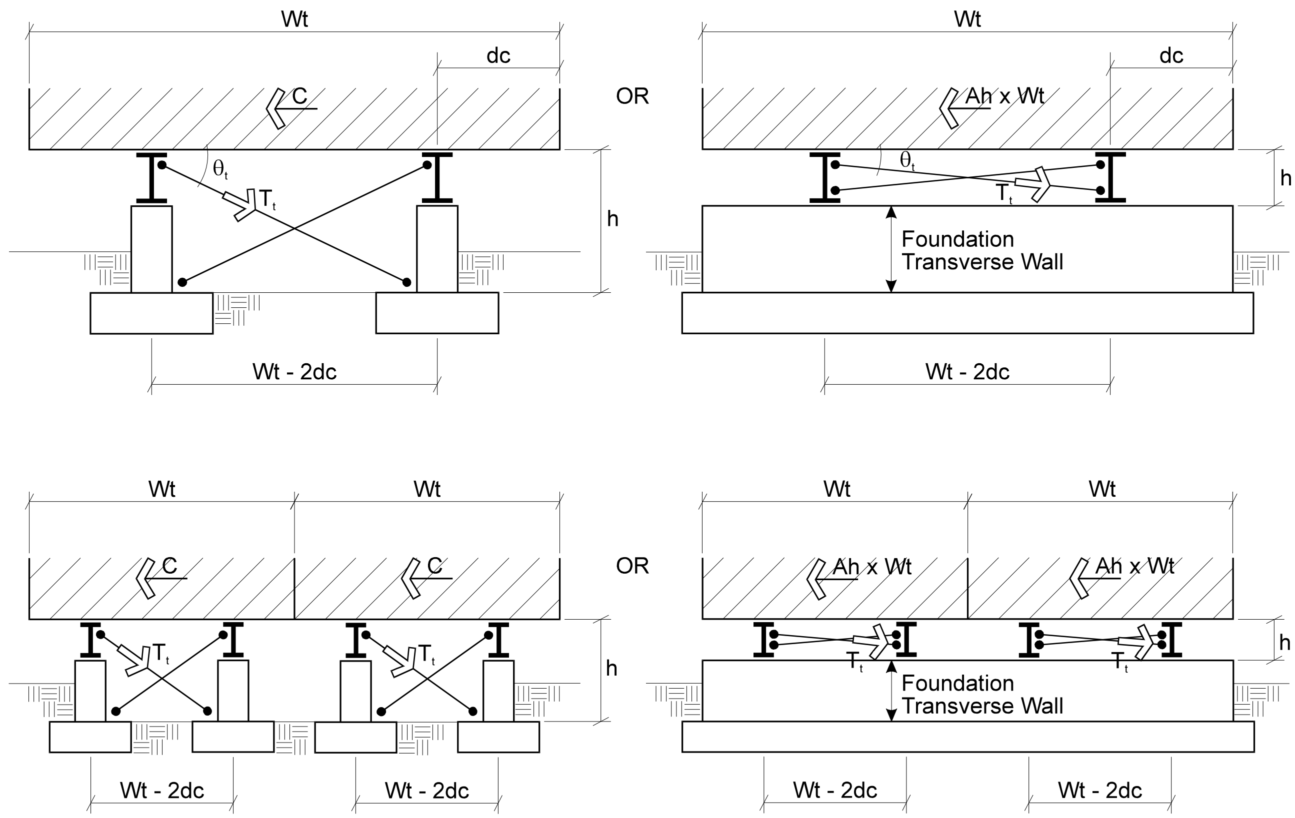
2. Enter the selected Table at the far left and move down either the Inland or Coastal wind speed column, as appropriate, until the required MPH value is reached. Slide to the next column to the right within the block of numbers covered by that wind speed.

3. Select the next smaller block of numbers based on the required seismic (<u>Aa</u>). Move to the right to the next column and locate the required ground snow load. The seismic (<u>Aa</u>) 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 **int**erior 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 equal to or greater than the horizontal anchorage requirements from the Tables. See the Manufacturer's Worksheet, item # 16(c) and example



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

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 (Ah) 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 (Ah) 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 (Wt) 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 (Aa) 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.

3. 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**.

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

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Example 1:

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

[2] Seismic Aa	Ground Snow (psf)	Wind Speed (mph)		40	50	[3] Length (ft) 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

Single-Section Width	Ah C, E, I [1]
	14'

Example 2:

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

[2] Seismic Aa	Ground Snow (psf)	Wind Speed (mph)		40	50	[3] Length (ft) 60	70	80	90	100
.40	0-30	Inland	80	100	92	92	92	92	92	92
			90	127	101	92	92	92	92	92
			100	156	125	104	92	92	92	92
			110	189	151	126	108	94	92	92
		Coastal	80	110	92	92	92	92	92	92
			90	139	112	93	92	92	92	92
			100	172	138	115	98	92	92	92
			110	208	167	139	119	104	93	92
	40	Inland	80-100	180	180	180	180	180	180	180
			110	189	180	180	180	180	180	180
		Coastal	80-100	180	180	180	180	180	180	180
			110	208	180	180	180	180	180	180
	50	Inland	80-110	202	202	202	202	202	202	202
		Coastal	80-100	202	202	202	202	202	202	202
			110	208	202	202	202	202	202	202
	60	All Wind		224	224	224	224	224	224	224
	70	All Wind		247	247	247	247	247	247	247
	80	All Wind		269	269	269	269	269	269	269
	90	All Wind		291	291	291	291	291	291	291
	100	All Wind		313	313	313	313	313	313	313

Multi-Section Width	Ah C, E, I [1]
	14'

chassis beams may also be used in lieu of exterior 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:

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

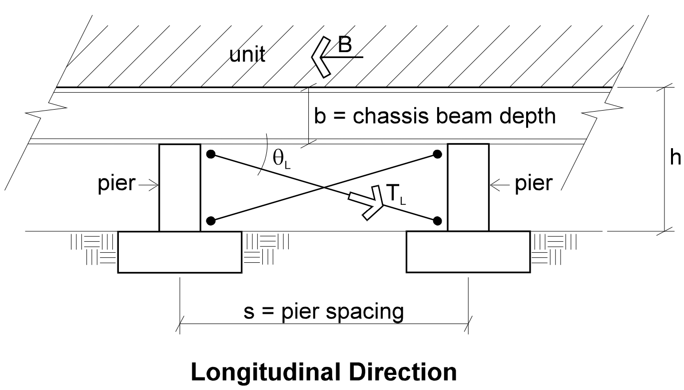
Note: For multi-section units using all four (4) chassis beam lines as vertical X-bracing lines, divide the above equation by 2 (see Fig.D-26 for an example).

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



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

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 (Av) with Tables C-1 or C-2 of Appendix C.

1. *For longitudinal foundation walls*, compare the required value for (Av) 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 (Av). There may be several numbers that meet this criteria.

   b. Any number that is greater than (Av) 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 (Av) 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 (Av). There may be several numbers that meet this criteria.

   b. Any number that is greater than (Av) 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 resistance.

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 (Av) with the capacity numbers.

   b. Find a capacity number that is greater than the required value for (Av). 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 requirements, 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 (Av) with the numbers in the left hand column of Table C-4.

   b. Find a number that is greater than the required (Av).

      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.

CHAPTER 7 - FINAL CHECK

700. GENERAL. Design values determined for the foundation sizes and detailing, that have been derived using procedures in the preceding chapters, will now be summarized. Follow the procedure near the end of the Design Worksheet of Appendix F for assembling relevant foundation information.

700-1. BEARING AREA AND VERTICAL ANCHORAGE.

A. Pier Footings and Piers under Chassis Beams.

1. Determine the area required for pier footings by comparing two values:

   a. The Required Effective Footing Area (Aftg).

   b. The Required Footing Area to resist overturning and uplift from withdrawal capacities found in Appendix C, where required.

2. Select the largest of the above two values. This value will determine the Pier Footing Size. The size and spacing of anchor bolts and the selection of reinforcing bar size, lap splice length, and reinforcing bar hook length for the piers has already been determined. The depth of the footings for frost and for withdrawal (where required) has also been determined. Bring these values forward.

B. Pier Footings and and Piers under Marriage Walls. Marriage walls only occur in multi-section units. Their piers only carry gravity loads and never participate in uplift or sliding. There are two pier situations that may occur at marriage walls: (1) the marriage wall is continuous without openings, or (2) there are locations where large openings in the marriage wall are intended to enlarge a room's space.

1. Where marriage walls are continuous: determine the area required for pier footings by using one value:

   a. The Required Effective Footing Area (Aftg) for marriage wall piers from the multi-section unit Foundation Design Tables in Appendix B.

   b. The piers are assumed equally spaced under the continuous portion of the wall.

2. Where marriage walls have a large opening: determine the area required for piers at the ends of the opening by using one value:

   a. The Required Effective Footing Area (Aftg) for marriage wall piers from the bottom of each multi-section unit Foundation Design Table in Appendix B by using the length of the opening.

   b. These piers are located at the ends of the opening directly under the posts that support the beam at the top of the opening.

C. Longitudinal Foundation Wall Footings and Longitudinal Foundation Walls.

1. Determine the correct footing size for longitudinal foundation walls, Types E & I, by comparing two values:

   a. The Required Effective footing width (Aftg).

   b. The Required footing width to resist uplift and overturning from the withdrawal capacities found in Appendix C, where required.

2. Select the largest of the above two values and use it as the appropriate footing size.

3. The foundation system brought forward can either be wood,concrete or masonry.

4. Bring forward values for the wall and footing as follows:

   a. Depth of footing

   b. Reinforcing bar size

   c. Lap splice length

   d. Reinforcing bar hook length

   e. Size and spacing of anchor bolts

   f. Treated wood foundation nailing requirements

700-2. HORIZONTAL ANCHORAGE IN THE TRANSVERSE DIRECTION: TRANSVERSE FOUNDATION WALLS.

A. Transverse Foundation Walls: Exterior (at unit ends) and Interior (to Underside of Chassis).

1. The number of transverse walls, wall footing sizes, anchorage requirements and foundation wall reinforcement have been determined to resist sliding, based on capacities found in Appendix C. Bring all these values forward where continuous transverse foundation walls are used.

2. The foundation system brought forward can either be wood, concrete or concrete masonry.

B. Transverse Foundation Walls Completed with Diagonal Braces.

1. Connection sizes and anchorage requirements have been determined. Bring these values forward where transverse foundation walls are completed with diagonal braces.

2. The foundation wall system brought forward can be only concrete or masonry. The galvanized steel diagonal straps connect to the top of chassis beams under the unit and to the top of masonry or concrete wall option selected.

C. Vertical X-Bracing Planes in Lieu of Walls. This applies only to Concept Design Types **C1**, **C2**, **E1**, **E3** and **E4** for either single or multi-section units.

1. Number, spacing and detailing information has been determined.

Bring these values forward where vertical X-bracing planes are used.

2. The foundation system brought forward can be only galvanized steel diagonal straps connected to the top of chassis beams under the unit and to the top of concrete footings.

700-3 HORIZONTAL ANCHORAGE IN THE LONGITUDINAL DIRECTION: LONGITUDINAL FOUNDATION WALLS.

A. Longitudinal Exterior Foundation Walls - Type E or I Units.

1. Connection sizes and anchorage requirements have been determined based on capacities found in Appendix C. Bring these values forward where longitudinal exterior foundation walls are used.

2. The foundation system brought forward can be wood, concrete or masonry.

B. Vertical X-Bracing Planes under Chassis Beam Lines-Type C Units Only.

1. Number, spacing and detailing information has been determined. Bring these values forward where vertical X-bracing planes are used.

2. The foundation system brought forward can by only galvanized steel diagonal straps connected to the bottom of chassis beams under the unit and to the top of concrete footings.

701. FINAL APPROVAL. All considerations important in the installation of the manufactured home should have been checked. If answers fall within the boundaries of this document, the foundation may be approved.

APPENDIX A
FOUNDATION DESIGN CONCEPT SELECTION

A-100. GENERAL. The foundation systems presented in this section were condensed from over 40 systems submitted by the manufactured housing industry. When a number of systems were similar in their detailing and the way they distributed loads, the system that was most representative of that group was selected for presentation in this section. Many variations from the detailing shown here are possible.

Some of the original systems are not included. The most common reason for rejecting a foundation system was lack of positive vertical anchorage. The superstructures of manufactured homes are too light to rely upon their mass to provide all resistance to overturning and uplift and must rely on the assist of their foundation to achieve adequate resistance.

A-100.1. IDENTIFICATION OF ACCEPTABLE FOUNDATION DESIGN CONCEPTS. The foundation systems are organized by the pattern of superstructure support and vertical anchorage. These two issues have been used to characterize the types of systems used in the Foundation tables: Types C, E, and I. There are no Type I systems presented in this chapter only because none were submitted by the industry for consideration. Type I systems were included in the Foundation Design tables due to their potential use. Their absence is not intended to imply that such systems are not viable, only that none are currently in use.

A-100.2. DELETIONS FROM THE FIRST EDITION. Concept E2 was deleted from this revision. It does not meet the permanent foundation criteria outlined in section 100-1.C. Specifically concrete footings are required for all foundation systems. It has been left in this Appendix but crossed out as a reminder to field officers of its inability to perform to the standard of this document.

A-100.3. LOADS THAT GOVERN. In many cases, the wind forces govern over seismic inertia forces in the design of foundation systems for manufactured homes. However, there are high seismic activity areas where seismic inertia forces control over wind. The detailing of some systems is better suited to regions with such high seismic activity. The selection of systems suitable for use in high seismic regions is based upon complete continuity in the connections between the superstructure and the foundation (and all its parts).

A-100.4. ECONOMIC FACTORS. Economics are not addressed in identifying the regional applicability of the different systems. Some systems would become economically unfeasible in regions with higher wind loads due to the size and depth required for their elements to provide anchorage. It is assumed that those who use this handbook as a design tool will discover the economic limitations of specific foundation systems on a case by case basis.

A-100.5. SELECTION TABLE. The table immediately following can be used to select appropriate foundation types for sites with special requirements.

Table A - 1

FOUNDATION SELECTION TABLE

Foundation Type	High Wind Zone			Engineering Design Required			Seismic Zone			Frost Zone
	All	Some	None	Yes	No	Maybe	All	Some	None	
C1 Reinforced masonry piers w/wire tie-downs & diagonal tie		**X**				**X**		**X**		
C2 Reinforced masonry or concrete piers	**X**				**X**		**X**			**X**
C3 Isolated deep piers	**X**			**X**			**X**			**X**
C4 Mat slab w/isolated piers	**X**			**X**			**X**			**X**
E1 Reinforced perimeter wall, unreinforced piers at chassis			**X**		**X**			**X**		**X**
~~**E2**~~ ~~Treated wood perimeter wall on gravel, unanchored metal piers~~		**DELETED** See E8	**X**		**X**			**X**		**X**
E3 Reinforced masonry or concrete perimeter walls & piers	**X**				**X**		**X**			**X**

Foundation Type	High Wind Zone			Engineering Design Required			Seismic Zone			Frost Zone
	All	Some	None	Yes	No	Maybe	All	Some	None	
E4 Reinforced perimeter walls & piers w/transverse footings	**X**					**X**	**X**			**X**
E5 Reinforced perimeter basement wall w/transverse steel girders	**X**					**X**	**X**			**X**
E6 Perimeter grade beam on deep piers w/transverse steel girders	**X**			**X**			**X**			**X**
E7 Reinforced concrete perimeter wall w/transverse steel girders	**X**					**X**	**X**			**X**
E8 Treated wood perimeter wall on concrete footing w/unanchored metal pier			**X**			**X**		**X**		**X**

APPENDIX B
FOUNDATION DESIGN LOAD TABLES

B-100. USE OF THE FOUNDATION DESIGN LOAD TABLES.

B-100.1 GENERAL. The Foundation Design Load Tables provide design values specific to the four conditions of foundation design: items A thru D below. Refer to Figure B-1 for diagrams of anchorage locations designed to resist wind or seismic forces acting on the structure, and footing size to prevent settlement. Refer to Appendix D for a more detailed derivation of the Foundation Design Load Tables. The four conditions are:

A. The required footing area based on the allowable soil bearing capacity under full gravity loading. The footing area is found in the Required Effective Footing Area Tables - Part 1 (pgs. B-3 to B-32).

B. The required anchorage to prevent uplift and overturning (A_V) - Required Vertical Anchorage Tables - Part 2 (pgs. B-33 to B-42).

C. The required anchorage to prevent sliding (Ah) in the transverse direction - Required Horizontal Anchorage Tables - Part 3 (pgs.B-43 to B-59).

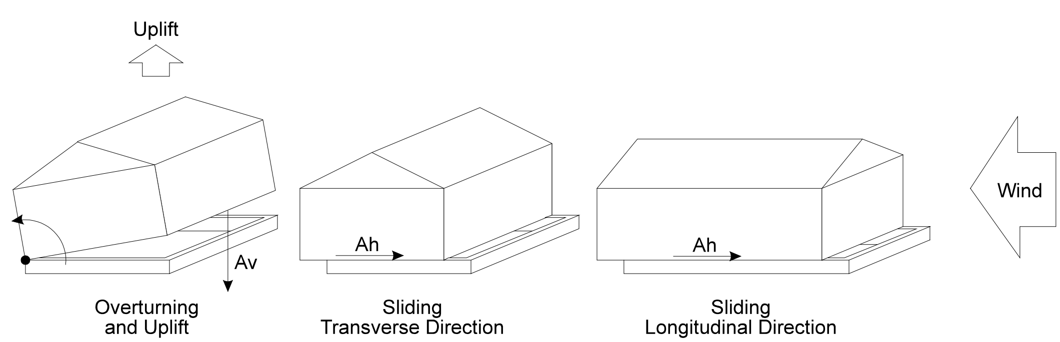
D. The required anchorage to prevent sliding (Ah) in the longitudinal direction - Required Horizontal Anchorage Tables - Part 4 (pgs. B-60 to B-84).

B-100.2. REQUIRED EFFECTIVE FOOTING AREA (Aftg). These tables provide the required effective footing area that will not exceed the allowable soil bearing capacity under full gravity loading of dead load plus live load.

B-100.3 REQUIRED VERTICAL ANCHORAGE (Av).

A. The Vertical Anchorage Table provides the required anchorage to resist uplift due to wind suction and overturning at the perimeter foundation wall or pier locations. Refer to Figure B-1.

B. Assumption: Uplift and overturning is resisted by anchorage to the piers and/or founda-



Anchorage Locations

Figure B - 1

tion walls.

B-100.4 REQUIRED HORIZONTAL ANCHORAGE (Ah) IN THE TRANSVERSE DIRECTION.

A. The Horizontal Anchorage Table provides the required anchorage to prevent sliding at the short foundation shear wall locations. Refer to Figure B-1.

B. Assumption: Sliding is resisted by anchorage to the short foundation shear walls and a portion of the dead load.)

C. Shear walls in the manufactured home are walls that have been designed and constructed by the manufacturer to resist lateral loads. The home's shear walls transfer lateral loads to the floor frame.

D. Assumption: Shear walls inside the unit are reasonably close to the location of short foundation shear walls for proper load transfer.

B-100.5 REQUIRED HORIZONTAL ANCHORAGE (Ah) IN THE LONGITUDINAL DIRECTION.

A. The Horizontal Anchorage Table provides the required anchorage to prevent sliding at the long foundation shear wall locations. Refer to Figure B-1.

B. Assumption: Sliding is resisted by anchorage to the long foundation shear walls and a portion of the dead load.

C. Shear walls in the manufactured home are walls that have been designed and constructed by the manufacturer to resist lateral loads. The home's shear walls transfer lateral loads to the floor frame.

D. Assumption: Shear walls inside the unit are reasonably close to the location of long foundation shear walls for proper load transfer.

INDEX to TABLES in APPENDIX B

Multi-Section **C**, **E**, **I**	B-90 to B-100

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

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×F_y) of the diameter of rod used. A 1/2"diameter anchor bolt has the following capacity: (0.6×36,000psi)×(π × 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 anchor 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": $A_{brg} = \pi \times (1.375^2 - 0.5625^2) \div 4 = 1.237^{sq. in.}$. 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: $873 \div 3.33' = 262$ 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 : $A_{brg} = \pi \times (1.75^2 - 0.6875^2) \div 4 = 2.03^{sq. in.}$. The vertical anchor capacity at the same same spacing = $2.03 \times 1.25 \times 565$ psi $\div$ 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: $F_{brg} = 0.35 \times f_c' = 0.35 \times 2500psi = 875psi$.

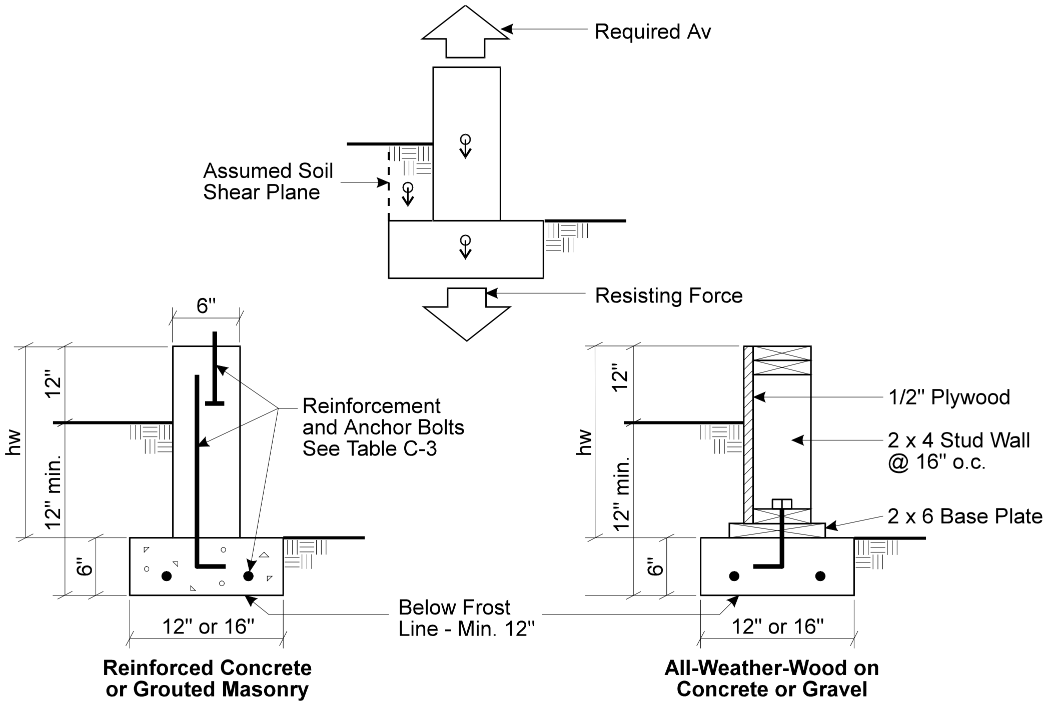
Example: Horizontal capacity per anchor bolt bearing = 875 psi × 1/2" dia. × 4" min. embed. = 1750 lb/bolt, rounded to 1800 lb/bolt. (Note: shear of the bolt did not control since it calculated to be 2830 lb/bolt, assuming A36 rod stock). Thus for 3 foot spacing: 1800 ÷ 3' = 600 plf, as shown in the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

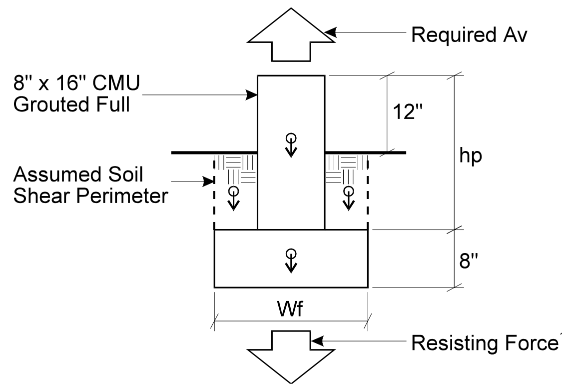
[3] Values shown in this table could be increased by widening the footing, provided the system is designed for the increased load, or by a more detailed analysis of the shearing strength of the soil overburden.

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

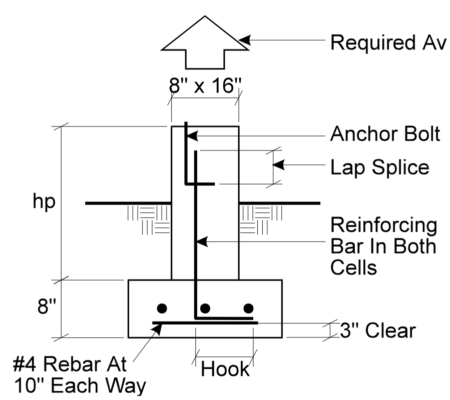
Vertical Anchor Capacity For Piers[1, 2]

(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"

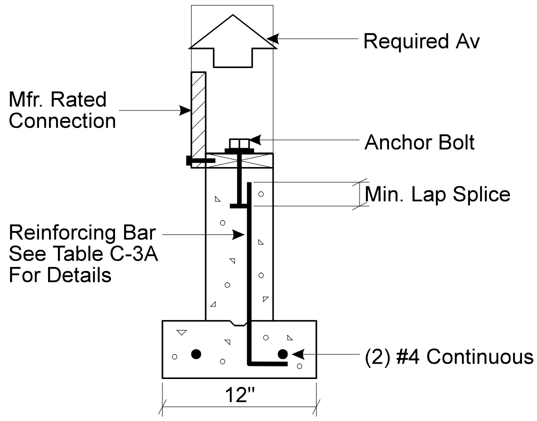


[1] The vertical anchor capacity is based upon the working capacity of ASTM A-36 rod stock anchor bolts in 2500 psi concrete or grout. To fully develop this capacity, anchor bolts must be properly lapped with the pier's vertical reinforcement.

[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)



Concrete or Masonry 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.

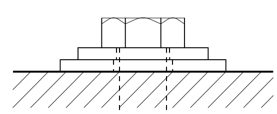
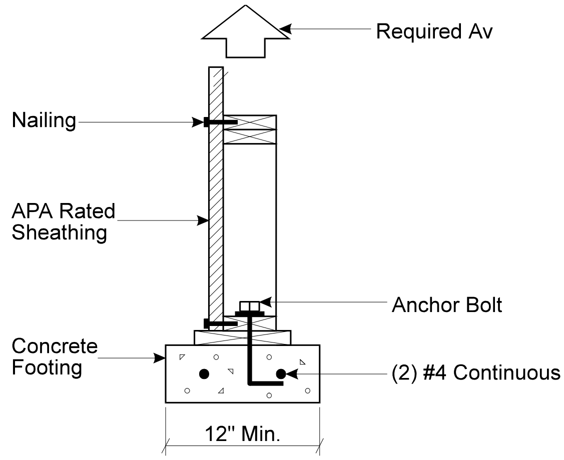


Table C-4B
Vertical Anchor Capacity For Longitudinal Foundation Wall[1, 2]
(In pounds per linear foot of wall)



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).

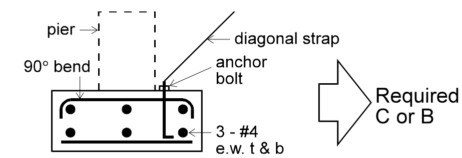
Table C-5A
Horizontal Anchor Capacity For Transverse or Longitudinal Shear Walls[1]
(In pounds per foot of wall)

Concrete or Masonry

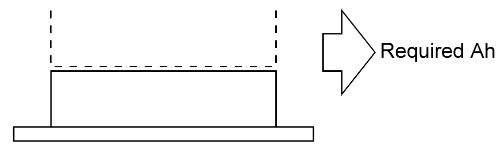
Horizontal Capacity[2] lbs./ft.	Required Anchorage[5]		
	Anchor Bolt[4]	Rebar	Spacing[6]
300	1/2"	#4	72" o.c. max.
600	↓	↓	36" o.c.
675	↓	↓	32" o.c.
900	↓	↓	24" o.c.
1350	↓	↓	16" o.c.
1800	↓	↓	12" o.c.
***			

See Table C-3A For Rebar Details

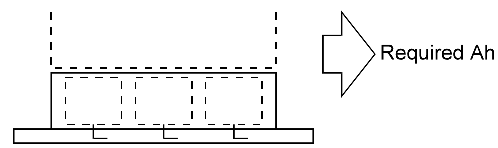
*** For required Ah greater than 1800 lbs./ft., consider using an engineered design with a higher capacity.



Pier Footing Used With X-Bracing



Concrete or Masonry



Treated Wood

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.)

APPENDIX D
DERIVATION OF FOUNDATION DESIGN

D-100. CONDITIONS AFFECTING DESIGN. Values for the Foundation Design Load Tables have been derived based on major foundation design factors, foundation design criteria, and design assumptions.

D-100.1 MAJOR FOUNDATION DESIGN FACTORS determine the appropriateness of foundations for manufactured homes:

A. Soil and site conditions.

1. Soil types
2. Bearing capacities
3. Drainage
4. Slopes

B. Load Conditions and Combinations. Various combinations of (1) through (5) with appropriate factors:

1. Dead loads
2. Occupancy live loads
3. Wind loads
4. Snow loads / Minimum roof live loads
5. Seismic loads

C. Foundation Design and Capacity.

1. Footing depth
2. Footing size
3. Reinforcing
4. Materials

D. Connection Compatibility with Manufactured Home. Adequate capacity plus a safety factor is required to transfer forces from the manufactured house to the foundation without failure.

D-100.2 CRITERIA FOR FOUNDATION DESIGN for manufactured homes must meet the following:

A. Assumptions made in foundation system design must be compatible with the design of the housing unit and actual site conditions.

B. Stress Limitations. The design must sustain all loads within stress limitations of connection systems.

C. Acceptable Foundation Design must provide for the Permanent Foundation criteria as specified in Section 100-1.C.

D-100.3 DESIGN ASSUMPTIONS

A. Values Included In Appendix B & C. The foundation tables in Appendices B & C are based on a number of design assumptions:

1. Building width is discussed in terms of minimum chassis beam spacing in Chapter 1: 100-1.A.5 and again in Chapter 6: 600-2.A.1. for comparison of nominal and range of actual width, and then is illustrated in Figure 6-1. It is clear that many actual widths are possible. The following actual widths and projections (dc) were used in the Tables of Appendix B:

Wt (nominal)	Wt (actual)	dc
12'	11'-8"(11.67')	32.25"(2.69')
14'	13'-8"(13.67')	41"(3.42')
16'	15'-6"(15.5')	45.25"(3.77')

2. The Overturning (Av) and Sliding (Ah) Tables in Appendix B assume hn=8.0 feet and assume a chassis beam depth of 10" (0.833 ft).

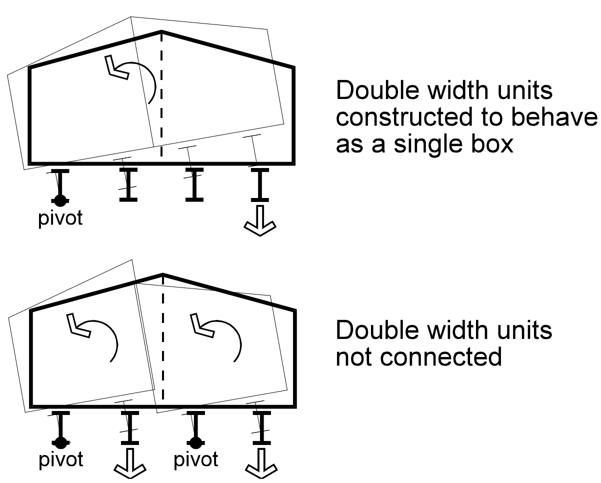
3. The manufactured home is located on a flat, open site with no protection from the wind.

4. Wind force on the manufactured home, instead of seismic force, is the controlling factor for the foundation overturning anchorage design in the transverse direction. Seismic forces or wind force may control sliding anchorage in the transverse or longitudinal direction.

5. Uplift, overturning, and sliding caused by wind or seismic forces acting on the manufactured home are transferred to the foundation by the structural integrity of the manufactured home.

6. The manufactured home unit, single or multi-width, is assumed to be a box with flexible floor and roof diaphragms. End walls and selected interior shear walls were assumed to transfer lateral forces based on tributary area methodology. The unit's shear wall locations must closely coincide with the foundation shear walls or vertical X-bracing planes. A structural engineer shall design the system if deviations from these assumptions exist.

7. Multi-section units are assumed to be connected at the marriage wall to act as a single box for overturning consideration, and do not act separately as illustrated in Figure D-1. This is particularly necessary in high seismic locations.



Marriage Wall Connection Options

Figure D - 1

B. List of Variables. These variables are used throughout Appendix D.

Aa Seismic coefficient representing effective peak acceleration

Ah Required horizontal anchorage (lbs. or lbs./LF)

Av Required vertical anchorage (lbs. or lbs./LF)

Av Seismic coefficient representing effective peak velocity related acceleration

Ce Exposure factor (See ASCE 7-93)

Ct Thermal factor (See ASCE 7-93)

Cp External wall or roof pressure coefficient (See ASCE 7-93)

Cs Roof slope factor (See ASCE 7-93)

Cs Seismic design coefficient (See ASCE 7-93)

dc Distance from perimeter of structure to chassis beam line.

DL Total dead load of structure for each foot of length

Fr Force resisting sliding

Fsl Sliding force (lbs.)

GCpi Internal wall or ceiling pressure coefficient (See ASCE 7-93)

Gh Gust response factor (See ASCE 7-93)

hn Height of the exterior wall acted on by lateral wind pressure

I Importance factor (See ASCE 7-93)

Kz Velocity pressure exposure coefficient (See ASCE 7-93)

LL Live load

Mo Overturning moment of structure

Mr Moment resisting overturning

p Design wind pressure

Pf Design roof snow load (See ASCE 7-93)

Pg Ground snow load (See ASCE 7-93)

Sp or Spacing: Spacing of foundation elements in the longitudinal direction.

V Basic wind speed (See ASCE 7-93)

Wt Width of structure (or 1/2 the total width of a multi-section unit)

D-200. LOAD CONDITIONS INCLUDED IN FOUNDATION DESIGN. The following load conditions have been used as assumptions in design of the foundation systems in this handbook. This information is important for engineers who may be designing connection details or modifying foundations designs. All Design Loads are based on ASCE 7-93, except as noted otherwise.

D-200.1 DEAD LOAD DESIGN FACTORS. Dead loads consist of the material weight of the manufactured home without furnishings or occupants. Dead load includes the weight of the roof, floor, walls, and chassis, and may include permanent attachments such as cabinets and attached appliances.

A. Dead Load Categories. Dead loads were grouped into two categories: heavy and light. The heaviest combinations of dead loads were used for the computation of footing areas, and the determination of inertia forces for the computation of sliding and overturning due to seismic activity. Heavier loads generate the largest inertia forces and produce the largest footings. The lightest combinations of dead loads were used for the computation of horizontal and vertical anchorage due to wind. Lighter loads offer less resistance to overturning and sliding and thus require greater anchorage. The following dead loads in Table D-1 have been included in the calculations for the

Foundation Design Load Tables on the next page.

B. Dead Load Equations for use in computing the required vertical and horizontal anchorage to resist overturning and sliding are listed below by type. The equations are for the total Dead Load per foot of Manufactured Home length. Figure D-2 illustrates the individual component loads and the total dead load situated at the geometric centroid of the unit.

Lightest combination of loads:

SINGLE-SECTION TYPES C, E, & I

DL = (34.5)2 + (6 + 8.6)Wt + 9 × 2
(walls)+(floor+roof)+(chassis beams)

DL = 87 + (14.6)Wt

MULTI-SECTION TYPES C, E, & I

DL = (34.5)2 + (26.25)2 +
2(6 + 8.6)Wt + 9 × 4
(ext. walls) + (marriage wall) +
(floor + roof) + (chassis beams)

DL = 157.5 + (29.2)Wt

Heaviest combination of loads:

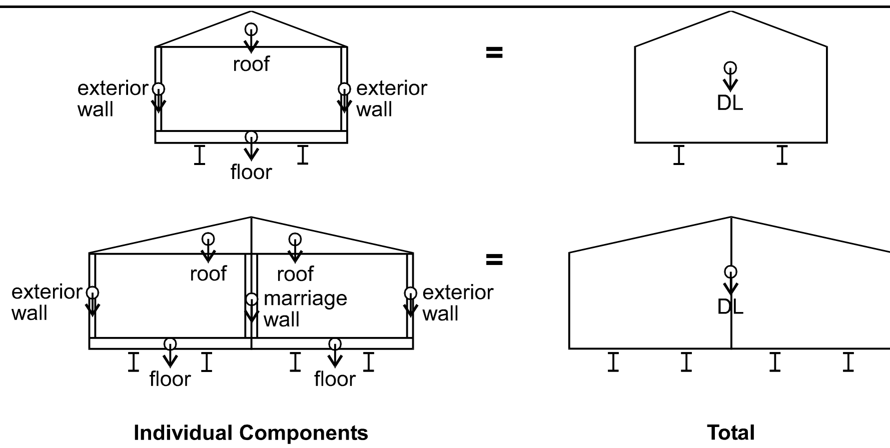
SINGLE-SECTION TYPES C, E, & I

DL = (44.25)2 + (13 + 9.7)Wt + 9 × 2
(walls) + (floor + roof) +
(chassis beams)

DL = 106.5 + (22.7)Wt

MULTI-SECTION TYPES C, E, & I

DL = (44.25)2 + (26.25)2 +
2(13 + 9.7)Wt + 9 × 4
(ext. walls) + (marriage wall) +
(floor + roof) + (chassis beams)



Dead Load Components and Total

Figure D - 2

DL = 177 + (45.4)Wt

TABLE D-1
DEAD LOAD ON FOUNDATION

LOCATION	ITEM	HEAVY (psf)	LIGHT (psf)	HEAVY (plf of length)	LIGHT (plf of length)
EXTERIOR WALL	7/16" siding	1.4			
	.019 aluminum		0.1		
	2 x 4 studs @ 16"o.c.	1.5	1.5		
	3 1/2" fiberglass insulation	1.0	1.0		
	1/2" gypsum	2.0	2.0		
	SUM =	**5.9**	**4.6**		
TOTAL	**7'-6" WALL**			**44.25**	**34.5**
FLOOR	carpet & pad	1.0			
	1/16" vinyl		0.7		
	5/8" plywood	1.7	1.7		
	2 x 10 joist @ 16"o.c.	2.6			
	2 x 6 joist @ 16"o.c.		1.4		
	11" fiberglass insulation	2.2			
	5 1/2" fiberglass insulation		1.2		
	mechanical	2.0	1.0		
	misc. partitions	3.5	0.0		
	SUM =	**13.0 ***	**6.0 ***	**13 × Wt + 9**	**6 × Wt + 9**
	* plus 9 plf for each manufactured home beam				
ROOF	asphalt shingles with felt	2.5			
	3/8" plywood	1.1			
	20 ga. steel		2.5		
	2 x 3 truss	1.5	1.5		
	9 1/2" fiberglass insulation	2.6	2.6		
	1/2" gypsum ceiling	2.0	2.0		
	SUM =	**9.7**	**8.6**	**9.7 × Wt**	**8.6 × Wt**
MARRIAGE WALL	2x4 studs @ 16"	1.5	1.5		
	1/2" gypsum (one side)	2.0	2.0		
	SUM =	**3.5**	**3.5**		
TOTAL	**7'-6" WALL**			**26.25**	**26.25**

D-200.2 LIVE LOAD DESIGN FACTORS

A. Description. Design live loads consist of the weight of all moving and variable loads (from use and occupancy) that may act on the manufactured home including loads on floors, operational loads on roofs and ceilings, or snow loads, but do not include wind, earthquake or dead loads. All live loads are assumed to be uniformly distributed and roof live loads are horizontally projected on sloped surfaces. The design live loads specified herein for the floor and attic are the minimums recommended by the ASCE standard. The design live loads specified herein for the roof are the minimum recommended by the *Minimum Property Standard*, HUD Handbook 4910.1, 1994 Edition. The roof live load used for the design of the foundation system should be the greater of the appropriate value indicated in the Data Plate shown here or as obtained from the ASCE 7-93 for snow load.

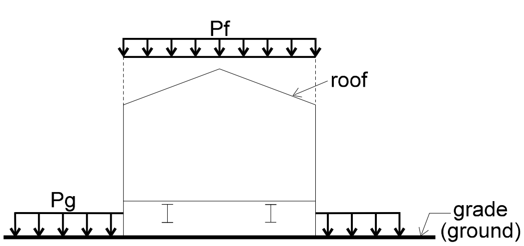
B. Design Assumptions. The following values for live loads were used in the engineering calculations and are included in the tables. They are provided here as background information only. The field inspector will not need to calculate live loads under normal circumstances. See box of live loads.

Minimum Uniformly Distributed Live Loads
(used for Foundation Design Load Tables)

Location	Live Load (psf)
Roof (slope 3/12 or less, ≤14°)	20*
Roof (slope over 3/12, >14°)	15*
(Over the entire width of the unit. Compare with snow load value. Use the larger value.)	
Dwelling rooms	40
(Floor design live loads over the entire area of the unit.)	
Attics	10
(uninhabitable, without storage)	

* Due to snow load factors, the 30 psf ground snow load used on the Foundation Design Load Tables is equivalent to a 20 psf roof live load. The 20 psf ground snow load is equivalent to a 15 psf roof live load.

D-200.3 SNOW LOAD DESIGN FACTORS



Snow Load Distribution

Figure D - 3

A. Ground Snow Load. The ground snow load values (Pg) to be used in the design of the manufactured home are found in Appendix H. The ground snow load is converted to a roof snow load to account for wind and thermal factors (see Figure D-3). The value (Pg) modified by snow load design factors has been included in the derived values for the Foundation Design Load Tables. The following assumptions were made to find Pf, the horizontally projected uniformly distributed design roof snow load:

B. Design Assumptions.

Basic Snow Load Equation:

$$Pf = 0.7 \times Ce \times Ct \times I \times Pg$$

Where:

1. Ground snow load (Pg) from the Ground Snow Load maps on pages H-11, H-12 and H-13.

2. Importance factor I = 1.0 (residential buildings)

3. Exposure factor Ce = 1.0 (locations where snow removal cannot be relied on to reduce snow loads)

4. Thermal factor Ct = 1.0 (heated structures)

5. Slope factor Cs = 1.0 (4/12 slope or less)

6. Flat roof factor = 0.7 (contiguous U.S.; Use 0.6 in Alaska.)

Therefore, the Required Effective Footing Area Tables are based on:

$Pf = 0.7 \times Pg$ (Roof snow load)

C. Drifted Snow. At locations where the manufactured home is adjacent to a higher structure, drifted snow loads MUST be calculated in accordance with ASCE 7-93. An average value including the drifted load may be used with the Foundation Design Load Tables.

D-200.4 WIND LOAD DESIGN FACTORS.

A. Model for Analysis. The methodology for resistance of the box to uplift, overturning and sliding utilizes equations for Main Wind-Force Resisting Systems as defined in ASCE 7-93.

B. Basic Wind Speed. The basic wind speed map is found on page H-14. Wind factors have been included in the derived values for the Foundation Design Load Tables of Appendix B.

C. Design Assumptions.

1. To convert mile per hour (MPH) wind speed to a basic wind velocity pressure (q) in pounds per square feet (psf) use the following equation from ASCE 7-93:

$$q = 0.00256 \times Kz \times (V \times I)^2$$

where:

a. Mean roof height is assumed to be less than or equal to 15 feet from grade.

b. Basic Wind Speed (V) is from the isobar map on page H-14 for the unit's geographic location.

c. Velocity Pressure Coefficient (Kz) is based on Exposure C: open terrain with scattered obstructions having heights generally less than 30 feet. This Category includes flat open country and grasslands. For these conditions, including item (a) above, Kz = 0.8.

d. Importance Category I (residential) for inland sites, sets I = 1.0, while for coastal sites (hurricane oceanline) I = 1.05. Linear interpolation can be utilized for sites between the oceanline and 100 miles inland; however, this was not done for the tables of Appendix B. Thus, only the above two values have been included.

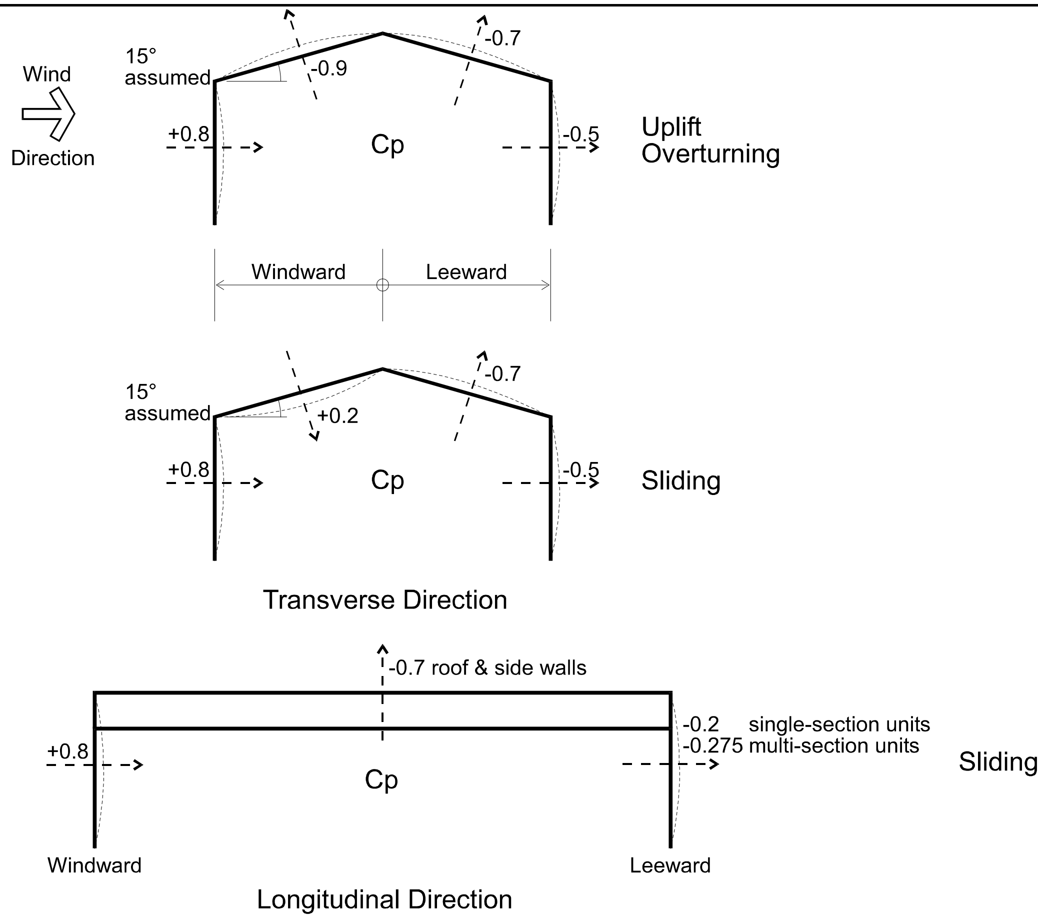
2. Velocity pressure (q) is applied to surfaces, i.e. walls and roof planes, to generate design wind pressures (p) for Main Wind-Force Resisting Systems. Design wind pressures (p) are based on external and internal effects utilizing the following equation from ASCE 7-93:

$$p = q \times Gh \times Cp - q \times (\pm GCpi)$$
(external) - (internal)

where:

a. The Gust Response Factor (Gh) is assumed to be based on Exposure C (see section D-200.4.C.1.c). The Minimum Property Standard (MPS) permits use of Exposure C regardless of whether the site is inland or coastal. Thus, for units of assumed mean height less than or equal to 15 feet, Gh = 1.32.

b. External Roof and Wall Pressure Coefficients (Cp) vary on the windward roof surface based on the structural issue being analyzed. Figure D-4 illustrates the various (Cp) values for the trans-

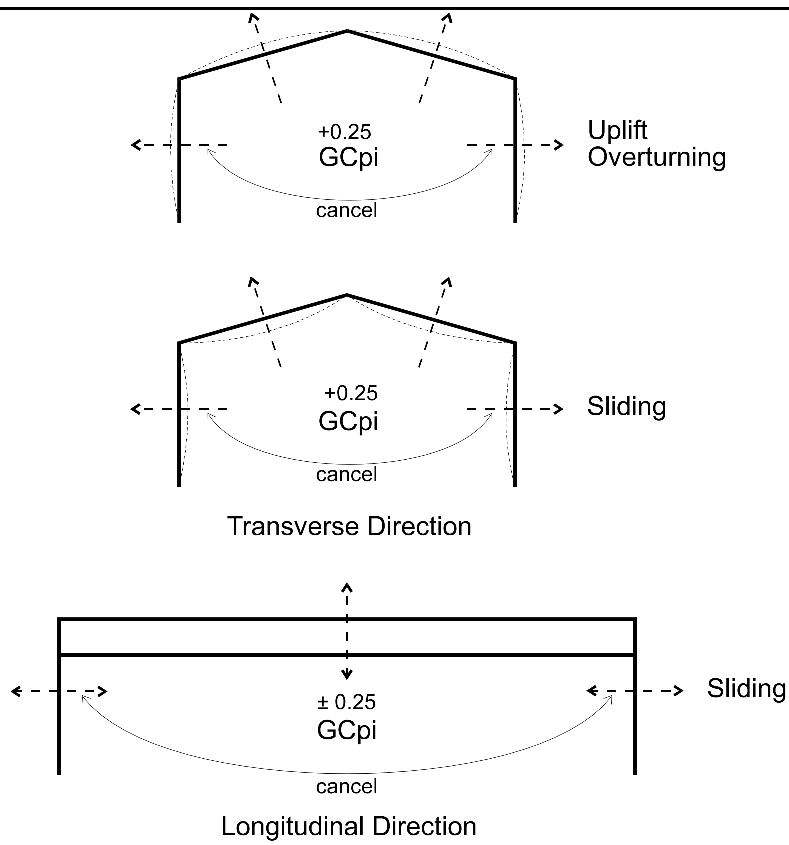


Exterior (Cp) Coefficients

Figure D - 4

verse and longitudinal directions. A roof slope of 10 to 15 degrees (2 in 12 to 3 in 12) produces 2 possible situations: (+0.2) pressure and (-0.9) suction. The value (-0.9) was selected to produce maximum suction for uplift and overturning while (+0.2) was selected to maximize sliding. Note that (+) means pressure on the external surface, while (-) means suction on the external surface. For the leeward wall in the longitudinal direction the proportions of the unit (L/Wt) are important to establishing the proper exterior (Cp) value. Single-section units, regardless of the combination of width or length, has a ratio L/Wt ≥ 4.0; therefore, Cp = -0.2. For multi-section units An average proportion of unit (28’ x 70’, or 32’ x 80’) was assumed. Thus, the L/Wt ratio was 2.5 and by interpolation Cp = -0.275. Single or multi-section units have a Wt/L ratio, which is ≤ 1.0 for all proportions of units. Thus, the leeward value for Cp = -0.5 in the transverse direction.

c. Internal Roof and Wall Pressure Coefficients assume a uniform distribution of openings on all sur-

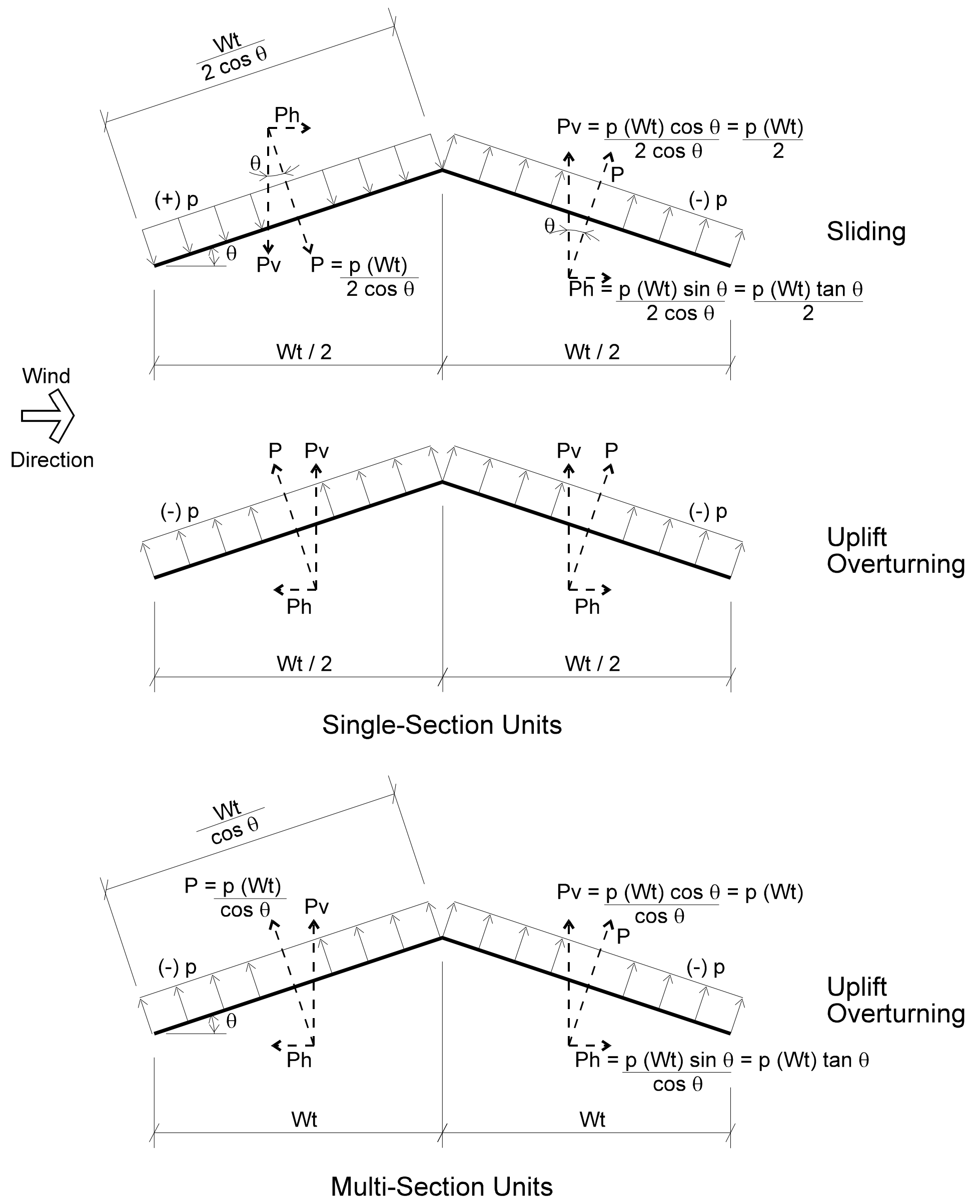


Interior (GCpi) Coefficients

Figure D - 5

faces, thus GCpi = ±0.25. Figure D-5 illustrates the pressures and suctions used for various structural considerations. Note that the walls receive offsetting values that cancel any internal effect; therefore, only the roof (GCpi) values are utilized for the calculation of overturning and sliding in the transverse direction. Internal roof Pressures are not utilized in the longitudinal direction.

d. Wind pressures and suctions are typically treated as uniformly dis-



Roof Plane - Wind Components - Transverse Direction

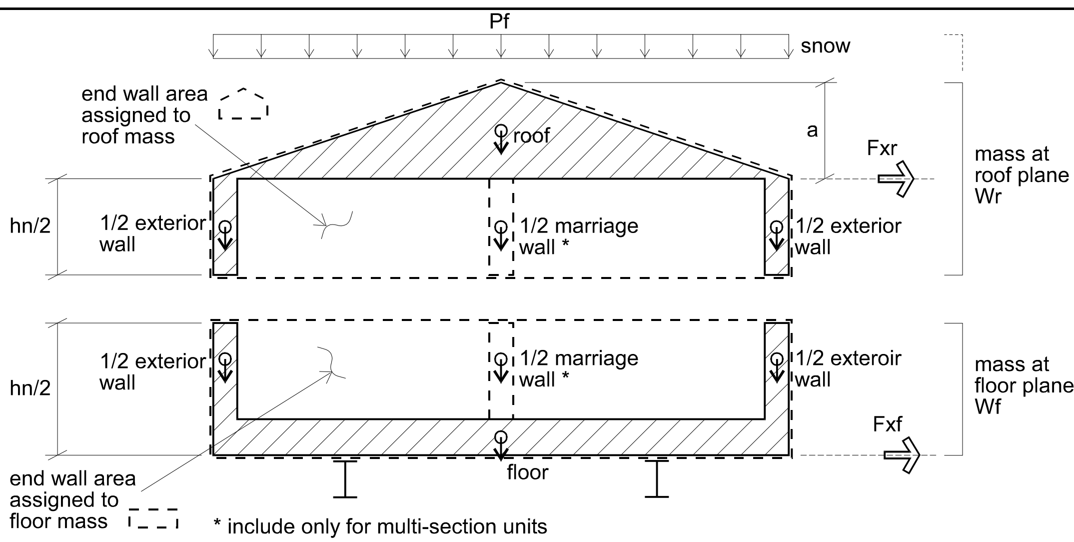
Figure D - 6

tributed and typically applied perpendicular to the orientation of any planar surface. This usually requires the calculation of horizontal and vertical components when wind is applied to sloping surfaces, in this case only roof planes. Figure D-6 illustrates that by the use of trigonometry the resultant force (P) on any sloping surface has components (P_V) and (P_H), which can be arrived at as shown. Note that for the vertical components (P_V) it is possible to merely multiply the pressure (p) by the horizontal length of the slope (Wt/2) for single section units or by (Wt) for multi-section units. This approach simplifies the sample calculations provided in section D-300 for uplift, overturning and sliding in the transverse direction.

D-200.5 SEISMIC LOAD FACTORS.

A. Seismic Versus Wind Forces. It has been stated in Chapters 4 and 6 that seismic forces did not control over wind forces in the computations for consideration of overturning in the transverse direction; however, seismic forces did sometimes control over wind for certain situations of sliding in the transverse and longitudinal direction. This is particularly true in the longitudinal direction because only the end wall elevations are exposed to the wind, producing small applied horizontal forces. Seismic inertia forces are a function of mass that is the same in both directions, which may be larger than the wind forces in particular when the geographic region is also a high snow region.

B. Dead Loads. The model assumes use of the “heavy” dead load values for roof, floor and wall components from Table D-1. It is assumed that the weight of the exterior walls and the weight of the marriage wall (for multi-section units only) are distributed half to the roof plane and half to the floor plane. The marriage wall was assumed continuous, without any large openings to maximize the dead load. This distribution of the dead load is illustrated in Figure



Seismic Dead Load Distribution

Figure D - 7

D-7 to arrive at inertia forces (Fxr) and (Fxf). The weight of the end walls was included in the total mass of the unit and distributed to the roof and floor as shown in Figure D-7 and defined by the equations below:

1. Areas at each end of a Single-Section unit:

$$A_r = \frac{Wt \times a}{2} + \frac{hn}{2} \times Wt$$

$$A_f = Wt \times \frac{hn}{2}$$

2. Areas at each end of a Multi-Section unit:

$$A_r = Wt \times a + 2 \times Wt \times \frac{hn}{2}$$

$$A_f = 2 \times Wt \times \frac{hn}{2}$$

3. These areas are multiplied by the heavy wall weight of 5.9 psf resulting in total roof and floor load additions respectively for Single or Multi-Section units as follows:

$$W_{endroof} = 2 \times 5.9 \times A_r$$

$$W_{endfloor} = 2 \times 5.9 \times A_f$$

The above loads are in pounds and are smeared into the unit's dead load for overturning by using an average length of 60 feet, while for sliding they are smeared into the unit's dead load by dividing by "L". See Section D-200.5.E.7.a for further clarification.

C. Snow Loads. When the flat roof snow load (Pf) is less than 30 psf, the snow load to be attributed to the mass at the roof plane shall be zero. Where siting and snow duration and conditions warrant, and roof snow load is equal to or exceeds 30 psf , the snow load shall be added to the mass of the roof plane. The local authority may permit a reduction in snow load by as much as 80%. See Figure D-7. Note that roof snow load (Pf) has been previously defined as 70% of the ground snow load (Pg) in section D-200.3B.

D. Miscellaneous Loads. No consideration of partial occupancy live load was included in the mass of the floor plane; however, mechanical and partition load was included in the floor plane.

E. Seismic Analysis Method. The Equivalent Lateral Force Procedure (ELF) was assumed for manufactured housing units, as defined by ASCE 7-93. No plan or elevation irregularities were assumed, Thus, the manufactured home superstructure was assumed to be a simple rectangular box with proportions of length to width not exceeding 5 to 1.

1. The Fundamental Period (T): the manufactured home is assumed to have the same period in either direction, transverse or longitudinal, determined from the following equation:

   $T = Ct \times h^{3/4}$

   where:

   a. Ct = 0.02 for the category of: all other buildings.

   b. the height from bottom of footing to the mean roof height (h) has been assumed as 13.5 feet.

   c. Thus: T = 0.14 seconds.

2. Site Coefficient (S): the site has been selected for the most significant soil classification, thus S = 2.0.

3. The Response Modification Coefficient (R): the structure has been selected as a bearing wall system with light frame walls with shear panels. Thus, R = 6.5.

4. Effective peak velocity-related acceleration coefficient (Av): is selected for the geographic location based on the map H-16 in Appendix H.

5. The Seismic Design Coefficient (Cs) is determined by the following equation:

$$\underline{Cs} = \frac{1.2 \times \underline{Av} \times S}{R \times T^{2/3}}$$

   Insertion of all the above values in the equation for (Cs) leads to the results tabulated below:

Av	Cs
0.15	0.204
0.2	0.273
0.3	0.409
0.4	0.546

6. But (Cs) need not exceed the following equation:

$$\underline{Cs} = \frac{2.5 \times \underline{Aa}}{R}$$

where:

   a. Effective peak acceleration coefficient (Aa): selected for the geographic location based on map H-15 in Appendix H.

   b. The results are tabulated below:

Aa	Cs
0.15	0.058
0.2	0.077
0.3	0.115
0.4	0.154

   c. The values for (Cs) are definitely smaller in item (6.b) above rather than in item (5.a), thus Cs is based on the equation in item (6). Thus, for this Manual assuming Aa = Av:

$$\underline{Cs} = \frac{2.5 \times \underline{Aa}}{R}$$

7. The basic equation for base shear (V_B), using the (ELF) method, is:

$$V_B = \underline{Cs} \times W$$

where:

   a. The total weight (W) is the summation of the roof plane mass and the floor plane mass, including snow as applicable, as a function of unit length. It is advantageous to keep the roof and floor loads separated for calculation ease and kept in units of lbs/ft of unit length as follows:

   For a Single-Section Unit:

$$w_{roof} = 9.7 \times Wt + 44.25 + \frac{W_{endroof}}{L} + \%P_f \times Wt$$

$$w_{floor} = 13.0 \times Wt + 44.25 + 18 + \frac{W_{endfloor}}{L}$$

For a Multi-Section Unit:

$$w_{roof} = 19.4 \times Wt + 44.25 + 26.25 + \frac{W_{endroof}}{L} +$$
$$2 \times \%P_f \times Wt$$

$$w_{floor} = 26.0 \times Wt + 36 + 44.25 + 26.25 + \frac{W_{endfloor}}{L}$$

Note: For overturning calculations, where (L) does not enter the equations, use L=60 ft as an average length to smear the end wall load. For Sliding (L) is always required and the end wall weight is smearing over the real length (L).

Where for either the Single or Multi-Section unit, the total dead load per foot of length of the unit becomes:

$$W = w_{roof} + w_{floor}$$

b. The seismic coefficient (Cs) is based on equation in item (6.b).

8. The base shear (V_B) is then distributed vertically as inertia forces (F_{xr} and F_{xf}) to the floor and roof levels according to the mass that exists at each level (see Figure D-7), based on the following generic equation:

$$F_x = C_{vx} \times V_B$$

where also generically:

$$C_{vx} = \frac{w_x \times h_x}{\sum_{i=1}^{n} (w_i \times h_i)}$$

a. The weight and height at each respective level is subscripted with an (x) while the sum of the product of each level's weight and height are generically subscripted with an (I). The uppermost level of the building (n) is in this case the roof. For a one story manufactured home, there will only be two levels, w_{roof} and w_{floor} reducing to two expressions substituting Single or Multi-Section unit values as follows:

$$C_{roof} = \frac{w_{roof} \times h_r}{w_{roof} \times h_r + w_{floor} \times h_f}$$

$$C_{floor} = \frac{w_{floor} \times h_f}{w_{roof} \times h_r + w_{floor} \times h_f}$$

Thus, the inertia forces in lbs/ft of unit length at the two respective levels becomes:

$$F_{xr} = C_{roof} \times V_B \qquad \text{and,}$$

$$F_{xf} = C_{floor} \times V_B$$

b. Sample spreadsheet output for two cases (snow Pg = 0 psf and snow Pg = 100 psf) indicates the range of (F_{xr}) and (F_{xf}) values at the roof and floor levels respectively for a single section unit. These examples include the 12, 14 and 16 nominal width units and are labeled as Tables D-2 and D-3. Note: nominal , rather than actual unit width (Wt) were used in the dead load calculations for conservatism.

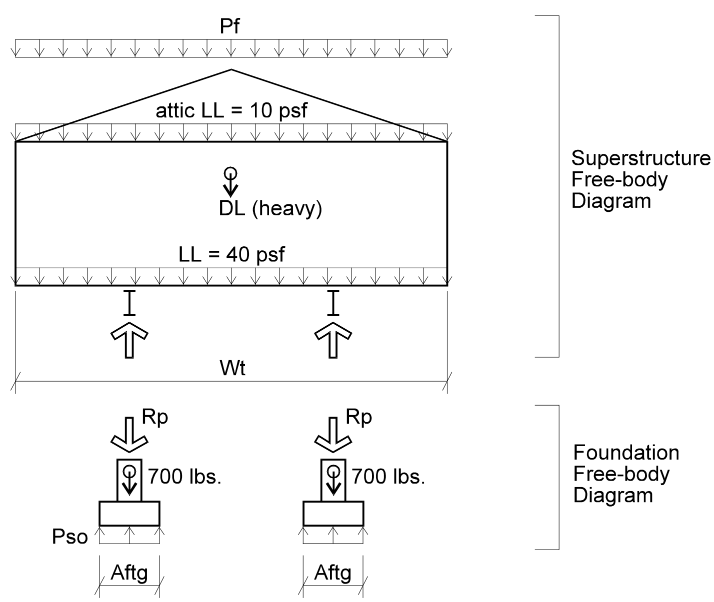
9. The forces (F_{xr} and F_{xf}) were applied to the manufactured home unit as illustrated in Figure D-7 and used for transverse and longitudinal overturning and sliding calculations for comparison to the wind forces. The forces that produced the largest required resistance values were used in the Foundation Design Load Tables - Appendix B. Values that are grayed in the Tables of Appendix B are controlled by seismic inertia forces.

D-300. SAMPLE EQUATIONS USED FOR FOUNDATION DESIGN LOAD TABLE VALUES.

D-300.1 REQUIRED EFFECTIVE FOOTING AREA. Refer to Figures D-8(A&B) and D-9(A&B) for the free-body diagrams illustrating the applied gravity loads on the superstructure and on the foundation for a Type **C** and Type **E** or **I** single-section unit, and a Type **C** multi-section unit with consideration of a continuous marriage wall and a marriage wall with a large opening. Note that the "heavy" dead loads are used from Table D-1. For allowable stress design methodology, the load combination from ASCE 7-93 is: DL(heavy) + LL(occupancy) + LL(attic) + SL(or min. roof LL).

Seismic

Smax= 2 R= 6.5 hn= 11.0 ft



Type C Single-Section Unit

Gravity Loads

Figure D-8A

Exposure Group I		Ct=	0.02	
Seismic Performance A to D		Assume no plan or elevation irregularities		
Equivalent Lateral Force Procedure				
Period:	Ta=Ct(hn)^3/4=	0.120802		
	Tmax=Ta*Ca	Ca=	1.5	(1.5 max for Av=.15)
		Tmax=	0.181203	

Cs max=2.5*Aa/R

Aa	Cs max
0.15	0.057692
0.20	0.076923
0.30	0.115385
0.40	0.153846

Snow Load: Pg= 0 psf Pf= 0 psf

	Wt		
DL	12.0	14.0	16.0
roof	160.65	180.05	199.45
floor	218.25	244.25	270.25
total	378.90	424.30	469.70

Width 12 ft

				Vbase=	21.86	29.15	43.72	58.29
					Fx=Cvx*Vbase Aa			
	w	h	w*h	Cvx	0.15	0.2	0.3	0.4
roof	160.65	11.0	1767.15	0.729654	15.95	21.27	31.90	42.53
floor	218.25	3.0	654.75	0.270346	5.91	7.88	11.82	15.76
sum	378.90		2421.90	1.0	21.86	29.15	43.72	58.29

Width 14 ft

				Vbase=	24.48	32.64	48.96	65.28
					Fx=Cvx*Vbase Aa			
	w	h	w*h	Cvx	0.15	0.2	0.3	0.4
roof	180.05	11.0	1980.55	0.729941	17.87	23.82	35.74	47.65
floor	244.25	3.0	732.75	0.270059	6.61	8.81	13.22	17.63
sum	424.30		2713.30	1.0	24.48	32.64	48.96	65.28

Width 16 ft

				Vbase=	27.10	36.13	54.20	72.26
					Fx=Cvx*Vbase Aa			
	w	h	w*h	Cvx	0.15	0.2	0.3	0.4
roof	199.45	11.0	2193.95	0.730173	19.79	26.38	39.57	52.76
floor	270.25	3.0	810.75	0.269827	7.31	9.75	14.62	19.50
sum	469.70		3004.70	1.0	27.10	36.13	54.20	72.26

Seismic Forces - Ground Snow < 30 psf

Table D - 2

Seismic

Smax=	2		R=	6.5		hn=	11.0 ft
Exposure Group I			Ct=	0.02			
Seismic Performance A to D			Assume no plan or elevation irregularities				
Equivalent Lateral Force Procedure							
Period:	Ta=Ct(hn)^3/4=		0.120802				
	Tmax=Ta*Ca		Ca=	1.5	(1.5 max for Av=.15)		
			Tmax=	0.181203			

Cs max=2.5*Aa/R	Aa	Cs max
	0.15	0.057692
	0.20	0.076923
	0.30	0.115385
	0.40	0.153846

Snow Load: Pg= 100 psf   Pf= 70 psf

	Wt		
DL	12.0	14.0	16.0
roof	1000.65	1160.05	1319.45
floor	218.25	244.25	270.25
total	1218.90	1404.30	1589.70

Width 12 ft

				Vbase=	70.32	93.76	140.64	187.52
					Fx=Cvx*Vbase			
					Aa			
	w	h	w*h	Cvx	0.15	0.2	0.3	0.4
roof	1000.65	11.0	11007.15	0.943856	66.37	88.50	132.75	176.99
floor	218.25	3.0	654.75	0.056144	3.95	5.26	7.90	10.53
sum	1218.90		11661.90	1.0	70.32	93.76	140.64	187.52

Width 14 ft

				Vbase=	81.02	108.02	162.03	216.05
					Fx=Cvx*Vbase			
					Aa			
	w	h	w*h	Cvx	0.15	0.2	0.3	0.4
roof	1160.05	11.0	12760.55	0.945695	76.62	102.16	153.24	204.31
floor	244.25	3.0	732.75	0.054305	4.40	5.87	8.80	11.73
sum	1404.30		13493.30	1.0	81.02	108.02	162.03	216.05

Width 16 ft

				Vbase=	91.71	122.28	183.43	244.57
					Fx=Cvx*Vbase			
					Aa			
	w	h	w*h	Cvx	0.15	0.2	0.3	0.4
roof	1319.45	11.0	14513.95	0.947095	86.86	115.82	173.72	231.63
floor	270.25	3.0	810.75	0.052905	4.85	6.47	9.70	12.94
sum	1589.70		15324.70	1.0	91.71	122.28	183.43	244.57

Seismic Forces - Ground Snow 100 psf

Table D - 3

APPENDIX E
OWNER'S SITE ACCEPTABILITY WORKSHEET

Owner's Name: ______________________________

Address: ______________________________

____

____

Telephone: ______________________________

Site Location: ______________________________

Legal Description: ______________________________

____

____

____

Have you provided a copy of a map pinpointing the site? yes no

Have you submitted a foundation plan? yes no
(See #10 of Manufacture's Worksheet)

Preliminary Site Information

Before approval of the site can begin, the applicant must provide preliminary site information to the field office. Refer to Chapter 2, "Site Acceptability Criteria" for clarification.

1. Provide survey results showing existing grade elevation. (201-1) ____________ ft.

2. Is the building in a flood-prone area? (201-2) yes no
   If the answer to 2 is Yes, answer 3, 4, & 5.
   If the answer to 2 is No, answer 6, below.

3. What is the Base Flood Elevation? ____________ ft.

   What is the Flood Protection Elevation? ____________ ft.

4. Has approval for drainage, grading and berming been approved for flood-prone sites? yes no

5. Have permits been provided? yes no
   (Permits must be obtained for any alteration of the building site in a flood protection area.)

6. Provide geotechnical report in areas of known high water table. (201-4) yes no

7. Provide geotechnical report if adverse site conditions are found or suspected. (203) yes no

8. Provide site-drainage plan complying with CABO R301.3 or local requirements. (301) yes no

9. Provide fill specifications if site is to be prepared with earth fill. (303-2) yes no

10. If a geotechnical report is required, what is the net allowable soil bearing pressure? (202) ____________ psf.

11. If no adverse soil conditions are known or suspected, and if the home is individually sited, assume a soil bearing pressure of 1,000 psf. and use this value when a determination of soil bearing pressure is called for. 1,000 psf.

APPENDIX E
MANUFACTURER'S WORKSHEET

Manufacturer's
Company Name: ______________________________

Address: ______________________________

____

____

Telephone: ______________________________

Determination of Building Structure and Size

The manufacturer shall provide the following information:

1. Type of unit — Single-Section / Multi-Section
2. Method, location and types of support:
   Refer to Figures 6-7 and 6-8 and Section 601-4
   Is the home a **C, E, or I**? ____________
3. Length of unit L ____________ ft.
4. Actual width of unit Wt ____________ ft.
5. Height of exterior wall ** ____________ ft.
6. Height of roof peak ** ____________ ft.
7. Roof slope ** ____________
8. Self weight of total unit (W) including mechanical equipment ** ____________ lbs.
9. Distance between chassis members ____________ ft.
10. One foundation design concept (See Appendix A) ____________
    (C1-C4; E1-E8; or I)

11. Recommended pier spacing **

   a. Exterior ____________ ft.

   b. Interior ____________ ft.

   c. Continuous Marriage Wall ____________ ft.

      Length of largest isolated marriage wall opening or average of largest two adjacent openings ____________ ft.

   d. Tie-down Strap (C1 concept only) ____________ (Number) ____________ ft. (Spacing)

12. One installation method recommendations (include documentation showing connection details pertinent to geographic area for seismic or wind). ** yes no

13. Interior shear wall locations (include documentation showing locations). ** yes no

14. Design wind speed used in designing connection details for horizontal anchorage (Ah) and vertical anchorage (Av) in the transverse direction. ** ____________ mph.

15. Seismic acceleration values used in designing connection details for horizontal anchorage (Ah) in the transverse and longitudinal directions. ** Av ____________ Aa ____________

16. Shear wall connection details with rated capacity for wind and seismic are provided. ** † yes no

   a. Connection locations at foundation end and interior walls shown? ** yes no

   b. Rated connection capacity for uplift and overturning ****** ____________ lbs./ft. (or lbs./tie-down)

   c. Rated connection capacity for sliding in transverse direction ****** ____________ lbs./ft. (or lbs./diag. strap)

   d. Rated connection capacity for sliding in longitudinal direction ****** ____________ lbs./ft.

e. Vertical X-bracing tension strap capacity ** ____________ lbs./diag. strap

f. Engineering calculation by licensed structural engineer? ** yes no

**** Optional values:** It is optional for the manufacturer to provide these values. If the manufacturer does not provide the values, it is the responsibility of the owner to supply values, based on engineering analysis by a licensed structural engineer.

† Item 16 is provided in California.

APPENDIX F
DESIGN WORKSHEET

Owner's Name: ______________________________

Address: ______________________________

Builder's Name: ______________________________

Site Location: ______________________________

PART 1: SITE CONDITIONS
(Accompanies Chapter 2)

1. Has the Manufacturer's Worksheet been provided? yes no

Existing Grade Elevation (201-1)

2. Does the site require a survey? yes no
   (Answer yes if: 1) elev. to be altered by grade or fill; 2) site near flood zone; 3) subdivision. Answer no if individually-sited with no alteration of building site.)

3. If yes to above, what is the surveyed existing grade elevation? __________ ft.

Flood Protection Elevation (201-2)

4. Is the building site in a flood zone? yes no
   (If yes to 4, then answer 5, 6, 7 & 8. If no, skip to 9.)

5. What is the Base Flood Elevation or the Flood Protection Elevation (use highest value)? __________ ft.

6. Is the site to be graded, filled, or bermed? yes no
   (If no, skip to 9.)

7. If yes to 6, have all permits been provided? yes no

8. If no to 6, then are the buildings to be built on elevated foundations? yes no
   (If yes, this handbook cannot be used. Refer to FEMA Manual.)

Frost Penetration Depth (201-3)

9. What is the maximum frost penetration depth? ____________ in.
   (see Appendix H, page H-4)

10a. Does foundation plan show base of footing extending below frost penetration depth? yes no
   (If yes proceed; if no, applicant should revise plans.)

10b. Does foundation plan show base of footing extending below topsoil layer (min. 12”) to undisturbed soil? yes no

Ground Water Table Elevation (201-4)

11. For subdivisions, does a Geotechnical Engineer recommend drainage of subsurface water? yes no
   (If no, skip to 13.)

12. Has groundwater drainage plan been provided? yes no

Soil Conditions (202, 203)

13. If any of the following adverse site conditions are discovered, specific recommendations by a Geotechnical Engineer will be required (applies to subdivisions and individually-sited homes.)

   Organic soil (8” topsoil layer) yes no

   Expansive (shrink-swell) soil yes no

   Sloping site yes no

   Subsidence yes no

   (Applicant may be referred to Geotechnical Engineer if any of the above are yes. If no, to all of above, move to next step.)

14. Is area in a known termite infestation area? yes no

   Region classification? ____________________
   (See Appendix H, Termite Infestation Map, page H-10) (If no, skip to 16.)

15. Has applicant complied with CABO R-308 or local ordinance for construction procedures and treatment? yes no
   (If yes, continue; if no, refer applicant to CABO requirements.)

PART 2: SITE PREPARATION

(Accompanies Chapter 3)

16. Acceptable surface drainage plan provided? (301) yes no
    (If no, one must be provided for subdivision)

17. Grading plan provided? (302) yes no

18. Fill specifications conforming to those cited in HUD Land Planning Data Sheet (79g)? (303) yes no
    (If fill is used, below the home's foundation, a report by Geotech. Eng. should be submitted to provide fill specifications.)

19. Finish grade elevation? (304) ___________ *
    (Check answers to Part 1: #4 & #5. The finish grade elevation must be higher than #5 if in flood zone.)

PART 3: DESIGN LOADS

(Accompanies Chapter 4)

Information from Manufacturer's Worksheet

20. Has all the information been provided on the Manufacturer's Worksheet? (Appendix E) yes no

21. What is the building self weight (W)? ___________ lbs.
    (Mfg. Wksht. #8)

22. What is the building length (L)? ___________ ft.
    (Mfg. Wksht. #3)

23. What is the distributed weight per foot of unit length? (w=W/L) ___________ lbs./ft.
    (402-1.B, C)

24. What is the building type? Single-Section / Multi-Section
    (Mfg. WkSht. #2)

    C, E, or I

    Foundation design concept?
    (C1, C2, C3, C4, E1, E3, E4, E5, E6, E7, E8, I) ___________ *

Dead Load (402-1)

25.	What is the light dead load value from Table 4-1? (402-1.A.1)	________ (lbs./ft.)	*
26.	What is the heavy dead load value from Table 4-1? (402-1.A.2)	________ (lbs./ft.)	*
27.	Does the answer from Question #23 fall within the values in #25 and #26? (402-1.D) (If the answer is yes, continue. If no, the foundation is not within the limits of this document and must be redesigned by a structural engineer.)	yes no	

Snow Load (402-2) / Minimum Roof Live Load (402-2.C)

28a.	What is average annual ground snowfall (Pg)? (See Ground Snow Load map, pages H-11, H-12 and H-13.)	________ (lbs./sq.ft.)	*
28b.	What is 0.7 multiplied by Pg?	________	psf.
29a.	What is the roof slope? (Mfg. Wksht. #7)	________	
29b.	What is the minimum roof live load for the roof slope? (D-200.2.B)	________	psf.
30.	Record the larger magnitude of item 28b or item 29b. Use this magnitude for roof load where required.	________	psf.

Wind Load (402-3)

31a.	What is the basic wind speed (V)? (See Wind Speed map, page H-14.)	________	mph.
31b.	If V is less than 80 mph, record *MPS* min. 80 mph for wind design. (402-3.A)	________	mph.
32.	Is the site inland or coastal? (402-3.B) (If inland, skip to question #38.)	Inland Coastal	
33.	If a coastal area, has the manufacturer provided connection details? (402-3.D) (Mfg. Wksht. #12)	yes no	

34. If yes to #33, what design wind speed has the manufacturer used in designing connection details? (Mfg. Wksht. #14) ____________ mph. *

35. Are the connection locations shown? (Mfg. Wksht. #16a) yes no

36. Are connection details provided for foundation shear walls? (For an answer of yes, all questions under Mfg. Wksht #16 must be answered satisfactorily.) yes no

37. Is the value for Question 34 equal to or greater than the number given in Question 31? (If yes, proceed. If no, return design to manufacturer for clarification.) yes no

Seismic Load

38a. What are the seismic acceleration values? (See Seismic maps, pages H-15 and H-16)

Aa ____________ *

Av ____________ *

38b. Is Av < 0.15? (if no, proceed. If yes, seismic need not be considered, skip questions 39 to 41.) yes no

39. Seismic performance category. (See H-300 for Special Requirements of Foundation Design.) ____________

40. What is the applicant's proposed design concept? (Design Wksht. #24) ____________ *

41. Do the Foundation Design Concept Tables approve the foundation system for use in seismic areas of Question #38 above? (See Appendix A) (If yes, proceed. If no, return to applicant for foundation design choice more suited to high seismic areas.) yes no

PART 4-FINAL DESIGN PROCEDURE

(Accompanies Chapter 6)

42. What is the actual building width? (Mfg. Wksht. #4) ____________ ft.

43. The nominal building width to be used in the Foundation Design Tables, (Aftg, Av & Ah) is Wt: ___________ ft.
(600-2.A and Figure 6-1)

44. Where are the foundation supports located? Check drawings submitted by the owner and Foundation Design Concepts in Appendix A. Circle the support locations shown on the Manufacturer's foundation concept plan.
Chassis Beams
Exterior Walls
Marriage Wall

45. Do these locations match the Foundation Concept shown in Appendix A? Do the locations match Question #24 on the Design Worksheet? yes no
(If yes, proceed. If no, return to Owner for clarification.)

46. Is Vertical Anchorage present? yes no
(601-2.B, 601-3.B & 601-4.B (Figures 6-7 & 6-8); Mfg. Wksht. #12 & #16)

APPENDIX A

47. What is the basic system type? ___________ *
(From Part 3: #24; Mfg. Wksht. #2)

48. What is the spacing between piers? Exterior: 4' 5' 6' 7' 8'
(Mfg. Wksht. #11)
(602-2) Interior: 4' 5' 6' 7' 8'

Continuous Marriage Wall: 4' 5' 6' 7' 8'

Largest or Average Marriage Wall Opening: ___________ ft.

Tie Down (C1) ______ ft.

APPENDIX B

Required Footing Size

49. The required Exterior Wall Footing, for the foundation type, is found in the Required Effective Footing Area table in App. B, Part 1.
(Use maximum value from item #30.) ___________ *

The Required Exterior Square Footing size is: Type C ___________ sq.ft.

Type E or I ___________ ft.
(width)

50. The Required Interior Footing area is: ___________ sq.ft.
(Also exterior piers for foundation type E)

51a. The Required Continuous Marriage Wall Footing area is: ___________ sq.ft.

51b. The Required Footing area under posts at the ends of marriage wall opening(s) is: ___________ sq.ft.

Vertical Anchorage Requirements in the Transverse Direction (602-4)

52a. Using the Foundation Design Load Tables (Appendix B, Part 2), determine the Required Vertical Anchorage. Exterior Av ___________ *
(lbs./pier spacing;
lbs./ft for E type;
lbs./tie-down spacing)

52b. Number of vertical tie-down locations for multi-section units: 2 or 4 or 6

52c. For units with additional vertical anchorage at the interior piers, determine the Required Vertical Anchorage. Interior Av ___________ *
(lbs./int pier spacing)

53. What is the manufacturer-supplied value? Exterior ___________ *
(#16b, Mfg. WkSht.)
Interior ___________ *

54. Is this value (#53) greater than the value given in #52a? yes no
(If yes, continue. If no, return to owner for clarification.)

Horizontal Anchorage Requirements In The Transverse Direction (602-5)

	trial 1	trial 2	trial 3	
55a. What number of transverse foundation walls was selected? (602-5.E) (If vertical X-bracing planes are used, complete items #55a, #56 and #57 for 2 transverse walls, and then skip to item #59.)	2	4	6	
55b. Are diagonal ties used to complete the top of the transverse short wall for horizontal anchorage? (602-5.G.1)	yes no	yes no	yes no	
Estimate height (h) for appropriate illustration in Figure 6-10.				ft.

		trial 1	trial 2	trial 3	
56. Using the tables, find the Required Horizontal Anchorage (Ah). (Appendix B; Part 3)	End Wall Ah				lbs./ft.
	Int Wall Ah				lbs./ft.
57a. What is the manufacturer's-supplied rated capacity for sliding? (#16c, Mfg. WkSht.)					lbs./ft.
57b. If answer to item #55b is yes, record manufacturer or product supplier rated strap tension capacity					lbs./strap
58a. Is value #57a greater than item #56? If yes, continue. If no, return to section 602-4.C and to question #55a and select a larger number of transverse foundation walls. If the maximum number selected (6) does not work, return to owner (who may wish to contact the manufacturer for clarification).		yes no	yes no	yes no	
58b. If answer to #55b is yes, required tension in diagonal (T_t). (Complete procedure in Section 602.5.G.1.)					lbs.
58c. Is value #57b greater than #58b? If yes, continue to item #62. If no, return to owner for product with greater capacity.		yes no	yes no	yes no	

59. If using vertical X-bracing planes in lieu of transverse short walls (and the formulas in section 602-5.G.2), determine anchorage values and sizes for diagonal members. (If shear walls are selected in item #55, skip to item #62.)

	trial 1	trial 2	trial 3	
a. Vertical X-bracing spacing proposed.				ft. *
b. Number of vertical X-bracing locations proposed. (Item #13, Mfg. WkSht. for trial 1.)				*

	trial 1	trial 2	trial 3	
c. Required horizontal anchorage (C) value, based on formula. (602-5.G.2.c)				lbs./ x-brace set
d. Estimated height (h) in Figure 6-10.				ft.
e. Tension (T_t) required. (602-5.G.2.d)				lbs./diag.
60. What is the manufacturer-supplied rated strap tension capacity? (#16, Mfg. WkSht.) (or capacity defined by literature supplied by product supplier)				lbs. *
61a. Is value #57 greater than value #59c? If yes, continue. If no, return to Section 602-5.G and to question #59 and select a greater number of X-brace locations as a next trial. Repeat until answer is yes, then continue.	yes no	yes no	yes no	
61b. Is value #60 greater than value #59e? If yes, continue. If no, return to section 602-5.G and to question #59 and select a greater number of X-bracing locations. If the maximum number selected does not work, return to owner (who may wish to contact the manufacturer for clarification or product supplier for clarification).	yes no	yes no	yes no	

Horizontal Anchorage Requirements In The Longitudinal Direction (602-6)

62a. Using the tables, find the required horizontal anchorage (Ah) in the longitudinal direction. (Appendix B, Part 4) (602.6.E)

Exterior Wall Ah ___________ lbs./ft.

62b. If using vertical X-bracing planes (and the formulas in section 602-6.F) determine anchorage value for X-bracing planes. (If using exterior long walls, skip to item #63.)

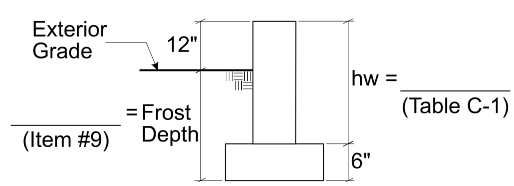
	trial 1	trial 2	trial 3
1. Number of chassis beam lines used for vertical X-bracing planes.	2 or 4	2 or 4	2 or 4

Item	trial 1	trial 2	trial 3	
Number of X-bracing planes proposed under each chassis beam along the length of the unit.				
2. Horizontal anchorage (B) required force, based on formula.				lbs.
3. Assumed height (h-b) based on Figure 6-11.				ft.
4. Tension (T_L) based on formula. (602-6.F.(3)).				lbs.
63. What is the manufacturer-supplied value for horizontal anchorage? (#16d, Mfg. WkSht.)				lbs./ft.
64a. For shear walls: is value #63 greater than #62a? If yes, skip to item #67. If no, contact owner for clarification.	yes no	yes no	yes no	
64b. For X-bracing: is value #63 greater than value #62b.2? If yes, return to item #62b.3. If no, increase number of vertical X-bracing planes and repeat items 62b.1 and 62b.2 until answer is yes. For multi-section units consider 4 lines of vertical X-bracing under all chassis beams.	yes no	yes no	yes no	
65. What is the manufacturer-supplied rated strap tension? (#16e, Mfg. WkSht. or product supplier)				lbs.
66. Is value #65 greater than #62b.4? If yes, continue. If no, contact owner to obtain straps with greater capacity, or return to item #62b.1 and increase the number of vertical X-bracing planes until answer is yes.	yes no	yes no	yes no	

APPENDIX C

Withdrawal Resistance Verification (603-2.B)

67. Using Appendix C, Table C-1 or C-2, verify that the foundation system will resist withdrawal. Answer question #67a for type E. Answer question #67b for types C, I, or type E with interior pier anchorage.



a. ***Withdrawal Resistance for long foundation wall.*** (Type E)

Circle the type of material that is to be used.

Reinforced Concrete
Masonry-Fully Grouted
Masonry-Grouted @ 48” o.c.
All-Weather Wood / Footing

1) Using Table C-1, which capacity is greater than required Av? (603-2.B.(1)) (#52a) ___________ lbs./ft.

2) Using Table C-1, what is the height of the wall + footing for required withdrawal resistance? (hw + 6”) ___________ in.

3) What is the height of the wall + footing for frost protection? (frost depth (#9) + 12”) ___________ in.

4) What is the greatest height #67a.2 or #67a.3? ___________ in.

   Circle the height which controls.

   Withdrawal
   Frost Depth

5) Record the bottom of footing depth from grade. (Item #67a.4 - 12”) ___________ in.

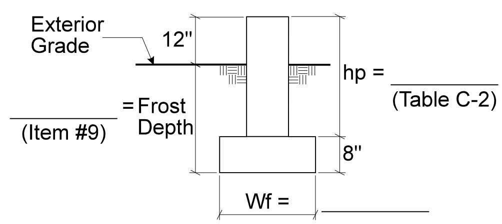
6) Using Table C-1, what is the required width of the wall footing for withdrawal? ___________ in.

7) Is item #67a.6 greater than or equal to item #49? yes no

   If yes, continue. If no, change footing width to item #49.

8) Record design exterior wall footing width. ___________ in.

b. ***Withdrawal Resistance for Piers.*** (Types C, C1 (concrete dead-man), I or type E with interior pier anchorage - multi-section units.)



Circle pier type:

Reinforced Concrete
Reinforced Masonry - fully grouted
Reinforced Concrete Dead-man

	Exterior	Interior (when used)	
1) Using Table C-2, which capacity is greater than required Av? (#52a and #52c) (603-2.B.(2))	___________	___________	lbs./pier *
2) Using Table C-2, what is the height of the pier + footing for required withdrawal resistance? (hp + 8")	___________	___________	in. *
3) What is the required height of pier + footing for frost protection? (frost depth (#9) + 12")	___________	___________	in.
4) What is the greatest height #67b.2 or #67b.3?	___________	___________	in.
Circle the height which controls.	Withdrawal Frost Depth	Withdrawal Frost Depth	
5) Record the bottom of footing depth from grade. (Item #67b.4 - 12")	___________	___________	in.
6) Using Table C-2, what is the required width of the square footing if withdrawal resistance controls or if frost depth controls?	___________	___________	in. *

c. ***Frost depth for marriage walls.*** What is the required depth of footing below grade for frost protection? (frost depth (#9)) (no withdrawal resistance) ___________ in.

Vertical Anchorage and Reinforcement for Longitudinal Foundation Walls and Piers (603-2.D)

68. Using Appendix C, Table C-3, C-4A or C-4B, verify that the foundation anchors will resist uplift. Answer question #68a for type E. Answer question #68b for types C, I, or type E with interior pier anchorage.

   a. ***Vertical Anchor Capacity for longitudinal foundation wall*** (type E). (603-2.D.2)

      1) Using Table C-4A (concrete & masonry), which capacity is greater than the required Av? (#52a, Design Wksht.) If treated wood wall, skip to item #68a.3. ___________ lbs./lineal ft. of wall

Circle correct washer choice for the capacity selected — Standard Washer / Oversized Washer

2) Using Table C-4A (masonry and concrete):

a) Required anchor bolt diameter ____________ in.

b) Required anchor bolt spacing ____________ in.

c) Using Table C-3A:

(1) Rebar size ____________ *

(2) Lap splice ____________ in.

(3) Rebar hook length ____________ in.

3) Using Table C-4B (wood), which capacity is greater than the required Av? (#52a, Design Wksht.) If using concrete or masonry wall, skip to item #68b. ____________ lbs./lineal ft. of wall

4) Using Table C-4B (wood):

a) Required nailing ____________ *

b) Minimum plywood thickness ____________ in.

c) Required anchor bolt diameter ____________ in.

d) Required anchor bolt spacing ____________ in.

b. ***Vertical Anchor Capacity for Piers***
(Types C, I, or type E with interior pier anchorage)
(603-2.D.1)

	Exterior	Interior (when used for anchorage in multi-section units)	
1) Using Table C-3, which capacity in the table is greater than the required Av? (From #52a, Design Wksht.)	____________	____________	lbs./pier

	Exterior	Interior	
2) Using Table C-3:			
a) Number of anchor bolts	1 or 2	1 or 2	
b) Anchor diameter	1/2" or 5/8"	1/2" or 5/8"	
3) Using Table C-3A:			
a) Rebar size	#4 or #5	#4 or #5	
b) Lap splice	______	______	in.
c) Rebar hook length	______	______	in.

Horizontal Anchorage and Reinforcement for Transverse Foundation Walls (603-3)

69. Using Appendix C, Table C-5A or C-5B, verify that the foundation anchorage will resist sliding at the transverse end foundation walls. Use for types C, E, or I.

	End Wall	Interior Wall	
a. ***For continuous foundations.***			
Using Table C-5A (concrete & masonry) or C-5B (wood), which capacity is greater than the required (Ah) (603-3) (item #56)?	______	______	lbs./ft.
1) Using Table C-5A, find:			
a) Required anchor bolt diameter	______	______	in.
b) Required anchor bolt spacing	______	______	in.
c) Using Table C-3A:			
(1) Rebar size	______	______	*
(2) Lap splice	______	______	in.
(3) Rebar hook length	______	______	in.
2) Using Table C-5B, find:			

a) Required nailing	___	___	*
	End Wall	Interior Wall	
b) Minimum plywood thickness	___	___	in.
c) Required anchor bolt diameter	___	___	in.
d) Required anchor bolt spacing	___	___	in.

b. ***For transverse short foundation walls completed with diagonal braces.*** (603-5)

Using Appendix C, Table C-5A, verify the diagonal anchorage capacity to the short foundation wall.

	End	Interior	
1) Record the required horizontal force (Ah × Wt) from 602-5.G.1.a and item #56.	___	___	lbs.
2) Table C-5A capacity for one 1/2" diameter bolt at 12" o.c.	1800	1800	lbs.
3) Number of bolts (Ah × Wt ÷ 1800; one minimum) at concrete or masonry top of short wall.	___	___	*
4) Size of anchor bolts	___	___	in.
5) Using Table C-3A:			
a) Rebar size	___	___	*
b) Lap splice	___	___	in.
c) Rebar hook length	___	___	in.

c. ***For vertical X-bracing planes in the transverse direction.*** (603-6)

Using Appendix C, Table C-5A, verify the diagonal anchorage to the pier footings and the tension capacity of the diagonals.

1) Record the required horizontal force (C) from item #59c. ___ lbs.

2) Table C-5A capacity for one 1/2" diameter bolt at 12" o.c. ___1800___ lbs.

3) Number of bolts (C ÷ 1800; one minimum) at top of a footing. ________ *

4) Record the required tension force (T_t) from item #59e. ________ lbs./diag.

5) Select tension strap capacity greater than or equal to T_t from owner's product supplier or manufacturer's supplied capacity (item #60). ________ lbs./diag.

6) Record diagonal strap data ________

Horizontal Anchorage for Longitudinal Foundation Walls (603-4)

70. Using Appendix C, Table C-5A or C-5B, verify that the foundation horizontal anchorage will resist sliding at the long foundation walls. Use for types C, E and I.

a. ***For continuous exterior foundation walls.***

Using Table C-5A (concrete and masonry) or Table C-5B (wood), which capacity is greater than the required exterior Ah? (602-6.E) (item #62a) ________ lbs./ft.

1) Using Table C-5A, find:

a) Required anchor bolt diameter ________ in.

b) Required anchor bolt spacing ________ in.

c) Using Table C-3A:

(1) Rebar size ________ *

(2) Lap splice ________ in.

(3) Rebar hook length ________ in.

2) Using Table C-5B, find:

a) Required nailing ________ *

b) Minimum plywood thickness ________ in.

c) Required anchor bolt diameter ____________ in.

d) Required anchor bolt spacing ____________ in.

b. ***For vertical X-bracing planes.***
(603-6.A.(2))

Using Appendix C, Table C-5A, verify the diagonal anchorage to the pier footings and the tension capacity of the diagonals.

1) Record the required horizontal force (B) from item #62b.2. ____________ lbs.

2) Table C-5A capacity for one 1/2" diameter bolt at 12" o.c. 1800 lbs.

3) Number of bolts (B ÷ 1800; one minimum) ____________ *

4) Record the required tension force (T_L) from item #62b.4. ____________ lbs./diag.

5) Select tension strap capacity greater than or equal to T_L from owner's product supplier or manufacturer's supplied capacity (item #60). ____________ lbs./diag.

6) Record diagonal strap data ____________

SUMMARY SHEET
(Accompanies Chapter 7)

71. Compare values from preceding questions. Select the largest value.

a. **Bearing area and vertical anchorage**

1. *Pier footings: types C, E & I.*

	Piers				
			Marriage Wall		
	Exterior	Interior	Cont.	At Post	
Required Effective Footing Area from questions #49, #50, & #51.	________	________	________	________	sq.ft.

Required footing area to resist withdrawal due to uplift from Question #67. (for single-section or 2 tie-down system, only the exterior piers resist uplift, for 4 tie-down only the interior piers and exterior walls resist uplift) ________ ________ sq.ft.

	Piers				
			Marriage Wall		
	Exterior	Interior	Cont.	At Post	
<u>Pier Footing Sizes</u> (largest of above)	________	________	________	________	sq.ft.

"Dead-man" footing size. ________ sq.ft.

<u>Reinforcing for pier footings:</u>
Bring forward answers from previous questions. (#68b)
(Types C , I, or E with interior pier anchorage.)

	Exterior	Interior	
Number of anchor bolts	________	________	
Anchor bolt diameter	________	________	in.
Rebar size	________	________	
Lap splice	________	________	in.
Rebar hook length	________	________	in.

	Exterior	Interior	Marriage Wall	
Footing depth: grade to bottom of footing	________	________	________	in.

Pier footing and "dead-man" footing reinforcing bars: <u>#4 at 10" o.c.</u>

"Dead-man" footing depth: grade to bottom of footing ________ in.

2. *Long Foundation wall footing: type E or I:*

Required Effective Footing Width

Required Footing Width for soil bearing (#49) ________ ft.

Required Footing Width to resist uplift withdrawal (#67a.6) ________ ft.

Wall Footing Size (largest of above) ____________ ft.

Footing Depth: Grade to bottom of footing (#67a.5) ____________ in.

Footing reinforcing bars. 2 #4 bars

Reinforcing for longitudinal foundation walls: Record answers from item #68a and record sizes and spacings.

From 68a.2: masonry and concrete:

Required anchor bolt diameter ____________ in.

Required washer size Standard Oversized

Required anchor bolt spacing ____________ in

Rebar size ____________

Lap splice ____________ in.

Rebar hook length ____________ in.

From 68a.4: wood: Record answers from item #68a.4 and record sizes and spacings.

Required nailing ____________

Minimum plywood thickness. ____________ in.

Required anchor bolt diameter ____________

Required anchor bolt spacing ____________ in

b. **Horizontal anchorage in the transverse direction - foundation walls**

1. *Continuous foundation walls* (#69a)

Number of transverse foundation walls (#55a) 2 4 6

Required Footing Width (minimum) 12 in.

From #69a.1: concrete / masonry:

	End Wall	Interior Wall	
Anchor bolt diameter	______	______	in.

	End Wall	Interior Wall	
Anchor bolt spacing	______	______	in.
Rebar size	______	______	
Lap splice	______	______	in.
Rebar hook length	______	______	in.
From #69a.2: wood:			
Required nailing	______	______	
Minimum plywood nailer	______	______	
Anchor bolt diameter	______	______	
Anchor bolt spacing	______	______	in.

2. *For transverse short foundation walls completed with diagonal braces* (#69b)

	End	Interior	
Number of pairs of diagonals (1 for single-section units, 2 for multi-section units) times number of short walls (end or interior) (#55a)	______	______	
Diagonal spacing (same as number of short walls)	______	______	
From #69b: concrete / masonry:			
Anchor bolt diameter	______	______	in.
Number of bolts	______	______	
Rebar size	______	______	
Lap splice	______	______	in.
Rebar hook length	______	______	in.

3. *For vertical X-bracing planes in lieu of short walls.* (#69c)

Number of X-brace locations (#59) ____________

Spacing of vertical X-brace planes (#59) ____________ ft.

<u>Items from #69c.3 and #69c.5</u>

Required anchor bolt diameter ____________ in.

Number of bolts at top of footing to connect diagonal ____________

Diagonal strap size ____________

Connection to top flange of chassis beam (describe) ___________________________

c. **Horizontal anchorage in the longitudinal direction - exterior foundation walls**

1. *Continuous foundation walls*

<u>Reinforcing for longitudinal foundation walls:</u> record only if larger sizes or closer spacing than recorded for vertical anchorage (#71a.2).

<u>From #70a.1: concrete / masonry:</u>

Anchor bolt diameter ____________ in.

Anchor bolt spacing ____________ in.

Rebar size ____________

Lap splice ____________ in.

Rebar hook length ____________ in.

<u>From #70a.2: wood:</u> record only if larger sizes or closer spacings than recorded for vertical anchorage (#71a.2)

Required nailing ____________

Minimum plywood nailer ____________

Anchor bolt diameter ____________

Anchor bolt spacing ____________ in.

2. *Vertical X-bracing planes under chassis beam lines* (#70b.)

Number of X-brace locations along one chassis beam line. ____________

Spacing of X-brace locations along one chassis beam line. ____________ ft.

Required anchor bolt diameter. ____________ in.

Number of bolts at top of footing at connection to the diagonal. ____________

Diagonal strap size. ____________

Connection to bottom flange of chassis beam (describe). ______________________

72. Do foundation dimensions and details comply with Foundation Capacities Table, based on Foundation Design Table Values? yes no

73. If #72 yes, approve. If no, return to applicant. **APPROVE**

DISAPPROVE

APPENDIX G
SAMPLE PROBLEMS

All the data necessary for the approval of the adequacy of a permanent foundation for the manufactured home can be located in this handbook and on worksheets submitted by the homeowner. The HUD field office (or user) must refer to Design Worksheet as a guide through the process of collecting and verifying data.

There are two steps in the approval process: (1) the Owner's Site Acceptability / Manufacturer's Worksheets, with accompanying forms as required, from the owner, and (2) the Design Worksheet. The reader is referred to the completed worksheet samples in Appendix E.

Example #1 is a proposed site for a **multi-section** manufactured home in Champaign, Illinois. The **marriage wall has two adjacent large openings of 16 and 12 feet respectively**. The remainder of the wall is continuous. Both the Owner's Site Acceptability / Manufacturer's Worksheet and the Design Worksheet for Example 1 have been filled out. Asterisks (*) on the Design Worksheet mark the items that were filled in based on data submitted by the owner. The remaining data on the Design Worksheet must be collected from the handbook as described herein.

COMMENTS - EXAMPLE # 1

Item # DESIGN WORKSHEET

Part 1 -- Site Conditions

9. Refer to the Average Depth of Frost Penetration map on page H-4. The average frost depth for Champaign Illinois is 30 inches.

14. Refer to the Termite Infestation map on page H-10. The site is in a moderate to heavy infestation region.

15. The owner has indicated compliance with CABO R.308.

Part 3 -- Design Loads

21. Calculate the distributed weight per foot of length by dividing the total weight of the home by its length: 33,040/56=590 lbs./ft.

Dead Load

25. From Table 4-1 (402-1.A1). The light dead load value is 560 lbs./ft.

26. From Table 4-1, the heavy dead load value is 805 lbs./ft.

27. Yes, the distributed weight of the home is within the limits defined by this document. The design tables may be used.

Snow Load

28. Refer to the Ground Snow Load (Pg) map on page H-12 for the central United States. The average ground snow load is 20 psf.

29. Refer to Section D-200.2.B for minimum roof live load based on roof slope. For a 2 in 12 roof slope, the minimum roof live load is 20 psf.

30. Comparison of roof snow load (14 psf) and minimum roof live load, minimum roof live load is greater; therefore, it controls.

Wind Load

31. Refer to the Design Windspeed map on page H-14. The site location is near the 70 mph design wind isobar. Use minimum 80 mph for *MPS* in lieu of map value.

32. Based on the map provided by the owner, the site is not near a hurricane coastline. The site is Inland.

Seismic Load

38a. Refer to the maps for Seismic acceleration Aa and Av on pages H-15 and H-16. The site has Seismic acceleration values: Aa = 0.05 and Av = 0.05.

38b. Residential construction is exempt from seismic considerations if Av is less than 0.15.

41. Checking the Foundation Design Concept Tables for Type **E1**, this foundation type is not recommended for seismic areas where Aa and Av are greater than or equal to 0.3. This is because the piers are unreinforced. The Type E1 concept is permitted in seismic areas where Aa and Av are greater than 0.3, if the piers are reinforced.

Part 4 -- Final Design Procedure

42. From the table (600-2.A.1), the nominal width for a 13'-6" home width is 14'-0".

44. The user will compare the Foundation Design Concept, Figures 6-7 and 6-8 with foundation drawings and details provided by the owner. The concept drawings identify the bearing and vertical anchorage locations. An anchorage system for the transverse and longitudinal directions must be clearly shown on the documents provided by the owner.

Required Footing Size

49. In order to determine the Required Footing sizes, the user needs the data from the following items on the Owner's Site Acceptability Worksheet: Nos. 10 or 11 and on the Design Worksheet: Nos. 24, 30, 43, 48.

Item Number	
#10 or #11	Net allowable soil bearing pressure = 1000 psf
#24	Foundation System, Multi-Section type **E1**
#30	Ground snow load Pg = 20 psf. Use 30 psf for the Foundation Design Table. The 30 psf value with load factors applied is equivalent to a minimum live load of 20 psf.
#43	Nominal Building width: Wt = 14'-0"
#48	Pier Spacing: Interior and exterior piers, 5'-0"; Continuous Marriage wall piers, 8'-0".

Next the user will locate the Required Effective Footing Area tables in Appendix B, Part 1. The user locates the table for a multi-wide E with a nominal width of 14 feet.

49. The user finds a note which indicates that the minimum longitudinal foundation wall footing width is 1 foot.

50. Interior pier and exterior pier

1) For the interior and exterior piers, the user finds the block of values for minimum roof live load of 20 psf.

2) Next, the user finds the two rows of values for a Net Allowable Soil pressure of 1000 psf (read ext, int row).

3) Under the column for a pier spacing of 5 feet, the required pier footing area is 2.1 square feet (1'-6" x 1'-6").

51a. Continuous Marriage Wall Piers

1) Refer to the same block of values as for the exterior/interior footings.

2) Next the user finds the second line of values for a Net Soil Pressure of 1000 psf (labeled mar).

3) Under the column for a marriage wall pier spacing of 8 feet, the required pier footing area is 6.9 square feet (2'-8" x 2'-8").

51b. Marriage Wall Openings

1) Refer to the lower block of values as for the ext/int footing.

2) Next, the user finds the average of two adjacent openings from item#48 (14 feet). Read area of footing at piers under posts as 11.4 sq.ft. (3'-6"x3'-6").

Vertical Anchorage Requirements In The Transverse Direction

52. In order to determine the Required Vertical Anchorage the user needs the data from the following items on the Design Worksheet: Nos. 24, 31, 32, 43. With this information, the user can determine Vertical Anchorage in the transverse direction by using the appropriate table in Appendix B, Part 2.

    1) The user locates the Tables for a Multi-Section E with a nominal width of 14 feet and 2 tie-downs.

    2) Then the user finds a block of values for the Inland condition.

    3) To the right of the 80 mph wind value, the user finds a value of 130 lbs./ft along the longitudinal exterior walls.

53. The user verifies that the manufacturer's design value (200 lbs./ft.) shown on line 16b of the Manufacturer's Worksheet is greater than the required value shown on line 52a. Otherwise repeat the process with four tie-downs.

Horizontal Anchorage Requirements In The Transverse Direction

55. Two (2) transverse foundation shear walls are initially selected in order to compare the required horizontal anchorage with the values provided by the manufacturer. This is trial #1.

56. In order to determine the Required Horizontal Anchorage the user needs data from the same items on the Design Worksheet that were required for Approval item number 52a plus item No. 22 (namely, the building length L = 56'-0"), No. 30, roof snow/minimum roof live load and No. 36, Seismic Acceleration values. Proceed knowing that you are exempt from seismic considerations.

    Next, the user will locate the Required Horizontal Anchorage table in Appendix B, Part 3.

    1) The user locates the tables for a Multi-Section E with a width of 14 feet and two (2) transverse walls.

    2) Then the user finds the block of values for the Inland condition and the line of values for a design wind speed of 80 mph.

3) Then the user finds Seismic Aa range 0.05-0.2 and snow load range 0-100 psf. Only one row of values remains.

4) For a length L of 56 feet, the user rounds the value to the next highest number shown on the top line of the table -- 60 feet.

5) Under the column of values for 60 feet, the user finds the required anchorage Ah = 420 pounds per lineal foot along the length of each transverse shear wall. Note that the value was not grayed over, indicating the force calculations were controlled by wind.

Note: if the manufacturer has specified (1) diagonal metal straps to complete the transverse short foundation walls, or (2) vertical x-bracing in place of transverse foundation walls, for comparative purposes, the user shall use the formulas in section 602-5.G.1 or 602-5.G.2 and proceed with item #55b or #59 respectively.

58. Verify the Manufacturer's design value shown on line 57a (400 plf) is greater than the required value shown on line 56. Since it is not (420 > 400), attempt trial #2 ans consider 4 short walls. Repeat steps 1) to 5). Read (Ah) exterior 140 plf and (Ah) interior 280 plf, both less than the manufacturer's value 400 plf. Thus, 4 short walls will provide adequate sliding resistance.

Horizontal Anchorage in the Longitudinal Direction

62a. In order to determine the Required Horizontal anchorage in the longitudinal direction the user needs the same data as used in steps 52 and 56 from the Design Worksheet.

Next, the user will locate the Required Horizontal Anchorage in the Longitudinal Direction tables in Appendix B, Part 4.

1) The user locates the table for a Multi-section unit Type E with a nominal width of 14 feet.

2) Then the user finds Seismic Aa range 0.05-0.1 and snow load range 0-100 psf.

3) Then the user finds the block of values for the Inland condition and the row of values for a design wind speed of 80 mph.

4) For a length L of 56 feet, the user rounds the value to the next highest number shown on the top row of the table -- 60 feet.

5) Under the column for 60 feet, the user finds the required anchorage force Ah = 67 plf along each of the longitudinal exterior shear walls. Note that the value was not grayed over indicating that the force calculations were controlled by wind, not seismic.

Note: if the manufacturer has specified a diagonal metal strap X-bracing in place of the shear wall, for comparative purposes, the user shall use the formulas in section 602-5.F, which are based n the required anchorage (Ah) found in the tables. This could be the case for Type C or I units.

64. Verify the manufacturer's design value on line 63 is greater than the required value shown on line 62a.

Withdrawal Resistance Verification

67. For type E foundations answer item 67a.

67a. For this example, a masonry foundation fully grouted was depicted on the documents submitted by the owner.

1) Checking the tabular columns of Table C-1, Appendix C, for Masonry-Fully Grouted, the lowest value greater than (Av) is 231 lbs. per foot. Thus, 231 > 130 (from item #52).

2) The footing depth (Hw) is found in the far left column, hw = 2'0'. This value corresponds to the minimum depth of the footing below grade which is shown in the illustration above the table.

3) The width of the footing is found at the top of the column, 12".

4) Based on item #9, the frost depth for Champaign, IL. is 30 inches. Based on Table C-1, the depth of the base of the footing below grade is :

from Table C-1:

```
hw =   24"
     + 6"  (footing thickness)
      30"  for withdrawal
           resistance
```

for frost protection:

```
hw =   30"  (depth below grade)
     + 12"  (min. wall height
            above grade)
       42"
```

therefore; frost protection controls over withdrawal resistance

```
   42”
 - 12”  (min. wall height
        above grade)
   30”  (bottom of footing
        to grade)
```

for establishing the number of block courses:

```
   42”
 - 6”   (footing depth)
   36”  min. required
        foundation wall
        height
```

Use hw = 40", which is a multiple of the 8" masonry unit -- 40" = 5 block courses.

5) Interior piers under (item #67b.3.) chassis beams do not participate in vertical anchorage for this example. Frost depth considerations are accounted for at the perimeter walls. Interior piers may be set below the 18 “ of topsoil on undisturbed soil. See item #50 for required footing size.

6) Item #67c.; Marriage wall piers do not participate in vertical anchorage in any case, and do not need to set at frost depth. Again, set footings below the 18” of topsoil onto undisturbed soil.

Vertical anchorage and reinforcement for longitudinal foundation walls and piers

68. For type **E** foundations answer item 68a.

68a.

1) From item #52, the value for (Av) was 130 lbs./ft. Using Table C-4A for a masonry foundation wall, the first value in the left hand column is 146 lbs. per foot of wall. The 146 lbs./ft. value utilizes the maximum recommended anchor spacing by code as 6’-0” o.c. The wood material connected to the anchor bolt with a standard washer controls the final capacity. (Note the similarity in capacities with a treated wood

foundation wall, Table C-4B, since wood bearing on washer controls).

2) For a masonry wall grouted solid, the following sizes are required:

On Table C-4A - on the same line as +146 lbs./ft., read:

a) Anchor Bolt diameter = 1/2"

b) Anchor Bolt spacing = 72"

On Table C-3A - on the same line as 1/2" anchor bolt diameter read:

c.1) Rebar size = #4

2) Lap splice = 16"

3) Rebar hook length = 6"

Horizontal Anchorage and Reinforcement for Transverse Foundation Walls

69a. From item number 56, the value for transverse (Ah) is 140 lbs. per foot along the transverse end (shear) wall and 280 lbs. per foot along the interior transverse walls. Using Table C-5A for a masonry foundation wall, the first value in the left hand column is 300 lbs. per foot of wall which is greater than either end or interior (Ah). The 300 lbs./ft. value is based on the maximum recommended anchor spacing of 6’-0” o.c. by code. The material connected to the anchor bolt will control the final capacity.

1) For masonry walls grouted solid, the following sizes are required:

On Table C-5A: On the same line as Ah = 300 lbs./ft., read:

a. Anchor bolt diameter = 1/2"

b. Anchor bolt spacing 72" (cores must be grouted solid)

On Table C-3A: On the same line as 1/2" anchor bolt diameter, read:

c.1) Rebar = #4

2) Lap splice = 16"

3) Rebar hook length = 6"

Horizontal Anchorage and Reinforcement for Longitudinal Foundation Walls

70a. From item #62a, the value for longitudinal (Ah) is 67 plf. From Table C-5A, again the 300 plf value is adequate. All other information for reinforcement is the same along the exterior longitudinal walls.

Summary Sheet

The values can be brought forward on to the summary sheet and the design approved.

EXAMPLE 2

Example #2 is a proposed site for a **single-section** manufactured home in Tampa Florida. The data on the Owner's Site Acceptability Worksheet remains the same as Example #1, with the exception of item 1. The grade elevation is 28 feet. The data on the Manufacturer's Worksheet, regarding the superstructure, remains the same as Example #1 with the exception of the following items:

Item #	Data
1.	Single-section (Nominal 14’ wide unit)
2.	Type C
7.	Roof slope = 4 in 12
8.	Unit weight = 16,500 lbs.
10.	Type C1
11a.	Pier Spacing = 7 ft.

11b. NA
11c. NA
11d. 7 Tie-down straps at 8'-8" spacing
Note: Tie-downs are required to be at 2'-0" in from each end of the unit. (Section 601-2.B.)
14. Design wind = 120 mph
16b. Uplift capacity = 3,150 lbs./tie-down
16c. Sliding capacity = 4,800 lbs./diag. set
16d. Sliding capacity = 4,800 lbs./diag. set
16e. Vertical X-bracing tension capacity = 5600 lbs./strap

Asterisks (*) on the HUD Approval Worksheet mark the items that were filled in based on data submitted by the owner. As demonstrated in Example #1, the remaining data must be collected from the handbook as described herein.

Item # DESIGN WORKSHEET

Part 1 -- Site conditions

9. Refer to the Frost Penetration map on page H-4. The average **frost depth** for Tampa Florida is **zero inches**.

14. Refer to the Termite Infestation map on page H-10. The site is in a **very heavy** infestation area.

15. Yes, the owner has indicated compliance with CABO R-308.

Part 3 -- Design Load

23. The distributed weight is the weight of the home divided by its length:

    16,500 / 56 = 295 lbs./ft.

25. From Table 4-1 (402-1), the light dead load value is 290 lbs./ft.

26. From Table 4-1, the heavy dead load value is 425 lbs./ft.

27. Yes, the distributed weight of the home is within the limits defined by this document. The design tables may be used.

Snow Load

28. Refer to the Ground Snow Load map on page H-13 for the Eastern United States. The average **ground snow load** is **zero**.

29. Based on a 4 in 12 roof slope, the minimum roof live load is 15 psf (D-200.2.B).

30. The **15 psf minimum roof live load** controls.

Wind Load

31. Refer to the Design Wind Load map for the Eastern United States on page H-14. The average wind load is near the 100 mph design wind isobar, which exceeds the *MPS* minimum of 80 mph. Thus, **100 mph wind speed** is used for the foundation design.

32. Based on the map provided by the owner, the site is located on a hurricane coastline. The site is **Coastal**.

33-36. The manufacturer should supply details consistent with a coastal high wind site.

Seismic Load

38. Refer to the Seismic Acceleration maps on pages H-15 and H-16. The seismic coefficients for Hillsborough County, Aa and Av = 0.05. Residential construction is exempt from seismic consideration since Av < 0.15.

41. Checking the Foundation Design concepts for Type C1, it is permitted for use when seismic coefficient Av < 0.15. It is not acceptable for use in areas where Aa and Av greater than or equal to 0.3.

Part 4 -- Final Design Procedure

43. From the Section 600-2.A table, the nominal width for a 13'-8" home width is 14'-0".

44. The user will compare the Foundation Design concept illustrations with foundation drawings and details provided by the owner. The concept drawings identify the anchorage locations. An anchorage system must be clearly shown on the documents provided by the owner.

Required Footing Size

49. In order to determine the Required Footing size, the user needs the data from the following items on the Owner's Site Acceptability Worksheet item #10 or #11 and on the Design Worksheet: Nos. 24, 28-30, 43, 48.

Item Number

#10 or #11	Net allowable soil bearing pressure = 1000 psf from Owner's Worksheet.
#24	Foundation System, Single-section type C1
#28-#30	Ground Snow Load Pg = 0 psf. Use a minimum roof live load of 15 psf for the Foundation Design Load Tables.
#43	Building nominal width: Wt = 14'-0"
#48	Pier Spacing: Exterior = 7'-0"

Next the user will locate the Required Effective Footing Area Tables in Appendix B, Part 1.

1) The user locates the tables for a Single-section Type C with a width of 14 feet.

2) Find the block of values for a Minimum Roof Live Load of 15 psf.

3) Next the user finds the row of values for a net allowable soil pressure of 1000 psf.

4) Last, the user finds the intersection of that row with the column for a 7'-0" foot pier spacing. The required footing area is 5.3 square feet (2'-4" x 2'-4").

Vertical Anchorage Requirements in the Transverse Direction

52a. In order to determine the Required Vertical Anchorage the user needs the data from the following items on the Design Worksheet: Nos. 24, 31, 32, 43 and 48. With this information, the field officer can locate and determine the Required Vertical Anchorage tables in Appendix B, Part 2.

Use the tables for a Type C1 system. Then multiply Av x Tie-down spacing.

Item No.	Data
#24	Foundation System: Type C1 - Single-section
#31	Design Windspeed: 100 mph
#32	Site Location: Coastal
#43	Building Nominal Width: 14'-0"
#48	Tie-down Spacing: s_t = 8'-8". Number of tie-downs is 7 from (N):

$$N = \frac{L - 2 \times 2'}{s_t} + 1$$

1) The user locates the Required Vertical Anchorage (Appendix B, Part 2) tables for a Single-section Type C1 with a nominal width of 14 feet.

2) Then the user finds a block of values for the Coastal condition.

3) Locate the row for a wind speed 100 mph. The user finds the required vertical anchorage Av = 350 lbs./ft. of home length and multiplies this by a tie-down spacing of 8.667 feet (3033 lbs.) or conservatively move across the row to the next largest anchor spacing (10’) and reads 3460 lbs. as an approximate check.

4) The Required Vertical Anchorage force for a tie-down is 3033 lbs.

54. The manufacturer's supplied value, item #53, is 3,150 pounds, which is more than the Required Vertical Anchorage of 3,033 pounds. Note: see optional details in Appendix A for Type **C1**. If the manufacturer's supplied value had been less than Av, the owner would have been notified. The owner would need to contact the manufacturer in order to have a licensed structural engineer verify the existing design or modify the anchor design or spacing to comply with the required anchorage.

Horizontal Anchorage in the Transverse Direction

56. In order to determine the Required Horizontal Anchorage, the user needs data from the same items on the Design Worksheet that were required for Approval item number 52a and item No. 22 (the building length L = 56'-0"). Also required is item #9 (6’-10”) from the Manufacturer’s Worksheet.

Next, the user will locate the Required Horizontal Anchorage table in the transverse direction in Appendix B, Part 3.

1) The user locates the tables for a Single-section Type C, E or I with a nominal width of 14 feet and initially selects two transverse walls for trial #1. This is required to initiate the process of selecting vertical X-bracing planes for horizontal anchorage in the transverse direction.

2) Then the user finds the block of values for the Coastal condition and the row of values for a design wind speed of 100 mph. All Seismic is on the same horizontal line, even though it need not be checked.

3) For a length L of 56 feet, the user rounds the value to the next highest number shown on the top row of the table -- 60 feet.

4) Under the column of values for 60 feet, the user finds the required anchorage (Ah) of 1240 pounds per lineal foot along the length of each transverse foundation wall (2 shear walls).

59c. The required horizontal anchorage per X-brace set (C) is calculated using the procedure of Section 602-5.G.2, illustrated in Figure 6-10.

Process always begins by selecting 2 short walls, then:

1. From item #56, Ah = 1240 lbs./ft.

2. Solving equation for H:

$$H = \frac{1240 \times 13.67 \times 2}{56} = 605 \text{ lbs./ft. of unit length}$$

Note: actual unit width, rather than nominal width is used here.

3. For a first trial, set spacing equal to a multiple of pier spacing: try 14'-0". Solving equation for horizontal force at each X-brace set (C):

   C = 605 × 14'-0" = 8475 lbs./X-brace set.

   Note: number of vertical X-brace planes =

   $$\frac{L}{\text{spacing}} + 1 = \frac{56}{14} + 1 = 5$$

   therefore, number of X-braced planes equals 5.

61a. Verify that the Manufacturer's design value on line #57a is greater than the required value (C) shown on line #59c. In this example, the manufacturer's design value of 4800 lbs. (#57) is less than the Required Horizontal Anchorage (C) = 8475 lbs. This indicates that the connection of unit to a foundation diagonal is inadequate for sliding resistance.

The owner would be contacted at this point and notified that the horizontal anchorage is not adequate. If an inspector or owner wanted to determine how many vertical X-bracing planes would be required, they could use the following:

<u>Trial #2:</u>

Piers must be present at the extremities of any vertical X-bracing plane; therefore, the next logical choice is the actual pier spacing of 7'-0".

1. From item #56, Ah = 1240 lbs./ft.

2. Solving equation for H:

$$H = \frac{1240 \times 13.67 \times 2}{56} = 605 \text{ lbs./ft. of unit length}$$

Note: actual unit width, rather than nominal width is used here.

3. C = 605 × 7'-0" = 4235 lbs./X-brace set.

   Number of vertical planes =

   $$\frac{56'}{7'} + 1 = 9$$

The required horizontal anchorage of 4235 is less than the manufacturer's rated capacity of 4800 lbs., thus 9 vertical X-bracing planes are required at the same spacing as the piers (7'-0").

59d. The user must estimate a height (h) on Figure 6-10, which can be revised later if necessary. Try h = 4 feet.

59e. From item #9, Manufacturer's Worksheet, Wt - 2 dc = 6.83':

$$\cos\theta_t = \frac{6.83}{\sqrt{4^2 + (6.83)^2}} = 0.863$$

therefore: θ_t = 30.4°

$$T_t = \frac{4235}{0.863} = 4907 \text{ lbs. tension in strap}$$

61b. The rated capacity of a strap in tension, item #60 is greater than the required T_t

(item #59e) for 9 vertical X-bracing planes 5600 > 4907, therefore OK.

Horizontal Anchorage Requirements in the Longitudinal Direction

62a. In order to determine the Required Horizontal Anchorage (Ah) in the Longitudinal Direction, the user needs data from the same items in the Design Worksheet that were required for item #56.

Next, the user will locate the Required Horizontal Anchorage Table in the Longitudinal Direction (Appendix B, Part 4).

1) The user locates the table for a Single-section, Type C, E, or I with a nominal width of 14 feet.

2) Then, the user finds the block of values for Aa = 0.05-0.10, ground snow 0-100 psf and coastal site.

3) The user finds the row of values for wind speed of 100 mph.

4) For a length (L) of 56 feet, the user rounds to the next highest length shown across the top row of the table - 60 feet.

5) Under the column for 60 feet, the user finds the intersection value with the row for 100 mph wind speed. Read Ah = 47 lbs./ft. of length along the longitudinal exterior foundation walls, if shear walls exist.

62b. For this example of a Type C1 foundation, no structural exterior longitudinal walls exist, thus vertical X-bracing planes are required between piers under chassis beam lines. Follow the procedure of Section 602-6.F and use the illustration in Figure 6-11 and Figure D-26.

Begin Trial 1 with the minimum required vertical X-bracing planes: n = 2; one pair under each chassis at both ends of the unit length. Follow the equation:

$B = \frac{47\,\text{plf} \times 56}{2} = 1316$ lbs. of horizontal force carried by each X-brace set.

64. Verify that the manufacturer's rated value (item #63) is greater than the required horizontal anchorage force (B) of item #62b.2. In this example the manufacturer's value of 4800 lbs. is greater than B. Thus, vertical X-bracing planes at both ends of the unit and under each chassis beam line is adequate.

62b.3 Approximate the height (h) in Figure 6-11 by assuming the chassis beam is 1 foot deep, thus: h = 4' - 1' = 3'.

62b.4 Return to the calculation procedure of section 602.6.F and determine the tension force in a diagonal strap:

first: $\cos\theta_L = \frac{7}{\sqrt{3^2 + 7^2}} = 0.919$

therefore: $\theta_L = 23.2°$

next: $T_L = \frac{1316}{.919} = 1432\,\text{lbs.}$

66. Verify that the manufacturer's (or product supplier) rated value (item #65) is greater than the required tension (T_L) from item #62b.4. In this example, the manufacturer's value of 5600 lbs. is greater than (T_L). Thus, the straps proposed are adequate as tension diagonals.

Withdrawal Resistance Verification

67b. For Type C1 foundation answer item 67b for concrete "deadman" footings.

For this example, square concrete footings used as "deadmen" are depicted on the documents submitted by the owner to anchor the tie-down straps. See Appendix A - concept details for Type C1 foundation.

1. From item number 52a, the value for Av is 3033 lbs. per tie-down anchor.

2. Use Table C-2, The Withdrawal Resistance for Piers, in Appendix C. Table C-2 can conservatively be used for concrete footings used as "deadman" anchors. The footing depth (hp) in the far left column can either be hp = 3'-4" for a 3'-0" sq. ft. footing or hp = 2'-0" for a 4'-0" sq. ft. footing. Assume the least costly solution is the 3'-0" square footing.

3. Based on item #9, the frost depth for Tampa, FL. is 0". Thus, the "deadman" footings are at an adequate depth. The pier footings under the chassis beams can be set 8" below grade, if undisturbed soil (not organic material) is available, otherwise, footing must extend to firm bearing strata.

Vertical Anchorage and Reinforcement for Long Foundation Walls and Piers

68. For type C foundations answer item 68b.

1) From item number 52a, the value for Av is 3033 lbs. per foot. The lowest value greater than Av on Table C-3 is 4240 pounds.

2) For the size of bolt set in concrete "deadman" to complete connection to the tie-down rod, from Table C-3:

   a) Number of anchor bolts = 1

   b) Anchor bolt diameter = 1/2"

3) Use Table C-3A for the reinforcement of the piers under the chassis beams. Even though these piers do not directly receive anchorage overturning force, it is desirable to reinforce them to assist in force distribution in the vertical X-bracing planes.

   a) Rebar size = #4

   b) Lap splice = 16"

   c) Rebar hook length = 6"

Horizontal Anchorage and Reinforcement for Transverse Foundation Walls

69c. From item number 59c (Assume the owner decided to use 9 X-bracing planes), the value for (C) is 4235 lbs. per diagonal. Use Table C-5A for concrete. The horizontal capacity of a single bolt is shown at a spacing of 12".

Bolt size	Capacity
1/2"	1800 lbs.

Three 1/2" bolts would be required to connect the diagonal to the footing. Detail the pier footing as shown in Table C-5A. Verify that the rated capacity of the strap exceeds the required tension (T_t).

Horizontal Anchorage and Reinforcement for Longitudinal Foundation Walls

70b. From item #62b.2, record the horizontal anchorage force (B) as 1316 lbs. per X-brace. Again, from Table C-5A, the shear capacity of a 1/2" diameter bolt in concrete is 1800 lbs. One anchor bolt is sufficient into the concrete footing. Detail the pier footing as shown in Table C-5A. Verify that the rated strap capacity exceeds the required tension (T_L).

Summary Sheet

The values can be brought forward on to the summary sheet and the design approved.

APPENDIX H
MAPS

H-100. GENERAL. The following collection of maps is intended to assist the user in the foundation selection and design process. The maps provide information for geographic locations within the 50 States of the United States covering a wide range of issues: flooding, frost penetration, expansive soils, landslides, subsidence, termites, snow, wind and earthquakes. The maps have been accumulated from various sources, most notably the U.S. Department of Commerce Weather Bureau, the U.S. Army Corps of Engineers Waterways Experiment Station, and the American Society of Civil Engineers.

H-200. SEISMIC PERFORMANCE CATEGORIES. Table H-1 is a condensed version of the ASCE 7-93 Seismic Performance Category Table as it applies to manufactured housing.

H-300. SPECIAL SEISMIC DESIGN CONSIDERATIONS FOR FOUNDATIONS.

H-300.1. General. Based on the Seismic Performance Category for the geographic location involved, special requirements must be satisfied that involve the foundation:

A. Seismic Performance Category A. There are no special requirements for the foundations of manufactured housing assigned to this Category.

B. Seismic Performance Category B. The site coefficient has been assumed as 2.0 for all Tables in Appendix B. The resulting capacities of the foundations, subjected to the prescribed seismic forces of the Tables in Appendix B shall meet the following requirements:

1. Structural Components. The design strength of foundation components subjected to seismic forces alone or in combination with other prescribed loads and their detailing requirements shall conform to the requirements of the applicable material codes (wood, concrete or masonry) referenced by the local authority having jurisdiction.

2. Soil Capacities. For the load combination including earthquake, the capacity of the foundation soil in bearing or the capacity of the soil interface between pile, pier or caisson and the soil must be sufficient to resist loads at acceptable strain considering both the short duration of loading and the dynamic properties of the soil.

C. Seismic Performance Category C. Foundations for buildings assigned to Category C shall conform to all of the Foundations for Categories A and B and to the following additional requirements of this section.

1. Investigation. The authority having jurisdiction may require the submission of a written report that shall include, in addition to the evaluations required in this section, the results of an investigation to determine the po-

tential hazards due to slope instability, liquefaction and surface rupture due to faulting or lateral spreading, all as a result of earthquake motions.

2. Foundation Ties. Individual drilled piers shall be interconnected by ties. All ties shall have a design strength in tension or compression, greater than a force equal to 25 percent of the effective peak velocity related acceleration (Av) time the larger column dead plus live load.

3. Special Pile Requirements. For uncased concrete drilled piers, there shall be a minimum of four longitudinal bars (with a minimum reinforcement ratio of 0.005) and No. 3 closed ties with maximum spacing of 3 inches.

D. Seismic Performance Category D. Category D does not add any additional requirements for manufactured housing. The requirements of Category C plus A and B shall be followed.

APPENDIX I
REFERENCES AND ADDITIONAL RESOURCES

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Executive Summary

This Handbook updates and revises the Permanent Foundation Guide for Manufactured Housing :Handbook 4930.3, August, 1989. This work was commissioned by the U.S. Department of Housing and Urban Development, Office of Policy Development and Research. The Handbook has received a critical review and has been somewhat reorganized and supplemented with additional graphics to simplify its application. The major revisions include:

- The definition of Permanent Foundation has been expanded and clarified in Chapter 1.
- Design loads have been updated to the current loading requirements for snow, wind and seismic forces of the Minimum Design Loads for Buildings and Other Structures, ASCE 7-93 Edition. The load maps of Appendix H have been replaced by the new maps in ASCE 7-93.
- The Seismic portion of the Handbook, which showed no influence over wind in the previous code, has now become a significant factor in the ASCE 7-93 for consideration of overturning and sliding. Thus, the Tables of Appendix B have required reorganization and expansion. Seismic table values are grayed over to indicate that seismic controls over wind for the parameters of a given Table.
- All of the Foundation Concepts, except Type E2, have been retained in this updated edition. A survey was sent to all HUD field offices which substantiated this decision. Appendix D has been expanded to include sample formula derivations for all of these Foundation Concepts; this includes text and graphics for all single-section and multi-section units for added clarity.
- Appendix A Foundation Concept Details have been redrawn and revised to reflect the new ASCE 7-93 Loads document and their relationship to Appendix B Tables.
- This update now includes consideration of large openings along the length of marriage walls in multi-section units. Appendix B Tables includes openings that range from 10 to 20 feet in 2 foot increments.

Although many pages have been added, the Handbook has become a logically organized and easy to use reference in the permanent foundation selection process and in the anchorage design to assure adequate structural performance for Manufactured Homes.