Multi-Hazard Foundation and Installation Guidance

for Manufactured Homes in Special Flood Hazard Areas

Second Edition Supercedes 1985 Version

March 2004

FEMA

FEMA 85

MANUFACTURED HOME INSTALLATION IN FLOOD HAZARD AREAS

FEMA 85 (Revised)

March 2004

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Washington, DC

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Preface

This document is a revised version of FEMA 85, *Manufactured Home Installation in Flood Hazard Areas,* which was published in September 1985. Since the original publication, there have been significant improvements in the methodology of siting of homes, calculations of design loads, and manufactured home foundation design and installation techniques.

FEMA 85 has been updated to reflect the guidance from the most current codes and standards. Pre-engineered foundation designs that incorporate pier and ground anchor systems, based on results from a series of first-of-its-kind saturated and dry soil anchor tests, are also included along with associated cost information. The anchor tests were conducted with the support of the Manufactured Housing Institute (MHI), Manufactured Housing Research Alliance (MHRA), and some manufacturers of manufactured housing. A detailed example, showing step by step procedures on how to design a foundation for a manufactured home, is also included.

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Chapter 1: Introduction

FEMA, a division of the Department of Homeland Security, first published *Manufactured Home Installation in Flood Hazard Areas* (FEMA 85) in 1985. The manual provided technical guidance concerning installation methods designed to make manufactured homes more resistant to flood and wind forces. Since the publication of FEMA 85, changes have occurred in construction practices and materials, and in regulatory requirements that govern manufactured home installation, mainly in response to an increase in knowledge about the performance of buildings in natural hazard events. As a result, much of the information in the 1985 manual has become outdated.

This new version of FEMA 85 provides updated information and expanded technical guidance based on the performance of manufactured homes in flood and wind events that have occurred since 1985, technological improvements that affect manufactured home foundation design and installation, and the requirements of successful state and local regulations.

1.1 Purpose and Scope of the Manual

This manual is intended for use by homeowners, manufactured park owners, public officials, construction professionals, designers, architects, and engineers. Like the original manual, this updated FEMA 85 primarily focuses on the installation and foundation requirements for manufactured homes installed in floodplains and in communities participating in the National Flood Insurance Program (NFIP).

Additional technical information provided in this manual includes:

- Guidance on the NFIP and U.S. Department of Housing and Urban Development (HUD) installation regulatory requirements
- Technical guidance on siting and installation of manufactured homes, covering issues of terrain, infrastructure, natural hazards (flood, wind, and earthquake), and soil
- Best practices procedures
- Anchor testing results
- Foundation performance criteria

- Pre-engineered foundation systems with benefit/cost calculations

Flowcharts, checklists, maps, formulas, and details are provided throughout the manual to help the reader understand the issues that must be considered when installing a manufactured home in a floodplain. Examples are also presented to demonstrate decisions and calculations designers must make to reduce the potential damage to manufactured homes from natural hazard events. In addition to FEMA 85, FEMA publishes many guides that may be applied to manufactured housing for various natural hazards. A list of these references can be found in Appendix A.

With its broader and more comprehensive scope, this manual should prove to be an invaluable aid in the siting and installation of manufactured homes. The manual is organized into 13 chapters, each covering a different aspect of manufactured housing in the United States today:

Chapter 1 presents an introduction to the manual and a historical overview of local, state, and Federal regulations that affect the design, construction, and installation of manufactured homes.

Chapter 2 discusses the characteristics of a manufactured home, the types of foundations used, and conventional installation techniques.

Chapter 3 covers current and anticipated regulatory requirements pertaining to the installation of manufactured homes in flood-prone areas. Local, state, and Federal requirements are discussed, including local and state building codes.

Chapter 4 discusses issues that must be considered in the siting of manufactured homes in or near floodplains.

Chapter 5 describes natural hazards that must be considered in site selection, foundation design, and installation of manufactured homes. The discussion covers flooding, including the special hazards associated with coastal flooding (e.g., storm surge, velocity flow, and wave impact), high winds, and seismic events. The combined effects of multiple hazards are also covered.

Chapter 6 discusses the geology and hydrology of soils and their effects on manufactured home foundation systems. Soil characteristics and the behavior of saturated soils are covered, and soil testing criteria are recommended for manufactured home installation.

Chapter 7 covers ground anchors used in conjunction with manufactured home foundations, including the results of laboratory and field tests of anchor performance in saturated soils.

Chapter 8 recaps siting issues presented in Chapter 4 and presents methods for mitigating flood hazards (e.g., elevation, relocation).

Chapter 9 describes different types of foundation systems, including their performance, installation procedures, maintenance requirements, possible modifications, and costs. Systems discussed include pier and tripod systems that incorporate ground anchors, braced piers and piles, slabs, crawlspaces, and proprietary systems.

Chapter 10 presents generic designs for pre-engineered foundations for the installation of manufactured homes in flood zones designated A, AE, A1-A30, A0, or AH on an effective FEMA Flood Insurance Rate Map (FIRM). Criteria are presented regarding maximum flood depth, flow velocity, wind speed, and seismic force.

Chapter 11 presents foundation systems that fall outside of the criteria specified for pre-engineered foundations in Chapter 10. Mandatory design criteria, performance requirements, and best practice recommendations are presented.

Chapter 12 discusses additional design considerations concerning attachments to manufactured homes (e.g., decks, carports, and porches), jacking-up of the home, utility services, and access and egress.

Chapter 13 presents itemized and total expected costs for installed foundation systems as established by the Oversight Committee. Costs for site preparation, earth fill, installation, anchors, and jacking are considered.

Appendixes A - G contain a bibliography, a list of Federal and state contacts, sources of flood information, a list of NFIP definitions, acronyms and abbreviations, pre-engineered foundation designs, and example calculations, respectively.

1.2 Background

1.2.1 Manufactured Homes in the United States

Manufactured homes fill a demand for affordable housing in many parts of the United States. In 2001, the Manufactured Housing Institute (MHI) reported that the industry shipped out 193,120 homes with the average price of a manufactured home being $48,800. Single section homes had an average price of $30,700, and double section homes had an average price of $55,100. The 2000 Census Bureau’s figures show that 67 percent of new manufactured homes were located on private property and 33 percent of new homes are located in manufactured housing communities. The 2000 Census also estimated that 8.6 million households nationwide live in manufactured homes. The average household size is 2.4 people. That means about 20 million people, close to 8 percent of the U.S. population, live in manufactured homes nationwide. About 25 percent of the manufactured homes are located in three states (Florida, California, and Texas).

1.2.2 Performance of Manufactured Homes in Wind and Flood Events

1.2.2.1 Performance of pre-1994 Manufactured Homes

In 1992, Hurricane Andrew struck Dade County, FL and destroyed 97 percent of the manufactured homes in its path. The manufactured homes structures, cladding, and accessories were observed to break up under the hurricane wind forces. As a result of this devastating damage, in 1994, HUD adopted new stringent structural resistance guidelines for the construction of manufactured homes to be placed in HUD wind zones II and III. Further provisions regarding wind-resistant doors and windows are required for manufactured homes built after January 17, 1995. These guidelines only address manufactured housing construction and not the installation of the homes.

After Hurricane Georges traveled through Monroe County, FL, in 1998, the FEMA Building Performance Assessment Team (BPAT) reported on the successes and failures of manufactured housing. Most of the observed damage during the BPAT occurred to homes placed before Monroe County had adopted the NFIP regulations that require that new and substantially damaged manufactured homes located in Special Flood Hazard Areas (SFHAs) be elevated to the base flood elevation (BFE) and anchored to resist flotation, collapse, or lateral movement.

Most of the flooding damage caused by Hurricane Georges observed in the manufactured homes constructed before 1994 can be attributed to lack of adequate elevation, the use of unreinforced piers (dry-stacked blocks) in high flood flow areas, inadequate anchoring, and failure of attached site-built additions (see Figure 1-1). Anchoring failures problems observed in installations include poorly attached anchors, lack of corrosion-resistant materials, homes not anchored tightly against support piers, and improperly attached tie-down straps.

Figure 1-1. Pre-1994 manufactured home that experienced substantial flood and wind damage.

1.2.2.2 Performance of post-1994 Manufactured Homes

The lessons learned from Hurricanes Andrew and Georges have resulted in manufactured homes being built stronger and installed more solidly; these homes are thus able to better resist extreme loading, in particular wind and flood loads.

Figure 1-2 shows the successful reinforced masonry pier foundation of a manufactured home installed after 1994. The manufactured home at Cudjoe Key in the Florida Keys (Monroe County), built to the 1994 standards, survived Hurricane Georges and suffered only cosmetic damage caused by flying debris (see Figure 1-3).

Figure 1-2. Reinforced masonry pier foundation system under a manufactured home installed after 1994 that performed well.

Figure 1-3. Manufactured home at Cudjoe Key, FL, built and installed prior to 1994 survived Hurricane Georges with only cosmetic damage (photo from the Florida Manufactured Home Association web site).

Federal, state, and local governments and the manufactured home industry have strived to institute construction practices and regulations to increase the safety of manufactured homes in natural hazards. The following list summarizes regulations and activities that have been passed or are in the process of being developed to help minimize the damage to manufactured homes from natural hazards.

- On July 13, 1994, HUD adopted new stringent structural resistance guidelines for the construction of manufactured homes to be placed in HUD wind zones II and III. Further provisions regarding wind-resistant doors and windows are required for manufactured homes built after January 17, 1995.

- Several states and localities (like Florida and North Carolina) have strong installation standards, which include requiring manufactured homes to meet model or standard building code requirements; the adoption of NFIP regulations; a manufactured home installer education, testing, and certification program for HUD homes; and aggressive inspection programs to ensure proper installations.

- Section 605 of the Act (42 U.S.C. 504) requires the Secretary of HUD to establish and implement a national manufactured housing installation program by December 27, 2005. This installation program must include installation standards, the training and licensing of manufactured home installers, and the inspection of manufactured home installations. HUD's program will be implemented in any state that does not have its own program, which includes all three of the above components, established by state law. Further, a state's adopted standards must equal or exceed the protection provided by HUD's national installation program to be exempted. More information on the development of this new program can be found at www.hudclips.org.

- The National Fire Protection Association (NFPA) has developed NPFA 501, *Standard on Manufactured Housing*, a consensus developed document that incorporates HUD's requirements regarding the "manufacturing" of manufactured homes into a national standard. NFPA is also developing NFPA 225, *Model Manufactured Home Installation Standard*, which will, in adopted areas, govern "installation" of manfactured homes.

Chapter 2: Manufactured Homes

2.1 Manufactured Home Characteristics

A manufactured home refers to a home or dwelling that is not "site-built," but that is built off site. These homes are trucked to and installed at a site. Since 1976, manufactured homes have been built in accordance to the HUD's Federal Manufactured Home Construction and Safety Standards; this legally distinguishes manufactured homes from factory-built "modular" homes as well as from "site-built" homes.

The definition of a manufactured home, according to 24 CFR Part 3280 is:

> "a structure that is transportable in one or more sections. A manufactured home in the traveling mode, is eight body feet in width or forty body feet or more in length, or, when erected on site, is three hundred twenty or more square feet. It is built on a permanent chassis and designed to be used as a dwelling with or without permanent foundation when connected to the required utilities, and includes the plumbing, heating, air-conditioning, and electrical systems contained therein. Additionally HUD defines a manufactured home to include calculations, which are used to determine the number of square feet in a structure. This will be based on the structure's exterior dimensions measured at the largest horizontal projections when erected on site. These dimensions will include all expandable rooms, cabinets, and other projections containing interior space, but does not include bay windows. The manufactured home mechanical and electrical systems are completely built into the manufactured home during construction."

2.1.1 Manufactured Home Support Systems

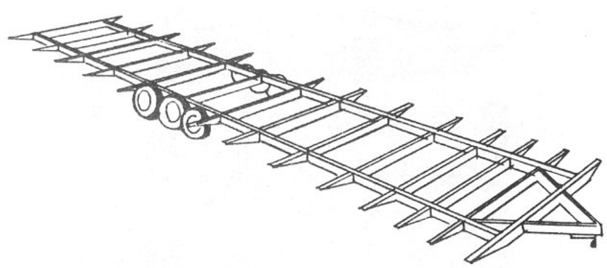
Manufactured homes are built like truck trailers, with a wheel-supported longitudinal chassis supporting a box. The support system is also the system to transport the manufactured home from the factory to the site. The system should be designed and constructed as an integrated, balanced, and durable unit.

Because the manufactured home will be transported by a vehicle for only a short period of time, the practice is not to invest in a heavy duty chassis like a truck, but to rely on the shell of the home to carry some of the load. It is possible to design the shell of the home to support itself without the double beam chassis under the floor.

An emerging trend is the use of integrated floor systems. In these systems, the floor joist and the chassis are integrated into one structure. There are two predominant types of integrated floor systems: steel reinforced perimeters (Figure 2-1) and steel floor beams incorporated into the floor trusses (Figure 2-2). The steel reinforced perimeter system consists of a steel frame that continues around the perimeter of the home and the floor joists run between the steel members, transferring the weight of the home to the steel perimeter members.

2.1.2 Chassis Support System

Currently the most common support system for manufactured homes is the chassis system. The traditional chassis system consists of two longitudinal 10-inch to 12-inch I-beams that serve as the main supporting members for a manufactured home (see Figure 2-1).



[This comes from FEMA 85, page 3.]

Figure 2-1. Traditional chassis system.

The chassis consists of the undercarriage wheel assembly and towing hitch assembly. The floor joists are structural members of the chassis. Two longitudinal I-beams complete the chassis/floor system. The minimum distance between the main chassis beams are:

Manufactured Home Width	Beam Spacing
12 feet nominal	6 feet – 3 inches
14 feet nominal	6 feet – 10 inches
16 feet nominal	8 feet – 0 inches

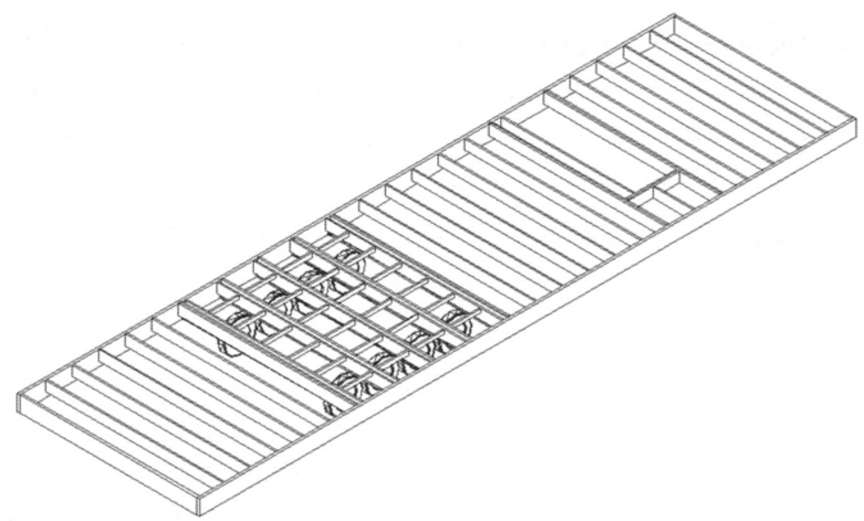
The chassis of a manufactured home, under the Federal Manufactured Housing and Construction Safety Standards, is not permitted to be removed.

According to HUD, the chassis shall be designed to sustain the following loads:

- Dead load from the manufactured home
- A minimum of 3 pounds per square foot (psf) floor load
- Superimposed dynamic load resulting from highway movement, but not to exceed twice the dead load

2.1.3 Integrated Support System

An emerging trend is the use of integrated supporting systems to support the manufactured home. There are two predominant types of integrated floor systems: steel reinforced perimeters (see Figure 2-2) and steel floor beams incorporated into the floor trusses (see Figure 2-3). The steel reinforced perimeter system consists of a steel frame that runs around the perimeter of the home and the floor joists run between the steel members, transferring the weight of the home to the steel perimeter members.



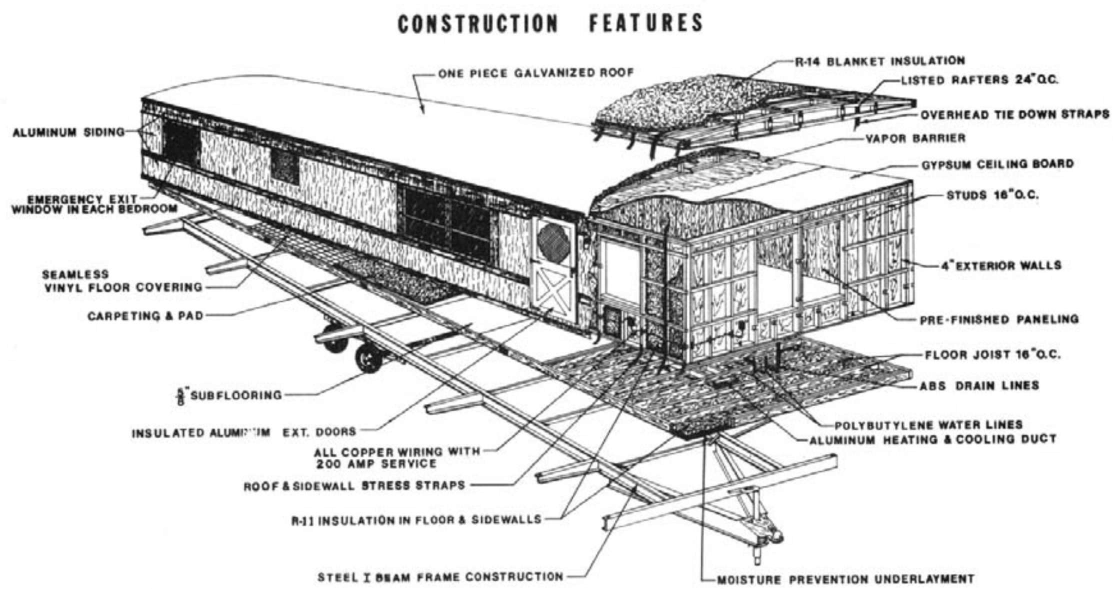
[Figure is from HUD's publication: Manufactured Home Producer's Guide to the Site-Built Market (page 13).]

Figure 2-2. Steel reinforced perimeters.

2.1.4 Envelope Construction

The floor decking material, which is attached to the floor joists, is usually wood particleboard or plywood. The manufactured home walls are constructed using wood studs with the exterior of the home generally of aluminum or wood siding. The roof/ceiling system is constructed using prefabricated roof trusses and a metal or wood/shingle exterior.

The envelope construction of manufactured homes is very similar to those of conventional site-built construction. These construction features include floor joists located at 16 inches apart center to center; and exterior stud walls, plywood sub-flooring, and roof rafters at 24 inches apart center to center. The features also include insulation, vapor barrier, gypsum wall and ceiling board, exterior roof and wall sheathing, doors and windows, and other finishing materials found in a site-built home.



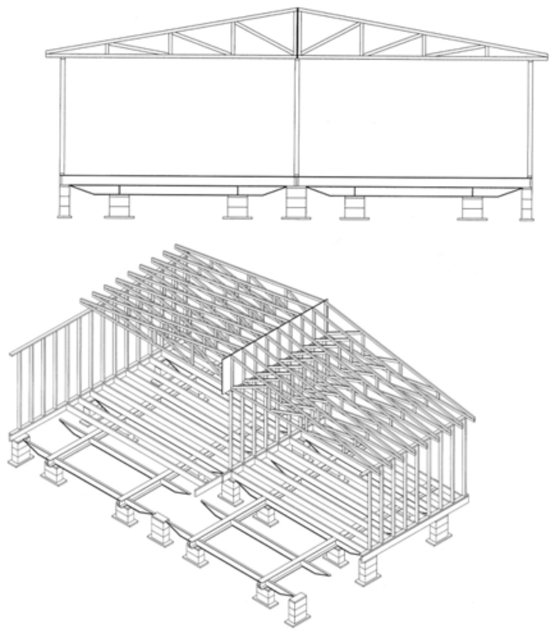
[This figure is from FEMA 85, page 3. Requested an updated figure from MHI.]

Figure 2-3. Steel floor beams incorporated into floor trusses.

2.1.5 Double Section

A double section refers to a manufactured home that is constructed from two single units and is, therefore, generally twice as wide as the normal 12- to 16-foot wide single unit. The design and construction of the chassis/floor system is comparable to the single section units. The double section is transported as two separated units and the open sections of the units are protected by a plastic barrier (see Figure 2-4). The sections are then attached at the site. The line where the two sections come together is called the marriage line. Marriage beams, beams joists, and walls are properly aligned and connected on site. The roof, walls, and floor along the marriage line must be properly aligned, sealed, and supported.

[Try to locate a photo of a double section being transported with one side covered with plastic.]



[Figure is from HUD's publication: Innovations at the Cutting Edge – New Ideas in Manufactured Housing (page 43)]

Figure 2-4.

2.2 Types of Foundation Systems

A foundation system is all the component(s) used to support and anchor a manufactured home and secure it to the ground. Existing guidance from HUD on the design of foundation systems is found in HUD -007487, *Permanent Foundation Guide for Manufactured Housing*.

Some of the conventional common types of foundation systems used to support a manufactured home located in a non-flood-prone region are:

- Piers and ground anchors
- Crawl space
- Slabs
- Basements
- Elevated foundations

2.2.1 Piers and Ground Anchors

This is the most common type of foundation system. Piers are installed under the main beam of the home sections, under the mating line of multi-section homes and at locations designated by the home manufacturer. Piers help to support the home and the anchors are used to hold down a home and resist wind uplift forces.

Examples of common type of piers include steel jack stands, hollow core concrete masonry blocks with open cells stacked vertically, and pyramid-shaped open steel frames with a base plate and an adjustable rod at the apex.

Auger-type (screw-in) type anchors are the most common anchors used to hold down the home and to resist wind uplift forces. The auger is attached to the home I beams by steel straps. Stabilizer plates are used to improve the overall structural performance of the system.

The advantages of this system are that it adapts easily to the site conditions, does not require a great deal of dimensional precision, and goes into place very quickly. Compared to the other systems, this system has the lowest initial cost and the shortest installation time. In some instances, unless the anchors are encased in concrete, Federal agencies do not consider the use of pier and ground anchor support systems a real property foundation.

2.2.2 Crawl Spaces

In this system, the home is supported by a load bearing perimeter foundation wall resting on elevated footing with economical piers or posts supporting the chassis and the ridge beam at designated points. The wall is constructed with conventional building material (e.g., poured concrete, concrete block, or treated wood). Attachment of the floor joists to the foundation wall provides the home's resistance to horizontal and uplift forces.

Some considerations in using this system include:

- This system must be precisely measured and constructed before the home is delivered to the site.
- The manufacturer must provide a foundation ready floor chassis system.
- Typically, a crane will be needed to move the home to the foundation.
- Working conditions under the home are often cramped and dark. This is potentially a problem for utility hookups and repairs.

The cost of this system is more expensive than the pier and ground anchor system. This system could be expected to meet all the conditions for a real property foundation.

2.2.3 Slabs

In this system, a thin concrete slab, insulated or uninsulated, supports the home on top of the earth. Unlike site-built construction, the slab is not part of the home floor. The slab acts a platform for the home.

The home is permanently attached to the foundation through the use of anchors embedded in the concrete, welded or bolted connections between the chassis, and permanent piers. Like the crawl space system, hollow-core concrete blocks can be used as perimeter load bearing walls. For this reason, the slab must be designed to withstand concentrated loads from the piers as well as distributed loads from the perimeter walls.

The advantage of this system is that it is relatively low cost; however, one of the disadvantages of this system is that it is not suitable for sloping lots, and it would be necessary to excavate to a level site.

2.2.4 Basements

A basement is both a support system for the manufactured home and an addition to the livable space of the home. Basements can be built partially or entirely above ground.

If the manufactured home has a chassis support system, the basement will probably have heavy steel cross beams to transfer the loads from the home to the basement walls, and columns in the center of the basement for marriage line support. If the manufactured home has a integrated floor system, the home will be supported at the perimeter and centerline wall, eliminating the need for heavy steel cross beams to transfer the loads.

Basements demand extreme care in their construction. The outside wall cannot be longer or wider than the floor of the manufactured home. Disposal of excavated soil can present a problem.

2.2.5 Elevated Foundations

A manufactured home sited in a floodplain area must be located on an elevated foundation. One of the basic flood mitigation methods for floodplains is to elevate the structure above the floodwaters. Elevating manufactured homes can be done with the use of earth fill or structural systems. Earth fill is used to elevate the ground beneath the manufactured home to above flood levels so that conventional foundations and installation methods may be used (see Figure 2-5).

Structural systems that have been employed to elevate manufactured homes include reinforced masonry and concrete piers (see Figure 2-6), reinforced masonry or concrete perimeter walls (see Figure 2-7), and timber piles/posts (see Figure 2-8),. Posts are made of wood, steel, or concrete and set in holes that are either dug by machine or hand. Piles are hammered, jetted, or augered in place. These structural systems are designed to resist expected flood, wind, and seismic forces while mitigating flood damages by elevating the home above the anticipated flood level.

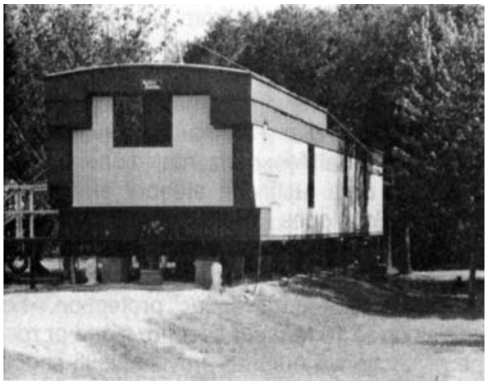


Figure 2-5. Fill foundation.

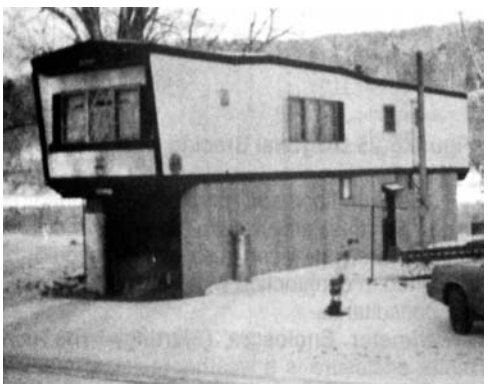


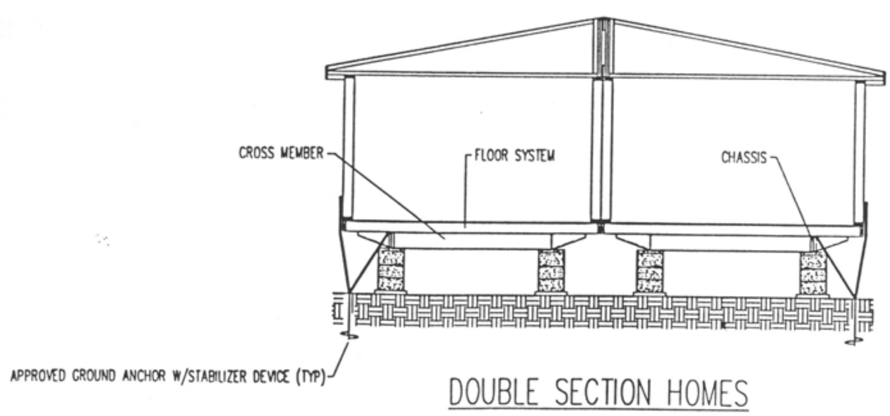
Figure 2-6. Reinforced concrete perimeter wall foundation.

Figure 2-7. Reinforced masonry perimeter wall foundation.

Figure 2-8. Timber pile foundation.

2.3 Conventional Installation

Installation of the manufactured home requires placement on a foundation system and connection to the required utilities. Conventional manufactured home foundation system installations involve supporting the manufactured home with piers (typically dry-stacked concrete masonry blocks resting on pre-cast concrete pads or plastic mats,). Piers are typically placed every 8 to 10 feet of length beneath the two chassis I-beams (see Figure 2-9). Frame ties are connected to the steel chassis or perimeter beams and run to ground anchors. Ground anchors, which are described in detail in Chapter 7, are used in conjunction with tie-downs and straps to help secure a manufactured home in place. The frame ties and anchors provide lateral support while piers provide vertical support. It should be noted that conventional manufactured home foundations and installation methods give very little consideration to the forces associated with flooding. They are not designed for flood effects such as hydrodynamic, hydrostatic, buoyancy, scour, and erosion.



[Insert an actual photo of a conventional installation]

Figure 2-9.

A manufactured home is normally placed on a prepared site that has been stabilized and improved to provide adequate support for the manufactured home and anchoring system. The types of site and area improvements vary widely across the country; some examples include simple ground stabilization (ground compaction), application of gravel, and construction of a concrete runner or slab.

2.4 Proprietary Systems

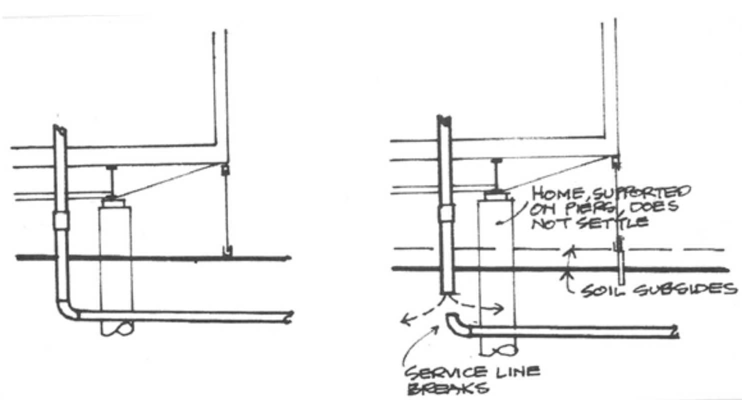
In addition to the foundation systems presented in this manual, many proprietary systems are available. A proprietary foundation is a system manufactured by a company that owns some protectable interest in the design. If a proprietary system is selected as the foundation system for the manufactured home, make sure that the system has been designed to resist the appropriate loads (see box), including any natural hazard loads that the structure may be at risk from, and make sure that the system has a professional engineer or architect's seal.

[Insert a figure of a design with an engineer's or architect's professional seal and point out the professional seal.]

Proprietary Foundation System Checklist
∉# Identify type of natural hazards to consider for the manufactured home. Follow the steps given in Chapter 11 of this manual.
∉# Identify natural hazards design loads for the manufactured home. Follow the steps given in Chapter 11 of this manual.
∉# Check design loads on engineering drawings or specifications. Design loads must be greater than or equal to the loads identified in Step 2 of Chapter 11.
∉# The drawing must have a professional engineer's or architect's seal, ensuring the system was designed by a professional.

2.5 Utilities and Mechanical Equipment

Utilities such as water, sewer, and gas services enter manufactured housing under the floor and originate from grade beneath the home. Careful consideration must be given in the placement of utilities and mechanical systems. To connect the manufactured home to these utility services and mechanical systems, the services and systems must extend from grade to the floor of the manufactured home. This location makes them susceptible to flood inundation (leakage) and damage from floating debris. Separation and protection of these systems is important. Utility systems must be protected from floodwaters, winds, and earthquakes as well as wave action in coastal construction. For additional information on utility and mechanical systems, see Chapter 12 of this manual.



Chapter 3: Regulatory Requirements

Federal, state, and local regulatory requirements must be identified and assessed as an initial step in the installation of manufactured housing in a flood hazard area. The following discussion provides a summary of applicable regulations. Appendix C presents additional resources regarding flood hazards and construction in flood-prone areas.

3.1 The NFIP and Its Purpose

The National Flood Insurance Program is the principal administrative mechanism of the Federal Government for reducing flood losses. It was established by Congress in 1968 to address concerns with traditional methods of dealing with flood damage, which generally did not effectively reduce flood losses, or discourage unwise development in floodplains.

Prior to 1968, the cost of flood losses was increasing every year, and taxpayers funded the majority of disaster relief from flood events. The primary goals of the NFIP were to reduce future flood losses through the use of community managed floodplain ordinances, and to provide protection from flood damage to at-risk properties through federally backed flood insurance.

Today the NFIP is administered by the Federal Insurance and Mitigation Administration (FIMA), a component of the Emergency Preparedness and Response Directorate of the Department of Homeland Security (DHS) – FEMA. FIMA's function within DHS is to lessen the impact of disasters on people's lives and property through damage prevention and flood insurance.

3.2 General NFIP Development Requirements

A main objective of the NFIP is to minimize and prevent flood damage through the use of building and development standards. NFIP development requirements and associated definitions are located in the Code of Federal Regulations in 44 CFR Parts 59, General Provisions and 60, Criteria for Land Management and Use. Within the following description of these requirements, there are several references to words and terms specific to the program. Appendix D contains a listing of some common NFIP terms, including those related specifically to manufactured housing, and corresponding definitions for the terms.

For communities that choose to participate in the NFIP, the NFIP performs a Flood Insurance Study (FIS) and creates FIRMs that show the extent of the base, or 1 percent annual chance, flood that defines the Special Flood Hazard Area. The 1 percent annual chance flood is so called because it has a 1 percent chance of being equaled or exceeded in any given year; it is also sometimes referred to as the 100-year flood. The SFHA is the area (at a minimum) in which development must be regulated by NFIP standards; the community must adopt floodplain development regulations that meet minimum NFIP standards, as well as any state standards, and apply these regulations to development occurring within the SFHA.

FISs and FIRMs can be viewed and ordered online at store.msc.fema.gov. They can be ordered as digital files or for delivery as hard copies. The catalog link on the main page will take you to a listing of products, including FISs and FIRMs. After choosing a type of product, you must choose the community in which the property or area that you are interested is located in order to find the specific FIS or FIRM that is needed.

After a community adopts floodplain development regulations, properties within the community become eligible for federally-backed flood insurance. Flood insurance policies offer coverage for buildings and their contents due to damage from flood events. Flood insurance coverage is generally not included in standard homeowners' insurance policies and must be purchased separately. However, some manufactured home coverage does provide for damage from floods. This is the only type of construction with which flood damage coverage is sometimes included as part of general building insurance coverage.

To meet NFIP floodplain development regulations, communities must institute a permit application and processing system for any development within the regulatory floodplain. The base floodplain is the regulatory floodplain unless the community has adopted a more restrictive floodplain. The community must review all applications and, before issuing any permits, the community must ensure that two basic criteria are met:

- All new buildings and substantial improvements to existing buildings will be protected from damage by the base flood.

- New floodplain development will not aggravate existing flood problems or increase damage to other properties.

The key provisions of floodplain development regulations that are necessary to meet these goals are as follows:

- Require that the lowest floor of new residential buildings within the floodplain be elevated to or above the level of the BFE and that commercial structures be either elevated or flood-proofed to this level.

- Designate a regulatory floodway that carries the waters of the base flood without increasing the water surface elevation a given amount (usually 1 foot) at any point. Within this designated floodway, no development can occur that will result in any increase in the existing BFE.

- Require that structures built before the adoption of floodplain development regulations (pre-FIRM) meet current regulations if they are substantially damaged or improved.

The general requirements for development in the SFHA follow:

Minimum NFIP requirements for Floodplain Management Regulations can be found in the Code of Federal Regulations, Chapter 44, Part 60, Subpart A (44 CFR 60 A). This section details general regulations to be applied in all participating communities, including those where there are no special flood hazard areas defined, no floodwater surface elevation data, and insufficient data to identify the floodway or coastal high hazard area, but where the community has indicated the presence of such hazards by submitting an application to participate in the NFIP. These requirements apply to all types of flood hazard areas and thus provide an overview of the NFIP basics. Following is a summary of the regulations in §60.3 (a) (3), which highlights design and construction requirements for structures. It states that all new construction and substantial improvements within flood-prone areas must:

- 60.3 (a) (3) (i) – be "*designed (or modified) and adequately anchored to prevent flotation, collapse, or lateral movement of the structure resulting from hydrodynamic and hydrostatic loads, including the effects of buoyancy,*"

- 60.3 (a) (3) (ii) – be "*constructed with materials resistant to flood damage,*"

- 60.3 (a) (3) (iii) – be *"constructed by methods and practices that minimize flood damages,"* and

- 60.3 (a) (3) (iv) – *"be constructed with electrical, heating, ventilation, plumbing and air conditioning equipment and other service facilities that are designed and/or located so as to prevent water from entering or accumulating within the components during conditions of flooding."*

§60.3 (a) (4) provides other general regulations to be applied in all participating communities. It states that within flood-prone areas, the community must:

"*Review subdivisions proposals and other proposed new development, including manufactured home parks or subdivisions, to determine whether such proposals will be reasonably safe from flooding. If a subdivisions proposal or other proposed new development is in a flood-prone area, any such proposals shall be reviewed to assure that:*

> *(i) all such proposals are consistent with the need to minimize flood damage within the flood-prone area*
>
> *(ii) all public utilities and facilities, such as sewer, gas, electrical, and water systems are located and constructed to minimize or eliminate flood damage, and*
>
> *(iii) adequate drainage is provided to reduce exposure to flood hazards.*"

Because these general regulations apply to all new construction and substantial improvement within flood-prone areas, they help to lay the framework for all of the more specific requirements in latter portions of the regulations.

3.2.1 Enclosed Areas

Regulations that describe requirements for enclosed areas apply to all areas of the identified SFHA, except within those communities that do not have water surface elevation data or floodway delineations for any part of their SFHA. These regulations apply to all new and substantially improved residential structures, including conventional and manufactured housing.

Within 44 CFR §60.3 (c) (5), requirements for areas below the lowest floor (the lowest floor of the lowest enclosed area including basements) of the structure are addressed. It states:

"*Require for all new construction and substantial improvements, that fully enclosed areas below the lowest floor that are usable solely for parking of vehicles, building access or storage in areas other than a basement and which are subject to flooding shall be designed to automatically equalize hydrostatic flood forces on exterior walls by allowing for the entry and exit of floodwaters. Designs for meeting this requirement must either be certified by a registered professional engineer or architect or meet or exceed the following minimum criteria: A minimum of two openings having a total net area of not less than one square inch for every square foot of enclosed area subject to flooding shall be provided. The bottom of all openings shall be no higher than one foot above grade. Openings may be equipped with screens, louvers, valves, or other covering or devices provided that they permit the automatic entry and exit of floodwaters.*"

Therefore, this enclosed area can only be used for parking, storage, or building access and must be designed to automatically equalize hydrostatic flood forces on exterior walls by allowing for the entry and exit of floodwaters. For non-engineered openings, basic design criteria include the following:

- The bottom of vents must be no more than 1 foot above grade,

- There must be at least 1 square inch of opening for each 1 square foot of enclosed space, and

- There must be at least two openings on different sides of the enclosed area. If there is more than one enclosed area, each area must have two openings on different exterior walls.

3.2.2 Floodways

44 CFR §60.3 (d) (3) provides requirements for proposed development in regulatory floodways. This requirement applies to all types of development in areas where a floodway has been delineated.

> "*Prohibit encroachments, including fill, new construction, substantial improvements, and other development within the adopted regulatory floodway, unless it has been demonstrated through hydrologic and hydraulic analyses performed in accordance with standard engineering practice that the proposed encroachment would not result in any increase in flood levels within the community during the occurrence of the base flood discharge*"

Although this section generally applies only to A1-30, AH, and AE zones, if there is floodway information available for Approximate A zones, this regulation should be enforced for development in this zone as well.

There is generally very little development or disturbance permitted in the floodway, because it is difficult to perform such development without raising the level of the base flood discharge as buildings in the floodway become obstructions to floodwaters.

3.2.3 Conclusions and Observations

NFIP development regulations are provided for more specific circumstances based on the type of development, the use of the structure, and the SFHA within which the development site is located.

Some community FISs and FIRMs prepared by the NFIP are 10 to 20 years old and thus may not reflect recent development in the watershed or may have used older, less accurate mapping techniques. Map modernization work is in progress, including the development of up-to-date flood hazard data for areas across the U.S. and the creation of maps and data in digital format such as the Digital Flood Insurance Rate Map (DFIRM). Although efforts to develop new flood hazard data and maps are already underway for many communities, it will take some time before new data and maps are available for all NFIP communities.

FIRMs often do not map flooding on small streams or in small drainage areas. This does not mean there are no flood problems in such areas, only that FEMA's study does not include a detailed assessment of them. In addition, FIRMs may not provide flood elevations or a floodway designation for floodplains in undeveloped areas. When these data are not available from a community's FIS or FIRMs, the community is required to investigate the possible existence of more recent or more detailed flood studies conducted by other agencies. A qualified engineer may be needed to review available data and determine if a new study should be conducted if it seems that no reasonable floodplain information is available. This is especially important if there has been a history of flood problems in the area that are not reflected on the FIRM or if the site is in a small watershed that has experienced a lot of recent development.

3.3 Flood Zone-specific NFIP Development Requirements

The minimum NFIP requirements for manufactured housing based on applicable regulations from 44 CFR are presented by type of SFHA in the following discussion. Table 3-1 provides a general description of the most common SFHAs.

Table 3-1. Common Floodplain Zones Found on FIRMs

Zone	Description
100-year or base floodplain zones	
A	The base floodplain mapped by approximate methods where no BFEs have been determined. Also called the Approximate A zone.
AE **A1-30**[1]	The base floodplain where BFEs have been determined and are shown on FIRMs.
AO	The base floodplain where there is sheet flow, ponding, or shallow flooding. Base flood depths are provided.
AH	The base floodplain in areas of shallow flooding. BFEs are provided.
V	The base floodplain in coastal areas where there is a velocity hazard due to wave action. No BFEs have been determined.
VE **V1-30**[1]	The base floodplain in coastal areas where there is a velocity hazard due to wave action. BFEs have been determined and are shown on the FIRM.
Other zones	
X (shaded)	This zone shows the area beyond the 100-year floodplain that would be

Zone	Description
B[1]	inundated by a 500-year event.
X (unshaded) C[1]	Areas outside of the 500-year floodplain.

[1]Zone designations found on older FIRMs that have been replaced by the designation listed in the same box above them.

3.3.1 Approximate A-Zones

3.3.1.1 Elevation and Anchoring

44 CFR §60.3 (b) (8) addresses regulations for manufactured homes to be placed in Approximate A zones. Because there are no BFE data available from the FIS or FIRM for this SFHA, 44 CFR does not list an elevation requirement related to any BFE for this SFHA. Instead , the regulations state that there must be elevation and anchoring to protect the manufactured home from damage or destruction. The section asserts that:

> "*.. all manufactured homes to be placed within Zone A on a community's FHBM or FIRM shall be installed using methods and practices which minimize flood damage. For the purposes of this requirement, manufactured homes must be elevated and anchored to resist flotation, collapse, or lateral movement. Methods of anchoring may include, but are not limited to, the use of over-the-top frame ties to ground anchors. This requirement is in addition to applicable State and local anchoring requirements for resisting wind forces*."

Definition

FLOOD HAZARD BOUNDARY MAP (FHBM)

An official map of a community where the boundaries of the SFHA have been approximated. This map is usually issued for communities that join the program in an Emergency Phase. Most communities move from the emergency to the regular phase at which time they are usually issued FIRMs.

3.3.1.2 Base Flood Data

Although there are no flood elevation data shown on the FIRM for Zone A, this information may be available from other sources such as local hydrologic and hydraulic (H&H) studies or U.S. Army Corps of Engineers (USACE) studies. If there are any other reliable BFE or floodway data available for the area, the community is required to use this information to help regulate floodplain development.

FEMA has also developed a methodology for estimating the BFE for specific sites in riverine flood areas. A one-dimensional flow modeling program called Quick-2 requires limited input data to determine an estimated BFE. For the program, floodplain topography information is necessary to create one or more cross-sections of the stream and to determine the slope of the stream. A peak stream flow discharge and a streambank "roughness coefficient" (based on the vegetation along the stream) are also necessary.

Quick-2 is only used on specific sites where no detailed hydraulic studies have been performed in order to approximate a BFE. For detailed studies of entire stream reaches, a more complex hydraulic model is required.

Certain circumstances require that BFE data be developed for Approximate A zones through the use of detailed study methodologies similar to those used in creating the FIS. According to 44 CFR §60.3 (b) (3), detailed base flood data are required when a new manufactured home park or subdivision is being planned that is greater than 50 lots or 5 acres in size (whichever is less). The regulations state that the community must

> "*Require that all new subdivision proposals and other proposed developments (including proposals for manufactured home parks and subdivisions) greater than 50-lots or 5 acres, whichever is the lesser, include within such proposals base flood elevation data*"

The BFE data must be included in the proposal for such a development. The community can perform a study to determine these elevations, or require the developer to fund or complete the study. When the 50-lot, 5-acre threshold is surpassed, and the development includes one or more lots that lie at least partially within the floodplain, BFE data must be developed through detailed study methodologies. If the developer completes the study, it is subject to approval by the community floodplain administrator. For more information, see FEMA's, *The Zone A Manual: Managing Floodplain Development in Approximate A Zone Areas*.

When BFE data are created or are available for an Approximate A zone, development in the area becomes subject to the rules for A1-30, AH, and AE zones (see the following section).

3.3.2 A1-30, AH, and AE Zones

3.3.2.1 Elevation and Anchoring

There are elevation requirements for new and substantially damaged structures that apply to all residential structures; the first finished floor of these structures must be elevated to or above the BFE. However, for manufactured housing, there is an exception to this requirement. The 3-foot pier rule allows certain new installations of manufactured homes in SFHAs to be elevated on a 3-foot pier foundation regardless of the base flood elevation. While the regulations make this method of elevation an option, it is generally not recommended in areas with flood depths greater than 2-3 feet, or in areas subject to high velocity floodwaters.

44 CFR §60.3 (c) (6) provides minimum requirements for certain types of manufactured housing placed or substantially improved in base flood areas A1-30, AH, or AE (riverine flood areas where a BFE is determined). The section applies only to housing placed in certain areas. 'Existing manufactured home park or subdivision' refers to parks that were in service prior to the community's adoption of floodplain development regulations. 'New manufactured home park or subdivision' refers to parks constructed after the adoption of the regulations. The section states that communities shall:

"*Require that manufactured homes that are placed or substantially improved within Zones A1-30, AH, and AE on the community's FIRM on sites*

(i) *Outside of a manufactured home park or subdivision*,

(ii) *In a new* [post-FIRM] *manufactured home park or subdivision,*

(iii) *In an expansion to an existing* [pre-FIRM] *manufactured home park or subdivision, or*

(iv) *In an existing manufactured home park or subdivision on which a manufactured home has incurred substantial damage as the result of a flood*,

be elevated on a permanent foundation such that the lowest floor of the manufactured home is elevated to or above the base flood elevation and be securely anchored to an adequately anchored foundation system to resist floatation, collapse and lateral movement."

The description in 44 CFR §60.3 (c) (6) (iv) applies to specific lots within an existing manufactured home park or subdivision. Once a manufactured home within an existing park or subdivision has been substantially damaged by a flood, from that point on, all manufactured homes installed on that particular lot must be elevated to the BFE.

Any manufactured housing placed in one of the four previously described areas must be elevated to the BFE. Therefore, within these zones, the top of the lowest floor of a new or substantially improved structure is required to be at the same elevation as the base flood. New or substantially improved pre-FIRM conventional homes are subject to the same requirements within A1-30, AH, and AE zones.

The elevation to the BFE requirement assumes that all other floodplain management requirements have been met, including provisions that require all portions of the building below the BFE to be constructed with flood-resistant materials, and all building utility equipment, including ductwork, to be protected from flooding (elevated or waterproofed). To ensure that these other floodplain management criteria are met, the NFIP encourages communities to adopt more stringent elevation requirements. By elevating the first floor a distance above the BFE, damage to horizontal support beams, flooring, utilities, and ductwork just below the top of the first floor can be avoided. The height of protection above the BFE is termed freeboard.

Additionally, the manufactured housing is required to be securely anchored to an adequately anchored foundation system to resist flotation, collapse, and lateral movement.

3.3.2.2 3-foot Pier Rule

For manufactured housing placed in A1-30, AH, or AE zones within areas that are not addressed in 44 CFR §60.3 (c) (6), 44 CFR §60.3 (c) (12) applies. This section stipulates that, for manufactured housing to be placed or substantially improved on sites in existing (pre-FIRM) manufactured home parks or subdivisions that are not subject to the provisions of 44 CFR §60.3 (c) (6), two elevation scenarios are possible:

- The lowest floor of the manufactured home must be elevated to or above the BFE (44 CFR §60.3 (c) (6)), or

- The manufactured home must be supported on reinforced piers or other foundations elements of at least equivalent strength that are no less than 36 inches in height above grade. This option is referred to as the 3-foot pier rule.

44 CFR §60. 3 (c) (12) states "*Require that manufactured homes to be placed or substantially improved on sites in an existing manufactured home park or subdivision within Zones A-1-30, AH, and AE on the community's FIRM that are not subject to the provisions of paragraph (c) (6) of this section be elevated so that either*

(i) *The lowest floor of the manufactured home is at or above the base flood elevation, or*

(ii) *The manufactured home chassis is supported by reinforced piers or other foundation elements of at least equivalent strength that are no less than 36 inches in height above grade and be securely anchored to an adequately anchored foundation system to resist flotation, collapse and lateral movement.*"

The option for elevation described in 44 CFR §60. 3 (c) (12) (ii) was adopted as part of 44 CFR §60.3 on November 1, 1989. From 1976-1986, all manufactured homes placed in pre-FIRM manufactured home parks and subdivisions were not required to be elevated to the BFE. However, the NFIP rescinded this provision in 1986 and attempted to hold manufactured housing being placed in these parks to the same standards as other new and substantially improved residential structures in the floodplain. Due to opposition to this change from several groups, including owners and residents of pre-FIRM parks and subdivisions, a task force was created to investigate alternative options. As a result, the 36-inch pier option was proposed as a compromise, and it was adopted by the NFIP.

The NFIP acknowledges that the requirement to elevate only 36 inches above grade may, in some cases, result in less than 100-year (1 percent annual chance probability) flood protection. However, this is a minimum standard and the NFIP strongly recommends elevating to at least the 100-year flood level.

3.3.3 AO Zones

There are no separate regulations for placing conventional residential structures and manufactured housing in AO zones. The requirements for all residential structures to be placed in AO zones are detailed in 44 CFR §60.3 (c) (7). It states that the community shall:

> "*Require within any AO zone on the community's FIRM that all new construction and substantial improvements of residential structures have the lowest floor (including basement) elevated above the highest adjacent grade at least as high as the depth number specified in feet on the community's FIRM (at least two feet if no depth number is specified).*"

AO zones are areas of shallow flooding where a depth for the base flood is provided rather than an elevation. FIRMs supply a level above grade to which structures must be raised for the zones that is based on an average depth. The base floodwater depth in AO zones is always between 1-3 feet. As a result, structures in the zone are required to be elevated between 1-3 feet above grade.

This level of elevation can be accomplished by using standard manufactured home installation techniques such as placing the home on dry-stacked block piers and securing it with ground anchors. Although a dry stacked block and ground anchors foundation style can provide adequate elevation, it can only withstand relatively low flood velocities. Therefore it is recommended that, where practical, fill be placed to elevate the building pad site before using this technique.

Since this type of foundation provides a 3-foot elevation and because flood depths in AO zones are never more than 3 feet, all new or substantially improved manufactured homes in AO zones have always been required to elevate to or above the base flood level, even if they were being placed in pre-FIRM manufactured home parks or subdivisions.

Although anchoring is not addressed specifically within this portion of the regulations, the requirements of §60.3 (a) (3) and (b) (8) still apply and thus adequate anchoring is required for manufactured housing within AO zones.

3.3.4 V, V1-30, and VE Zones

All residential construction in Coastal High Hazard Areas (V zones), including both manufactured housing and conventional housing, is subject to regulations detailed in 60.3 (e) (1) – (7). Although these regulations are only required for V zones, A zones located in coastal areas are often subject to the same hazards present in V zones, including wave effects and high velocity flows. Therefore, structures in these areas, referred to as coastal A zones, can often benefit from being constructed to meet minimum NFIP V zone floodplain development requirements. Sections 60.3 (e) (3) through (7) address specific building requirements. Summaries of these sections are provided below.

3.3.4.1 Setbacks

> §60.3 (e) (3) requires the community to, "*Provide that all new construction within Zones V1-30, VE, and V on the community's FIRM is located landward of the reach of mean high tide.*"

In coastal areas, there is a mean high tide line used for regulatory purposes. This means that the high tide line is physically shifting over time as beach and coastal areas are dynamic. However, the community, region, or state will have a regulatory line defined. The NFIP does not allow any development or construction to occur seaward of this line. Figure 3-1 illustrates how the mean high tide line defines the area of no development in coastal regions.

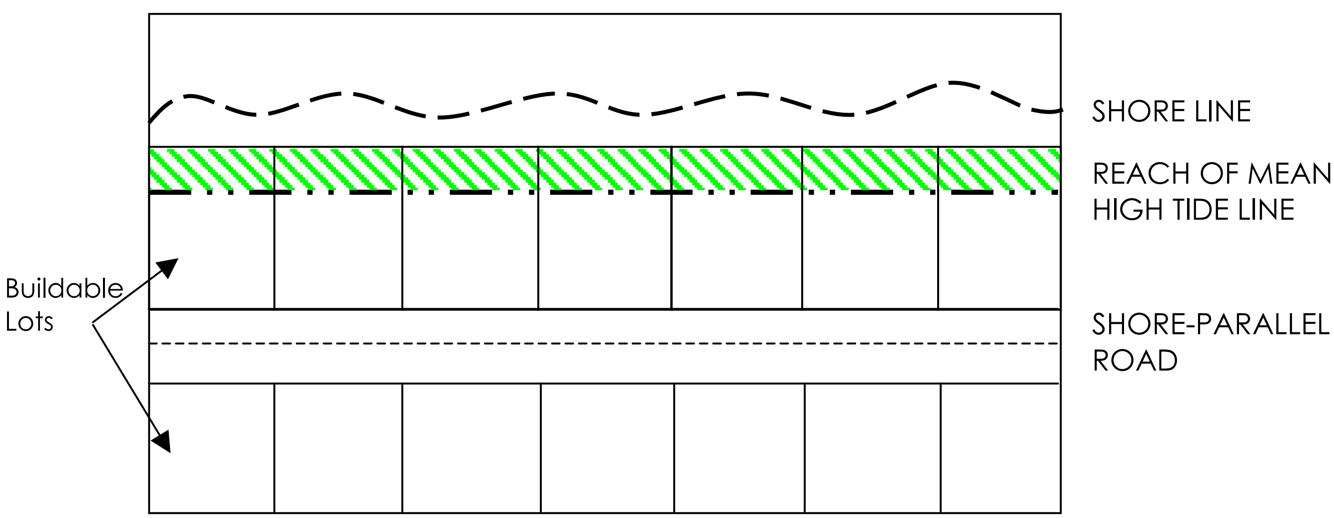


Figure 3-1. Mean high tide line development restriction.

(INCLUDE ORTHO OF AN ACTUAL BEACH AREA HERE FOR THE FINAL VERSION. TAKE PHOTO FROM COASTAL CONSTRUCTION MANUAL VOLUME 1, PAGE 8-5.)

3.3.4.2 Elevation

> §60.3 (e) (4) requires the community to "*Provide that all new construction and substantial improvements in Zones V1-30, VE*

and also Zone V if base flood elevation data is available, on the community's FIRM, are elevated on pilings and columns so that

(i) *The bottom of the lowest horizontal structural member of the lowest floor (excluding the pilings or columns) is elevated to or above the base flood level; and*

(ii) *The pile or column foundation and structure attached thereto is anchored to resist flotation, collapse and lateral movement due to the effects of wind and water loads acting simultaneously on all building components. Water loading values used shall be those associated with the base flood. Wind loading values used shall be those required by applicable State or local building standards. A registered professional engineer or architect shall develop or review the structural design, specifications and plans for the construction, and shall certify that the design and methods of construction to be used are in accordance with accepted standards of practice for meeting the provisions of paragraphs (e) (4) (i) and (ii) of this section.*"

Elevation requirements for structures in the V zones differ from those in the A zones. The elevation of the top of the lowest floor is used as the reference elevation for A1-30, AE, A, and AO zones. This means that the top of the lowest floor must be at or above the BFE. Structures in V zones must be elevated so that "*the bottom of the lowest horizontal structural member of the lowest floor is elevated to or above the base flood.*" This is usually 12 inches or more below the top of the lowest floor (Figure 3-2 illustrates the reference level requirement). Therefore, the minimum required elevation level for structures in V zones can be 1 foot or more higher than what it would be in A zones. However, for manufactured housing in V zones, the 3-foot pier rule also applies as is mentioned in the detailed in the discussion for §60.3 (e) (8).

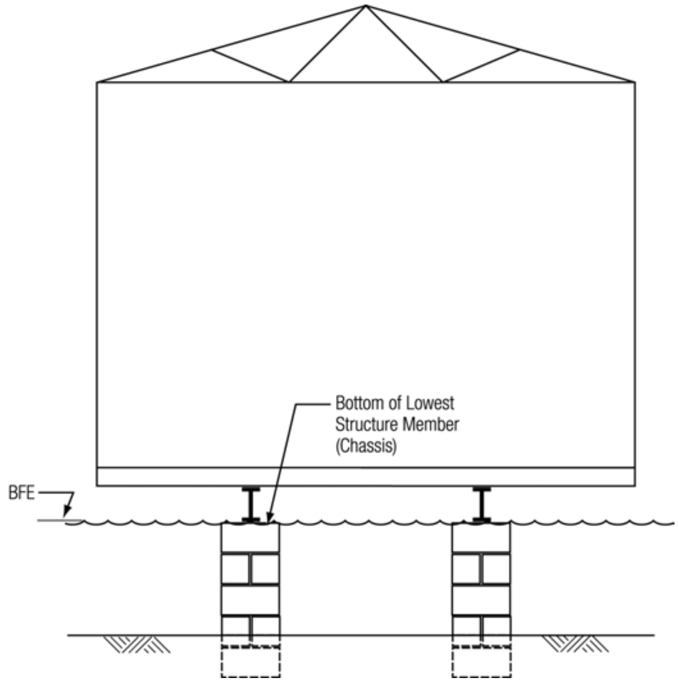


Figure 3-2. Pier/column foundation.

In Coastal High Hazard Areas (V zones), the bottom of the lowest structural member must be at or above the BFE as shown in Figure 3-2 (unless the 3-foot rule is applicable). For riverine flooding areas (A zones), the reference level is actually the top of the lowest floor. However, equipment that is often affixed to the bottom of a manufactured house must also be protected from floodwaters, so this type of elevation is preferable.

FEMA's *Coastal Construction Manual* (FEMA 55) recommends that for areas subject to coastal flooding, the bottom of the lowest horizontal structural member should actually be elevated above the BFE; the manual thus advocates the use of freeboard. Additionally, the manual states that the lowest horizontal structural members in coastal areas should be perpendicular to the expected wave crest.

Section §60.3 (e) (5) (ii) of the regulations addresses flood and wind loadings to be used in the design of a foundation, and its attachment to the structure, to ensure that the foundation and structure will resist floatation, collapse, and lateral movement.

Breakaway walls must be designed to resist between 10 to 20 psf, and must collapse under a load less than that experienced during the base flood. However, the foundation has to resist wind and flood loads acting simultaneously. Flood loading that would result from the base flood is to be used for the foundation design. §60.3 (e) (5) does not give specific wind loads to use for design, but rather indicates that wind loads from applicable

Example

ANCHOR AND TIE-DOWN SYSTEMS

Anchor and tie-down systems must meet load requirements stipulated in locally adopted building codes in order to be resistant to flooding and wind forces. Many communities across the country have adopted or are in the process of adopting the International Code Series, which includes the International Residential Code of 2003 (IRC 2003). The IRC 2003 stipulates working load requirements of 3,150 pounds with a 50 percent overload or 4,750 pounds for manufactured home anchoring systems.

Florida's manufactured home installation requirements, *Rules of Department of Highway Safety and Motor Vehicles Division of Motor Vehicles, Chapter 15C-1*, for homes made before July 14, 1994, have the same loading standards for anchor systems as those found in the IRC 2003 - a working load of 3,150 pounds with an ultimate load of 4,725 pounds. However, for homes manufactured after July 14, 1994, the system must be able to resist a working load of 4,000 pounds with an ultimate load of 6,000 pounds.

state or local standards should be used in the design of the foundation and its attachments.

These NFIP loading design regulations are related to those imposed by HUD's Manufactured Home Construction and Safety Standards (MHCSS) in which there are provisions for support and anchoring systems based on HUD Wind Zones I, II, and III; however, there are notable differences between the NFIP provisions and HUD's standards. HUD's standards dictate design requirements for the body and frame of the building. Although foundation design wind loadings are addressed in HUD's regulations, the regulations do not require that foundation designs include provisions for loading from flood forces and therefore are not adequate for structures in flood areas. The HUD standards do not take seismic loading into account for the design of foundations and attachments.

The Manufactured Housing Act of 2000 (MHIA 2000) called for the creation of a HUD committee, the Manufactured Housing Consensus Committee (MHCC); one of the committee's responsibilities is to propose updates to HUD's MHCSS at least once every 2 years. The MHCC is currently working to develop a national model installation standard for manufactured housing that must be equaled or exceeded by state standards (in states responsible for installation programs) and manufacturers' installation instructions. Standards for installation related to foundation designs in flood hazard areas are being considered.

§60.3 (e) (8) applies specifically to manufactured housing placement in V1-30, VE, and V zones. Elevations requirements are similar to those for manufactured housing being placed in A1-30, AH, and AE zones.

> §60.3 (e) (8) states that communities must "*Require that manufactured homes placed or substantially improved within Zones V1-30, VE and V on the community's FIRM on sites*:
>
> (i) *outside of a manufactured home park or subdivision,*
>
> (ii) *in a new manufactured home park or subdivision,*
>
> (iii) *in an expansion to an existing manufactured home park or subdivision, or*
>
> (iv) *in an existing manufactured home park or subdivision on which a manufactured home has incurred substantial damage as the result of a flood,*
>
> *meet the standards of paragraphs (e) (2) – (7) of this section and that the manufactured homes placed or substantially improved on other sites in an existing*

> *manufactured home park or subdivisions within Zones V1-30, V and VE on the community's FIRM meet the requirements of paragraph (c) (12) of this section*."

These regulations are similar to those for manufactured homes being placed in A1-30, AE, AH, and A zones (with base flood data). The section refers back to §60.3 (c) (12), which is where the two options are stipulated to elevate manufactured homes. Either the manufactured home can have its lowest floor elevated to or above the BFE, or the manufactured home can be supported through the use of "*reinforced piers or other foundations elements of at least equivalent strength that are no less than 36 inches in height above grade and be securely anchored to an adequately anchored foundations system to resist flotation, collapse and lateral movement*."

In the second option, the home is not elevated above the BFE and remains not only vulnerable to inundation, but also vulnerable to being lifted by the hydrostatic forces of rising floodwaters (buoyancy) and displaced by the hydrodynamic forces of moving floodwaters. Once a home is lifted or displaced, it not only can be destroyed, but can also damage or destroy adjacent properties. To reduce the potential for damage, the NFIP requires homes not elevated above the BFE to be secured to resist floatation, collapse, and lateral movement.

Again, the use of the terms 'existing' and 'new' refer to the periods before the community's adoption of floodplain development regulations (pre-FIRM) and on or after the day that the community adopted the regulations (post-FIRM), respectively.

Although the 3-foot pier foundation is an option for manufactured homes in V zones (coastal high hazard areas), it is important to note that structures in these flood zones are subject to wave action, intense hydrodynamic pressures, and generally deeper flood depths than in riverine areas. Foundations in V zones thus need to be fortified to withstand flood forces from wave action and greater flood depths; the 3-foot pier foundation would probably not withstand wave forces resulting from substantial storm surge. Additionally, manufactured homes are required to meet the same performance standards as conventional structures. Therefore, although the construction requirements might allow a 3- foot pier foundation, performance requirements (including those described in 60.3 (a) (3)) often require that higher building standards be used.

3.3.4.3 Breakaway Walls

In §60.3 (e) (5), communities are required to

> "*Provide that all new construction and substantial improvements within Zones V1-30, VE and V on the community's FIRM have the space below the lowest floor either free of obstruction or constructed with non-supporting breakaway walls, open wood lattice-work, or insect screening intended to collapse under wind*

and water loads without causing collapse, displacement, or other structural damage to the elevated portion of the building or supporting foundation system. For the purposes of this section, a breakaway wall shall have a design safe loading resistance of not less than 10 and no more than 20 pounds per square foot. Use of safe loading resistance of 20 pounds per square foot (either by design or when so required by local or State codes) may be permitted only if a registered professional engineer or architect certifies that the designs proposed meet the following conditions:

(i) *Breakaway wall collapse shall result from a water load less than that which would occur during the base flood; and*,

(ii) *The elevated portion of the building and supporting foundation system shall not be subject to collapse, displacement, or other structural damage due to the effects of wind and water loads acting simultaneously on all building components (structural and non-structural). Water loading values used shall be those associated with the base flood. Wind loading values used shall be those required by applicable State or local building standards*.

Such enclosed space shall be useable solely for parking of vehicles, building access, or storage."

Structures in all V zones that have enclosed space below the lowest floor can use only breakaway type walls. The walls must be subject to the loading requirements that state that they must resist at least 10, and no more than 20 psf of loading. As in the A zones, this space is useable solely for parking, building access, and storage.

3.3.4.4 Structural Fill

In §60.3 (e) (6), communities are required to "*Prohibit the use of fill for structural support of buildings within Zones V1-30, VE, and V on the community's FIRM.*"

This regulation only applies to V zones where structural fill is not permitted. Structural fill is permitted in A zones outside of the floodway and can be a viable option for allowing elevation of manufactured homes to a level above the BFE or at least above the level of frequently occurring floods. It is important to ensure that the fill is properly compacted and graded when it is placed. Compaction will make the fill more structurally sound, and proper grading will help to prevent erosion and promote drainage away from the structure.

3.3.4.5 Alteration of Coastal Features

§60.3 (e) (7) states that communities must "*Prohibit man-made alteration of sand dunes and mangrove stands within Zones V1-30, VE and V on the community's FIRM which would increase potential flood damage*."

Sand dunes are important because they serve as a physical barrier to structures from coastal flooding and absorb some of the most destructive forces from wave action associated with coastal floods. Therefore, they help to prevent or at least decrease damage to structures located along the coast.

Mangroves perform important flood control functions as well. They protect upland areas from the more destructive forces associated with wave action and coastal flooding, help to prevent erosion, and protect areas further inland from wind. Mangroves also perform important water quality functions as they are pollutant absorbers and help to filter salt water.

INSERT MORE TEXT FROM CHRIS??

3.3.5 Coastal A-Zones

Although Coastal A-Zones are not differentiated from non-coastal A-Zones by the NFIP, there is a benefit to treating them differently and using V-Zone standards for floodplain management and development purposes. Coastal A-Zones are located adjacent to and landward of V-Zones and are subject to similar flood hazards, including wave effects, velocity flows, erosion, scour, and high winds. Although the forces in Coastal A-Zones are not as severe as those in V-Zones, they are still generally more destructive than those in non-coastal A zones and therefore require additional consideration.

FEMA's *Coastal Construction Manual* recommends that buildings in Coastal A-Zones meet the NFIP regulatory requirements for V-Zone buildings, including the requirements listed as follows:

- Performance requirements concerning resistance to flotation, collapse, and lateral movement
- Elevation requirements
- Foundation type
- Certification by an engineer of design and construction
- Enclosures below the BFE
- The use of structural fill

3.4 HUD Manufactured Home Construction and Safety Standards

Prior to 1975, there was no mandatory regulation standard governing the design of manufactured homes. A voluntary standard regulating the design and construction of manufactured homes was available for adoption by states and localities.

Since 1976, the U.S. Department of Housing and Urban Development's Manufactured Home Construction and Safety Standards (MHCSS) or "HUD-Code" regulate the design and construction of factory-built manufactured housing, but do not currently regulate the installation of the structures, or on-site improvements. Program standards are found in the Code of Federal Regulations in 24 CFR 3280. Much of the regulations in the standard came after Hurricane Andrew in 1992.

The program has been in effect since 1976, and all manufactured homes built on or after June 15, 1976, are subject to its requirements. Although building codes are usually regulated at a local level, an exception is made with manufactured housing because it is most often built outside of the locality where it is eventually sited for use. Prior to the MHCSS, the quality of manufactured housing was unreliable, which resulted in the severe restriction or banning of the housing within several localities.

Under the program, manufacturers who build manufactured homes for sale in the United States are required to follow HUD-mandated design and construction standards. The standards are enforced either through HUD or state administrative agencies that perform reviews of manufacturers' designs, and inspect the homes during their construction to ensure compliance with the standards.

According to 24 CFR 3280, the purpose of the MHCSS is to establish standards for "all equipment and installations in the design, construction, transportation, fire safety, plumbing, heat-producing and electrical systems of manufactured homes which are designed to be used as dwelling units."

The MHCSS established performance requirements for the design and construction of manufactured homes. A manufactured home designed and constructed in accordance with these standards will have a data plate and a certificate label attached to it. The data plate will be affixed in a permanent manner near the main electrical panel or other readily accessible and visible location. The data plate contains the following information:

- The name and address of the home's manufacturing plant
- The serial number and model designation of the unit
- The date it was manufactured

- A list of the certification label numbers that are affixed to each transportable section

- A list of factory-installed equipment, including the manufacturer's name and the model number for each appliance

- Reference to the roof and wind load zones for which the home is designed

The certificate label will be a 2-inch by 4-inch aluminum plate. The plate will be permanently attached to the home on the tail-light end of the home, approximately 1 foot from the floor and 1 foot in from the road side.

Figure 3-3 is a HUD certification plate for manufactured homes constructed between September 1, 1971, and June 14, 1976. Figure 3-4 is a certification plate for homes built after June 15, 1976.

Insert Figure 3-3. Circa 1971 Certification Plate.

Insert Figure 3-4. Certification Plate after June 15, 1976.

Siting and installation requirements for manufactured homes are generally a state or local regulatory responsibility and are not currently within the scope of the MHCSS. Some local and state regulations require licensed or registered installers, and or require permits to be obtained prior to installation. Inspections are often required in conjunction with the permits, to ensure correct installation. The MHCSS does require that installation instructions be included in the owner's manual supplied with each new manufactured home. This requirement is to ensure that the purchaser has the correct procedures available for installing the manufactured home. Typical owner manuals are shown in Figure 3-5.

Figure 3-5. Typical owner manuals.

Most of these current standards of MHCSS do not relate specifically to the installation of manufactured housing. However, there is a section, 24 CFR 3208.306, that deals with the anchoring system of the manufactured housing and is titled, 'Windstorm Protection,' that was added in 1994 after Hurricane Andrew. This section of the regulations requires that the manufacturer provide instructions, including drawings and specifications, detailing at least one acceptable system of anchoring the manufactured home that has been approved by a registered professional engineer or architect (24 CFR 3208.306 (b)). 24 CFR 3208.306 details the requirements for the instructions and stipulates wind loading requirements for design. At this time, the owners' manuals are not required to instruct the designer to consider the forces of floodwaters or seismic loads when designing the foundation system.

Although 24 CFR 3280 is currently in effect, an act passed by the Federal Government in 2000, the Manufactured Housing Improvement Act, requires that HUD adopt a national model installation standard that must be equaled or exceeded by state standards (in states responsible for installation programs) and manufacturers' installation instructions. The Manufactured Housing Consensus Committee was created to help HUD develop the installation standard. The MHCC has finalized its recommendations for a revised standard that, if accepted by HUD, will result in changes from HUD's existing standards.

The MHCC's Model Manufactured Home Installation Standards include requirements for pre-installation and installation considerations, site preparation, foundations, and home installation procedures. Additionally, standards on installation, preparation, and/or testing of optional features, appliances, utility system connections, and life safety features have been incorporated. The standard is designed for adoption and use by authorities who are responsible for the safety and health of manufactured home users. The standards address natural hazards by incorporating the following requirements:

- A section on Installation of Manufactured Homes in Flood Hazard Areas that states that FIRMs must be consulted prior to installation to determine a property's flood risk and identify whether floodplain development permits may be necessary.

- In areas prone to flooding, special elevation and anchoring techniques are required, as well as consultation with a registered professional engineer and local authorities to ensure installation conforms to all applicable codes and regulations.

- Piers, anchoring, and support systems of the foundation in flood hazard areas must be capable of resisting loads associated with design flood and wind events.

- Oil storage tanks in flood hazards areas must be protected from damage by anchoring and elevation or other design.

- Appliances located on the outside of the manufactured home and air inlets must be elevated to or above the design flood elevation (DFE).

- Special requirements for footings and foundations for manufactured home placement in freezing climates.

- The installer is required to secure the manufactured home against the wind according to the authority having jurisdiction's provisions.
- Anchors type requirements (longitudinal) for manufactured homes subject to higher winds (Wind Zones II and III).
- Provisions for maximum diagonal tie-down strap spacing dependent on the wind zone in which the property is located.

The standard can be viewed online at www.nfpa.org/ECommittee/HUDManufacturedHousing/hudmanufacturedhousing.asp.

3.5 State and Local Regulations in Installation

At this time, regulations applying to the installation of manufactured homes in flood hazard areas are inconsistent between states, and there are no comprehensive Federal regulations or guidance. However, there are 37 states participating with HUD in a state and Federal partnership to regulate and enforce the Federal manufactured housing program in their state.

Many state governments regulate all, or part, of the manufactured housing industry in the state. Some areas that may be regulated include retailers, transporters, and installers.

If the state regulates manufactured home installation in flood hazard areas, then clear communication with local governments is necessary to ensure that both state and local agencies understand their responsibilities, and that all elements of floodplain management requirements are being enforced.

For states with state-regulated manufactured home installation, the appropriate state government departments responsible for manufactured housing installation, floodplain management, water resources, building codes, or coastal zone management should be consulted prior to installation of a manufactured home in a flood hazard area.

The new HUD standards will create a baseline standard for manufactured housing installation; it will present the minimum requirements for installation that must be equaled or exceeded by states and are also a minimum requirement for manufacturers' installation instructions. Therefore, although some state agencies will still be responsible for permitting and inspecting manufactured home installation, there will be a minimum standard in place that has not been available before.

Each state also has designated a state-coordinating agency to assist in the implementation of the NFIP. This agency is a focal point for information on flood insurance, floodplain management, and coordination of the diverse state agencies with responsibilities for riverine and coastal

Example

STATE MANUFACUTRED HOME INSTALLATION REGULATIONS

In Florida, the State Department of Highway Safety and Motor Vehicles (HSMV) regulates manufactured housing installation on a statewide basis. Under HSMV's rules, Chapter 15C-1, manufactured housing installation and foundation component requirements are presented.

Materials to be used in the installation of manufactured homes must be HSMV approved. HSMV's Bureau of Mobile Home and Recreational Vehicle Construction lists approved products on their website at casey.hsmv.state.fl.us/Intranet/dmv/Forms/BMHRV/ANCHLIST.pdf

The state also requires that individuals and dealers that install and/or set-up manufactured housing must be licensed by the HSMV. Installers are required to take a pre-licensure course and pass an exam before being licensed.

On a local level, permits are required to set-up manufactured housing and must be obtained from local building permitting or zoning offices.

floodplains. A listing of state coordinating agencies is included in Appendix B.

The authority of each state's coordinating agency varies and can best be determined through direct contact. These agencies can be important sources of physical data, information on community eligibility for flood insurance, state regulations, references to other agencies, and, in some instances, technical assistance.

Local governments play the key role in floodplain management. Most local jurisdictions have specific zoning ordinances and regulations pertaining to manufactured homes and manufacture home developments. In addition, they can provide sources of flood hazard data and other regulatory information. Local offices that may be of assistance include Departments or Offices of Public Works, Building, Engineering, Zoning, and Planning.

3.6 Building Code Requirements

Building codes are also beginning to specifically address manufactured housing installation. Two of the major building codes within the U.S. today are the International Code Council's (ICC) International Code Series, and the National Fire Protection Association's code titled NFPA 5000 - Building Construction and Safety Code. The International Code Series includes the International Residential Code for 2003 (IRC 2003), which applies to one- and two-family dwellings.

3.6.1 IRC 2003

The IRC 2003 is a comprehensive residential building code that includes provisions for development in the SFHAs that meet the minimum requirements of the NFIP. In IRC 2003, many of these provisions are included as Section R323, which is titled Flood-Resistant Construction. This section includes requirements for elevation, flood-resistant materials, and enclosures below the BFE for structures located in the SFHAs, all of which mirror basic NFIP requirements.

The IRC 2003 contains a section specifically dedicated to Manufactured Housing Used as Dwellings, Appendix E. Section 502 of this appendix describes requirements for Foundation Systems, which, in part, refer to the general provisions of the code. Under the IRC, all footings for manufactured housing shall:

- Extend below the frost line.
- Be constructed of materials specified by the code, including masonry and concrete.
- Be made of solid material (concrete and masonry footings).

- Be designed in accordance with seismic specifications, including minimum reinforcement near the bottom of the footing, and specifications on joints between footings and stem walls if located in a Seismic Design Category D_1 or D_2 area.

Appendix E of the IRC 2003 also details requirements for anchorage installation. According to the code, anchor load requirements are as follows:

- The manufacturer's installation directions should provide preload requirements and load capacity for various soil types.

- Approved ground anchors must be capable of resisting at least 3,150 pounds in the direction of the tie plus a 50 percent overload or 4,725 pounds.

Finally, a section titled Ties, Materials, and Installation is AE605 in Appendix E and describes materials to be used for ties. Ties must be:

- Fastened to ground anchors with turnbuckles or other adjustable tensioning devices, and

- Capable of resisting a working load of 3,150 pounds with less than a 2 percent elongation, and a 50 percent overload of 4,725 pounds.

3.6.2 NFPA 5000

NFPA 5000's Chapter 39 describes Flood Resistant Construction and includes many of the minimum NFIP requirements. According to the code, manufactured housing located in the flood hazard area must adhere to the following requirements:

- Foundations must be designed and constructed as required by SEI/ASCE 24, Flood Resistant Design and Construction.

- In flood areas subject to high velocity wave action, structural fill, slabs-on-ground, and foundation walls are prohibited.

- The lowest floor of the structure must be elevated to or above the design flood elevation.

- Manufactured homes must be installed using methods that minimize flood damage and shall be securely anchored to a foundation (meeting the requirements of SEI/ASCE 24). These requirements are in addition to the manufacturer's specifications and state and local anchoring requirements for resistance to wind.

- Where temporary structures are proposed, the permitting authority must consider flood warning time as well as the location of the structure in relation to any floodways, alluvial fan areas, or high velocity wave action areas before granting a permit.

NFPA 5000 also dictates that the resource ASCE-7, *Minimum Design Loads for Buildings and Other Structures*, is to be used to determine the design loads associated with wind, seismic, snow, and ice events. The code states that all buildings and other structures shall be designed to resist these design loads.

Chapter 4: Site and Development Options

Site evaluation is a critical step in the decision-making process of installing a manufactured home. If done properly, site evaluation can substantially minimize the likelihood of a home being damaged by flooding and other natural hazards. A complete and detailed understanding of the advantages and disadvantages of potential sites for manufactured home installation helps lead to informed decisions; not all sites are suitable for development.

Siting and development decisions are sometimes made without proper consideration of a property's vulnerability to flooding and other hazards. An accurate assessment of the property's hazard vulnerability should be made prior to siting and development, but ideally before a piece of property is purchased, especially if development is the only intended use for it. By conducting such an assessment, a property owner or developer will help to prevent some of the following types of damage, losses, and associated problems:

- Injuries and loss of life
- Damage or loss to buildings
- Damage to attendant infrastructure
- The need for emergency evacuation

A thorough evaluation of property for development purposes is completed through a five-step process:

1. Compile lot/parcel information for one or more candidate properties, and, for each property, follow steps 2 through 5 below.

2. Review information for basic siting and development to determine if local, regional, state, and Federal regulatory requirements allow the development and installation of a manufactured home.

3. Conduct a hazards analysis and risk assessment.

4. Determine whether the hazards can be mitigated through siting, design, or construction and whether the residual risks to the site and the building are acceptable.

5. Proceed either with the purchase or development of a property, or reject the candidate properties, and find and evaluate other properties.

During the data/information collection process, a variety of information is gathered that relates to basic siting as well as to the hazard analysis portion of the process. After collecting basic information about the property (e.g., the lot size, zoning and land use requirements, and utility and infrastructure availability), the potential property owner or developer can determine if these property characteristics lend themselves to development. If it is determined that development is feasible, the potential property owner would then conduct steps 3 and 4 of the process to assess the property's hazard vulnerability.

Taking the results of the data/information review into consideration, a determination about development of the property becomes the last step in the siting evaluation process. Is the property suitable for development and for the installation of a manufactured home? If the basic siting review shows that the property is developable, and a hazard analysis and risk assessment also indicates development may be feasible, then the proposed construction must be designed and constructed to adequately resist the hazard threat. If the proposed site will allow for all of the requirements, the site can be considered suitable for manufactured home installation. These steps are basic to siting so that a manufactured home on the site meets all local, regional, state, and Federal requirements, including hazard-resistant construction requirements.

4.1 Compiling Site Information

After a site for possible purchase and/or development has been identified, basic information about the site is collected for a development analysis. It is vital that all pertinent information is collected in order to complete a thorough analysis.

Community building permitting or planning and zoning offices are often helpful in steering potential property buyers toward information they need to evaluate a property. This is true of individuals looking at isolated lots or lots within existing subdivisions, as well as developers and planners interested in manufactured home subdivision development. A checklist of information to be collected is provided in Table 4-1. Not all of this information will be available for all sites and properties.

Although much of the information listed in Table 4-1 will need to be obtained locally, state and Federal Government resources can also be useful. Table 4-2 presents a listing of the most likely resource (i.e., local, state, or Federal Government) for obtaining specific information.

Table 4-1. Information Checklist

PROPERTY LOCATION	
Municipal, township, county, or other local jurisdiction Street Address Parcel designation (e.g., tax map ID) Subdivision information Special zoning or land use districts	Flood-prone area designation Seismic hazard area designation High wind area designation Other hazards areas Natural resource protection area designation
PROPERTY DIMENSIONS	
Total acreage Property shape Property elevations and topography Location relative to adjacent properties; configuration of adjacent properties	Acreage outside of designated floodplain area or other hazard-prone area Acreage landward/outside of natural, physical, or regulatory construction or development limits (i.e., usable acreage)
LEGAL AND REGULATORY INFORMATION	
Land use designation at property and adjacent properties Zoning classification and resulting restrictions on use Building code and local amendments Flood hazard area: elevation and construction requirements Erosion hazard area: construction setback and regulations Natural resource protection area: siting, construction, or use restrictions Easements and rights-of-way on property (including beach access locations for nearby properties or the general public) Local/state siting and construction regulations	Regulatory front, back, and side setbacks Local/state permitting procedures and requirements Local/state regulations regarding use, construction, and repair of erosion control measures Riparian rights Local/state restrictions on cumulative repairs or improvements Conditions or other requirements attached to building or zoning permits Subdivision plat covenants and other restrictions imposed by developers and homeowners' associations Hazard disclosure requirements for property transfer, including geologic hazard reports
PHYSICAL AND NATURAL CHARACTERISTICS	
Soils, geology, and vegetation – site and region Site drainage – surface water and groundwater Storm, erosion, and hazard history of property Development/potential flood debris upstream and adjacent to property Erosion control structure on site: type, age, condition, and history	Proximity to inlets and navigation structures Previous or planned community/regional beach/dune restoration projects (coastal) Relative sea-level/water-level changes – land subsidence or uplift (coastal) Wind missile hazards – telephone poles, trees
INFRASTRUCTURE AND SUPPORTING DEVELOPMENT	
Access road(s) Emergency evacuation route(s) Electric, gas, water, telephone, and other utilities – on-site or off-site lines and hookup	Sewer or septic Limitations imposed by utility, infrastructure locations on property use
FINANCIAL CONSIDERATIONS	
Intended use: owner-occupied or rental property Real estate taxes Development impact fees Permit fees Hazard insurance: availability, premiums, deductibles, and exclusions Property management fees	Special assessments for community/association projects (e.g., private roads and facilities) Maintenance and repair of private erosion control structures Increased building maintenance and repairs in areas subject to high winds or wind-driven rain Building damage costs (insured and uninsured) from previous storms, floods, and other hazard events

Table 4-2. Local, Regional, and State Responsibilities

Local	Regional	State
• Building Permitting	• Deeds and Property Records	• Building Codes and Standards
• Deeds and Property Records	• Emergency Management	• Coastal Zone Management
• Emergency Management	• Environmental Protection	• Emergency Management
• Environmental Protection	• Geographic Information Systems	• Floodplain Management
• Floodplain Management	• Health	• Geologic Survey
• Municipal Engineering	• Planning and Zoning	• Natural Resource Management
• Planning and Zoning	• Post-storm Damage Assessments	• Post-storm Damage Assessments
• Soil and Geology	• Soil and Geology	
• Subdivision Review	• Subdivision Review	
• Tax Assessor	• Tax Assessor	
• Utilities	• Utilities	

4.2 Basic Siting Review

After collecting pertinent site information, a thorough review of the information is necessary to ensure that development of the site is feasible. Particularly, requirements per the building codes and planning and zoning codes should be checked early in the evaluation process to ensure that development of the property with installation of a manufactured home is possible for the given property. After a basic siting review has been performed, a hazards analysis and risk assessment should be conducted.

4.3 Hazards Analysis and Risk Assessment

A hazard analysis and risk assessment is performed by determining what types of hazards exist for a particular area or site, and then evaluating the risk level for that site. It is important to consider flooding in this analysis as well as other hazards such as dam failure, land subsidence, seismic hazards, and severe wind.

For community wide assessments, there are several FEMA tools available for use to conduct a Hazards Analysis and Risk Assessment, including the FEMA software Hazards U.S. – Multi-Hazard (HAZUS-MH) and

Mitigation Planning How-to Guides (FEMA 386). Under the Disaster Mitigation Act of 2000 (DMA 2000) communities are required to complete hazard mitigation plans, which include a hazard identification and risk assessment section, should they wish to remain eligible for post-disaster mitigation funding. As a result, many regional and local governments have already used tools like HAZUS-MH and the *How-to Guides* to conduct their own risk assessments, which may be available for review.

HAZUS-MH runs on an ArcGIS platform and allows users to determine a variety of risk information, including an area's vulnerability to flooding, seismic events, and hurricane winds. The *Planning How-to Guides* provide a step by step process for conducting a hazard identification and risk assessment and provide links to important sources for information, including nationwide vulnerability mapping.

4.3.1 Flooding

Table 4-3 provides a list of the types of hazards that can result from by flooding and the flood sources or types of flood-prone areas where they are generally of concern. In addition, some non-flood related hazards are presented in Table 4-3.

Table 4-3. Flood Hazards

Flood Hazard	Associated Flood Hazard Areas or Property Characteristics
Long duration flooding	Large water bodies • rivers • oceans • bays Water bodies with slow drainage • lakes • ponds
Inadequate storm drainage	Flat or poorly graded land Land located directly adjacent to a flood source
Impact forces	Coastal areas subject to wave action flooding Riverine flooding areas subject to high velocity flooding
High velocity flows	Coastal areas subject to wave action Steeply-sloped riverine flooding areas or areas otherwise subject to high velocity flood flows

Erosion	Coastal areas subject to wave action Steeply-sloped riverine areas with high velocity flood flows or areas otherwise subject to high velocity flood flows
Sediment deposition	Coastal overwash areas
Movable stream beds	Dynamic river systems
Flood depth	Areas adjacent to the flood source Areas with poor capacity for drainage

Two of the best sources to research a property's susceptibility to flooding are the community's Flood Insurance Rate Map and Flood Insurance Study. A FIRM is a map developed by the NFIP for a particular community that must be reviewed and then accepted by the community. Once accepted, it becomes the official regulatory tool used to determine flood-prone areas where floodplain development regulations apply. The FIRM shows the extent of the 1 percent annual chance flood, and might also include flooding corresponding to the 0.2 percent annual chance flood (also known as the 500-year flood). For areas where detailed studies have been performed, FIRMs will also show BFEs along streams and may provide delineations of floodways.

A FIS summarizes the methods used to develop the hydrologic and hydraulic studies, which together determine the extent of the 1 percent annual chance floodplain. The FIS also presents a summary of results of the study, including information about floodwater surface elevations and velocities for detailed study areas.

The FIRM is used in conjunction with the FIS to determine the flood risk for a given area or piece of property. If the property is located in the base floodplain where a detailed study has been performed, the FIRM and FIS will provide the following valuable information: [WILL INSERT SCREEN SHOTS OF FIRM, FIS PROFILES, AND TABLES]

- The elevation of a base flood at a site as well as elevations for the 10-, 50- and 500-year floods
- The average velocity of floodwaters within the floodway for a base flood (where a floodway study was performed)
- Areas of coastal wave action flooding

- Riverine flooding areas
- Areas susceptible to ponding
- Areas susceptible to sheet flow or alluvial fan flooding
- Areas protected by U.S. Army Corps of Engineers (USACE) approved levees

In addition, information about an area's susceptibility to flooding can often be gathered from community officials and past storm event records and reports. Such reports usually provide information about what types of damage were inflicted on structures. For coastal areas, there may be information about beach and shoreline erosion after a major storm event.

A field assessment for a particular site is a way to collect information for a hazard analysis. Information gathered during a field visit (ideally conducted by a geologist or an engineer) can help to assess what type of impact such forces can have on a structure built on a site. This is determined by assessing what type of structures and potential debris are located upstream and adjacent to the property that have the potential to impact the structure during a flood event. A field assessment can also be conducted to estimate the erosion potential for a site by investigating existing land slopes on the site as well as vegetation cover. Finally, the site's grading/topography should be evaluated. As part of the assessment, it should be determined whether or not the site will drain in a reasonable amount of time in order to prevent long duration flooding. This issue is generally only relevant for smaller storm events or more localized flooding for which floodwaters have somewhere to drain.

4.3.2 Accessibility

Not only should the flood susceptibility of the actual site for the manufactured home be determined, but the flood susceptibility of the access path to and from the site should also be assessed. Inhabitants of structures in flood-prone areas should always be ready to evacuate an area should a flood warning be issued by the local or state government and should not wait for flood conditions to begin before evacuating the area. In fact, drowning in vehicles is the number one cause of flood deaths. A car can float in less than 2 feet of moving water and it can be swept downstream into deeper waters. Victims of floods often put themselves in perilous situations by mistakenly thinking that a washed-out roadway or bridge is still open. Therefore, accessibility to manufactured housing during flood events needs to be considered during the siting process. Potential property buyers or property owners should assess possible evacuation routes from the property and determine if they are above the anticipated flood levels.

Actual damage to roadways during flood events, as well as high-wind, seismic, and land subsidence events, can leave roads impassable for several days or even for weeks after a major disaster. Even roadways that are located outside of, but adjacent to flood-prone areas can be affected by flood events because flood flows can undermine roadways by causing severe erosion along stream banks.

Similarly, accessibility to potential sites after major wind and seismic events should be considered. If immediate accessibility is needed to and from a site located in an area prone to damage from a wind or seismic event, the potential buyer should seriously consider whether or not to develop the site. After wind and seismic events, roadways can be blocked by debris and remain unusable for several days while cleanup efforts are underway.

4.4 Other Hazards

In addition to flooding, there are a variety of other hazards that should be considered during the siting process. Table 4-4 presents some of these hazards for consideration and their associated hazard-prone areas.

Table 4-4. Hazard-prone Areas

Hazards	Associated Hazard Areas	Source for Determination
Dam failure	Dam failure inundation areas located downstream of dam structures	Dam failure inundation maps usually created at the state, regional or local level
Land subsidence	Steeply sloped land	USGS Landslide National Map
Seismic	Areas along fault lines	USGS Seismic Maps Building Codes
debris	Coastal areas Tornado-prone areas	Wind Zone Maps (as found in FEMA 320) Building Codes

Sources to use to determine an area's susceptibility to dam failure, land subsidence, seismic events, or severe winds are also provided in the table. Additionally, historical storm or hazard event records are also good resources for determining risk vulnerability.

Dam failure inundation maps provide the best tool for determining the risk from a dam failure event and are usually available at the state or local level. Every state has a Dam Safety Officer responsible for coordinating the state's Dam Safety Program. State-specific information about state dam safety regulations is available at the Association of State Dam Safety Official's web site - www.damsafety.org.

To avoid damage that can be caused in areas subject to land subsidence, structures should be sited away from steep slopes and areas where land subsidence has been known to occur in the past.

Generally, coastal areas are susceptible to high winds from storm and hurricane events. Areas of seismic activity are well documented and local government officials are usually aware of the seismic threat for a particular area. A good reference to determine the susceptibility of a property to wind and seismic hazards is the ASCE-7 Minimum Design Loads for Buildings and Other Structures document. ASCE-7 provides maps that show the risk of wind and seismic activity for the entire United States and details design considerations for areas based on the risk posed by these hazards.

Wind contour line maps show the nominal design 3-second gust wind speeds, which are important design considerations, but also show relative to one and other the areas subject to the greatest threat of wind damage. Similarly, seismic risk is mapped as the maximum considered ground motion (for 0.2 second and 1.0 second spectral response accelerations) for a given geographic area. Susceptibility to seismic damage is also dependent on the site's soil type.

For properties sited in high-wind hazard areas, it is important to consider what type of physical features on the property could pose a serious threat to a structure. Questions like what is the design wind speed? Can manufactured homes withstand this wind speed (i.e., what is the maximum wind speed that they can withstand?)? What types of measures are needed to make it possible? Consideration of attendant utilities and infrastructure during a windstorm is also important. During wind events, large structures or items such as trees and telephone poles can be damaged and either collapse or become separated from their anchoring to the ground so that they become sizable pieces of debris. Buildings should generally be sited away from or in a manner that provides protection from such items because debris can be sent airborne and act as missiles during a wind event.

For seismic events, the manufactured home should be designed to withstand the forces expected from a design seismic event for the region. In addition, large items such as trees and telephone poles can be damaged by a seismic event and possibly collapse, impacting nearby structures.

4.5 Mitigating the Hazards

Although the best way to avoid damage to a manufactured home is to site the home away from areas susceptible to hazards, if it is sited in or near a hazard-prone area, two aspects should be considered during the siting process:

- Placement options
- Construction techniques for mitigation

4.5.1 Placement Options

One way to develop a flood-prone property without exposing buildings and attendant infrastructure to flood damages is to site the building beyond the limits of the floodplain. Of course, this is only an option if a portion of the property suitable for development is actually located outside of the floodplain. This portion of the property will have higher ground elevations and will thus be better protected from floodwaters. For properties located entirely within the flood-prone area, this method is not an option.

Another option for siting in flood-prone areas is to determine if there are portions of the property that, while susceptible to flooding, are not exposed to some of the more destructive characteristics of flooding like long duration flooding, high flood levels, and higher velocity flows.

Generally, within a flood area, the further a building is sited from the flood source, the less likely it is to experience high velocity flows. Within riverine flooding areas, the highest velocity flows are usually recorded within and near the floodway. In areas vulnerable to coastal flooding, wave action and/or storm surge can cause floodwaters to be particularly destructive. These types of forces are the strongest in FEMA high hazard coastal zones labeled as V zones on FIRMs.

Similarly, flood levels usually decrease as the distance from the flood source increases. Setbacks from the flood source help to keep structures out of areas most susceptible to high velocity and high depth flooding. Damage to structures is directly related to the depth of floodwaters to which they are exposed; a well-documented relationship between flood depths and flood damage is used to estimate damages to structures for given flood events. FEMA Depth Damage Functions were developed by the Federal Insurance Administration (FIA) and are based on data from several million flood damage claims. The functions correlate dollar value of damage expected to given depths of flooding. These functions vary based on the type and use of the structure.

Additionally, higher floodwaters make access to and from structures difficult both during and after a flood event and greatly increase the safety hazards of flooding. For this reason, development in the floodplain is strongly discouraged within areas of higher depth flooding (greater than 2-3 feet).

Long duration flooding is generally dependent on the flood source and the type of flood event (e.g., hurricane, snow melt event). Areas most prone to long duration flooding are those located along larger water bodies (including larger rivers and seas, oceans and bays), and areas exposed to storms with long duration precipitation (e.g., hurricanes and northeasters).

INCLUDE PICTURES OF PAST FLOODING – LONG DURATION EVENTS – SUSQUEHANNA DURING AGNES?

Figure 4-1 shows a floodplain/floodway schematic. The floodway is generally the area where floodwaters are deepest and have the fastest flow rate. Development in the floodway is discouraged through floodplain management regulations and, in some communities, it is prohibited. Under minimum NFIP regulations, in order to place a new structure within the floodway, a floodplain development permit applicant must show that the development will not result in any increase to the 1 percent annual chance flood elevation. Because this type of development almost always results in a water surface elevation increase, development in the floodway is discouraged by most communities and, in some cases, it is prohibited.

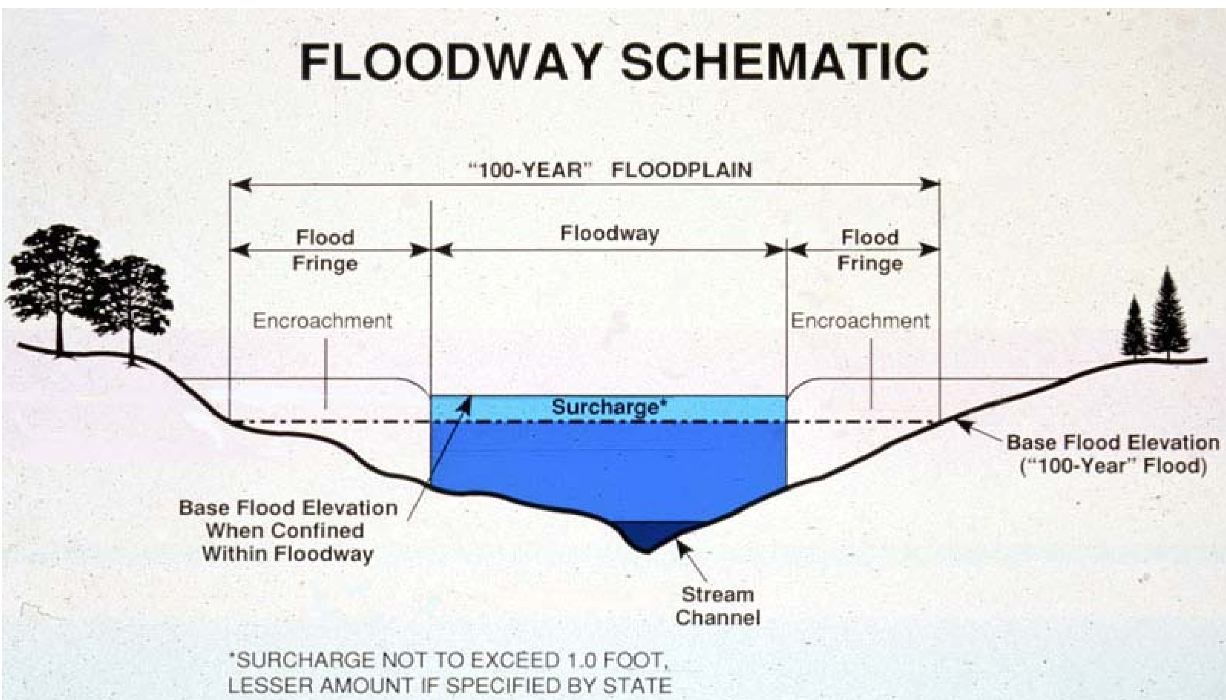


Figure 4-1. Floodway schematic.

4.5.2 Design and Construction Techniques

Chapter 8 of this manual provides methods for design and construction of manufactured housing and its installation in flood-prone areas to mitigate against flood hazards as well as hazards associated with wind and seismic events. A thorough review of these measures and their applicability and feasibility is another consideration in the evaluation of site alternatives. A site located in the Special Flood Hazard Area is deemed not suitable for development if mitigation methods cannot be implemented at the site. Ideally, all development would occur outside of the SFHA; however, all construction, including the installation of manufactured homes, in the SFHA, must be built and installed to resist damage from flooding. Some questions for consideration in determining if design and construction techniques to prevent flood damage are feasible for a particular site follow:

- Can a manufactured home be installed to an adequate level above the base flood level through the use of fill and/or foundation design? How high above grade is the base flood level?

- Can the manufactured home's foundation be designed and constructed (within budget) to withstand the expected design velocity flows? If fill is planned for use at the site, will it withstand forces from velocity flows?

- Can adequate storm drainage be designed?

- Can a foundation be designed and constructed (within budget) that will be able to resist long duration floodwaters if they are an issue at the site?

4.6 Conclusions

There are several issues to consider in analyzing a site for manufactured home installation including community regulations, physical and natural characteristics of the property, availability of utility connections, financial considerations, and the site's vulnerability to natural hazards. Although there are sometimes options for dealing with obstacles and problems pertaining to the property, including mitigation measures to prevent damages from natural hazards, there will be some properties that simply do not provide viable options for manufactured home installation. A property could be unsuitable for several reasons, including:

- Zoning regulations.

- Excessive costs are associated with installing the home to meet local and state regulations, including floodplain development regulations.

- Flooding at the site is likely to be high velocity and/or over 3 feet in depth.

- Other natural hazards such as erosion or high winds pose a significant threat to the site.

Chapter 5:

Natural Hazards - Design Considerations

Many areas in the United States are vulnerable to more than one type of natural hazard. For example, some coastal areas can be subjected to severe flooding and wind events simultaneously. Manufactured homes located in floodplains should not only be designed to withstand flood loads, but wind and earthquake (if appropriate) loading also have to be considered. Wind and earthquake loads on a structure will probably increase when the structure is elevated to mitigate flood damage. This chapter describes all the natural hazards (flood, wind, and earthquake) that must be considered when making decisions about siting and selecting a foundation system for a manufactured home. Additional guidance on determining flood hazards is provided as Appendix C.

5.1 Flood Forces From Standing or Slowly Moving Floodwater

5.1.1 Frequency and Duration

Frequency of flooding is the rate of occurrence of floods at a particular location. It is a primary consideration in selecting the installation site. This is the probability, expressed as a percentage, that a flood of a specific size on a specific stream will be equaled or exceeded in any year. For example, the flood that has a 1-percent probability (1 in 100) of being equaled or exceeded in any year is referred to as the 100-year flood. This term is simply a convenient way to express probability.

These frequency terms indicate relative frequencies and sizes for comparing flood events. A 100-year flood is expected to occur less often than a 50-year flood and more often than a 500-year flood. At the same point along the same flooding source, such as a river, ocean, or bay, a 100-year flood will have a higher flood elevation than a 50-year flood and a lower flood elevation than a 500-year flood. The 100-year flood is particularly important for homeowners because it is the basis of NFIP flood insurance rates and regulatory floodplain management requirements.

It is important to note that a 100-year flood is a probability term and does not mean that the flood will happen exactly once every 100 years. Nor does it imply that once a 100-year flood occurs, there is little chance of another 100-year flood occurring in the near future. To the contrary, changes in climatic conditions, such as those caused by El Nino, often result in a cluster of floods that occur over relatively short times at the same location.

Repeated occurrence of flooding over time, even when a single event does not result in the total loss of a manufactured home, can produce a cumulative wear-and-tear effect on a typical installation. Flood frequency data are useful in the design of foundation and elevating systems in that they comprise an essential element in formulating assumptions as to how often these systems will be exposed to flood forces.

Information about the 100-year flood (also called the base flood) can be found in the FIS and the FIRM, including the flood elevation and the extent of flooding. In areas where detailed studies have been performed, flood elevation information may also be available for the more frequent 10- and 50-year floods as well as the less frequently occurring 500-year flood.

For historical flood events, flood frequency estimations can sometimes be found in the FIS in the Principal Flood Problems section. Documentation of past flood events that may include estimated frequencies are sometimes available from other Federal sources as well as state and local agencies. A list of such sources and agencies is presented in Table 5-1.

Table 5-1. Sources for Information about Past Flood Events

Other Federal Sources	State Agencies	Local or Regional Agencies
USACE Floodplain Information Reports	Departments of Environmental Conservation/Protection	Flood Control Districts
USGS Water Resources Investigations	Departments of Floodplain Management	Levee Improvement Districts
Natural Resources Conservation Service (NRCS) Watershed Studies	Departments of Natural Resources	Local Planning Commissions
Federal Highway Administration (FHA) Floodplain Studies	Departments of Transportation	Local Public Works Departments
Tennessee Valley Authority (TVA) Floodplain Studies	Departments of Water Resources	Municipal Utility Districts
	Geologic Surveys	River Basin Commissions
		Water Control Boards

The duration of a flood is the amount of time from inundation of an area to the recession of floodwaters. Duration influences how long the manufactured home and its foundation will be subjected to pressures and forces exerted by floodwater, the strength of soils and building materials, the degree of floodwater seepage, and the length of time that a structure may be inaccessible. For identical flood depths and velocities, long duration flooding is usually much more destructive that short duration flooding.

An important design consideration related to duration is that, even if the manufactured homes are not damaged, people can still be out of their homes for an extended period of time if there is long duration flooding. It is one thing to have water in the park or covering the site for a day or so every 10 years. It is quite another to have the park or site under water for 2 weeks at a time.

Rate of rise is a measure of how rapidly water depths increase during flooding. A slow rise of floodwaters will allow seepage of water into a manufactured home, thereby counteracting uplift forces. When water rises rapidly, the balance between seepage and the uplift forces will not occur in time. This will result in buoyancy or failure of the manufactured home floor.

Water that rises more rapidly, such as areas of steep terrain, will recede more rapidly and water that rises more slowly, such as gently sloping floodplains, will recede more slowly. The rate of rise and fall also affects how much warning there will be of an impending flood. For example, homeowners in the floodplains of large rivers like the Mississippi may know days in advance that flooding is occurring upstream and will eventually reach their homes. But in the floodplains of streams with high rates of rise, the occupants may have only a few hours' notice of an approaching flood or perhaps none at all. This is important in planning for emergency evacuation and in determining the feasibility of emergency loss mitigation procedures.

Although surrounding terrain is a good indicator, flooding duration for particular areas is best determined from historical data and accounts of past flood events. This information might be available locally from accounts given by homeowners and local emergency management staff, or it may be documented in the FIS or local, state, or Federal studies. See Table 5-1 for a list of potential sources of information.

5.1.2 Flood Elevation and Depth

The base flood elevation is the elevation of the flooding, including wave height, having a 1 percent chance of being equaled or exceeded in any given year. The probability of 1 percent chance is the same as the 100-year flood. The elevation of the flooding is the height of the floodwater above or below an established reference datum. Ground elevation is the height of the ground surface above or below an established reference datum. The standard datums used by most Federal agencies and many state and local agencies are the National Geodetic Vertical Datum (NGVD) of 1929, and the North American Vertical Datum (NAVD) of 1988; however, other datums are in use. Ground elevations are established by surveys; flood elevations are calculated for a particular flood event.

BFEs associated with particular flood events can be found on Flood Insurance Rate Map panels. Figure 5-1 shows an example of a FIRM. If the manufactured home is to be installed at point 1 (red box), the home is located in an AE flood zone and has a BFE of 9 feet.

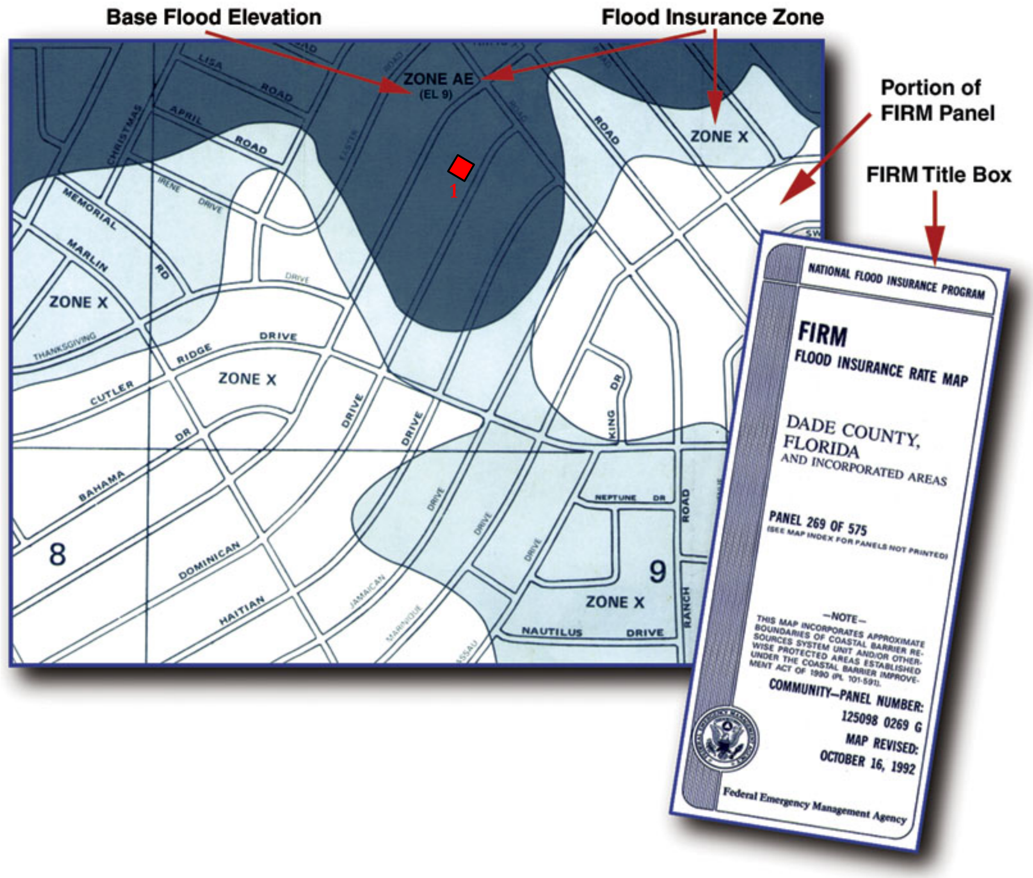


Figure 5-1. Example of a FIRM.

Flood depth is the difference between the water surface elevation at the time of flooding and the normal grade elevation of the flooded area. For example, if the BFE and the ground elevation are based on the same datum, the flood depth at any point is equal to the flood elevation minus the ground elevation at that point (see Figure 5-2). Flood depth is a very important consideration when elevating a manufactured home.

Design flood elevation (DFE). The elevation to which development in the regulatory floodplain is built. The minimum requirement for this elevation in NFIP communities is the 100-year flood water surface elevation (BFE). In areas where a higher degree of protection is promoted or required, a freeboard is added; in this case the DFE is some height (1, 2, or more feet) higher than the BFE.

As stated in Chapter 3, for existing manufactured home parks, the NFIP requires the lowest floor to be elevated to or above the BFE, or to be supported by foundation elements that are no less than 36 inches in height above grade (also referred to as the “3-foot rule”). For V-Zones, the bottom of the lowest horizontal structural member is considered the lowest floor of a manufactured home. In conventional manufactured home construction, the bottom of the lowest structural member of the lowest floor is the same as the bottom of the chassis (Figure 5-2).

Some communities may adopt more stringent requirements calling for an additional elevation requirement some height above the BFE; this additional height, called freeboard, added to the BFE is the design flood elevation. Freeboard provides a margin of safety above the estimated 100-year flood and against extraordinary or unknown risks. As in all natural hazard events, the design event can only be predicted in probabilistic terms and some uncertainties remain in any analysis. Freeboard is intended to allow for those uncertainties.

Adopting more stringent flood requirements makes a community less vulnerable to flooding and can make the community eligible for lower flood insurance rates. Check with your local floodplain manager, building inspector, or zoning office for any freeboard requirements adopted by your community.

In areas labeled as approximate 100-year flood zones (A and V) where no BFE has been determined, an acceptable level of protection is defined by the local ordinance. However, communities are required to obtain, review, and reasonably utilize BFE and floodway data from a Federal, state, or other source that has developed such data.

If no such data exist, for development of 5 acres or 50 lots (whichever is the lesser), the developer must perform a detailed hydraulic study to determine the BFE. For other sites and smaller developments, the community is encouraged to conduct a detailed study or have the applicant conduct one; however, it is not required.

NFIP guidance found in FEMA's publication, *The Zone A Manual: Managing Floodplain Development in Approximate Zone A Areas* suggests other methods for determining an appropriate DFE. These methods cannot be used to determine the BFE for an elevation certificate or insurance rating, but are meant for floodplain management purposes only. They include the following:

- Existing topography data can be used along with the approximate 100-year floodplain depicted on the FIRM to estimate the elevation of the floodplain boundary and thus the floodplain elevation. This is called the point on boundary method or contour interpolation.

- If the site is within 500 feet upstream of a detailed studied portion of a stream, and floodplain and channel bottom slope characteristics are relatively similar, data extrapolation can be used to estimate the BFE. The flood profile from the FIS can be used to extrapolate this information.

Other methods that can be used to estimate a DFE include:

- A BFE can be estimated using FEMA's Quick 2 software where hydrologic information and limited topography data are needed.

- High water marks for floods - High water elevations and frequency estimates for major floods should be available from the local jurisdiction, especially for more recent floods, or from state or Federal publications documenting historic floods.

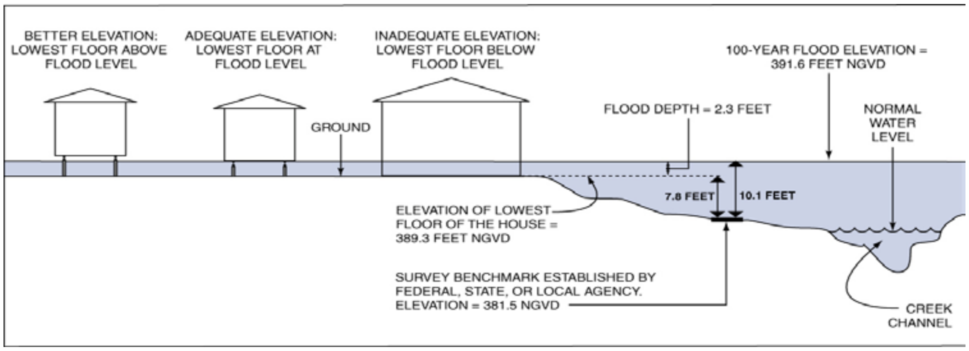


Figure 5-2. Relationship of BFE, flood depth, and datum.

5.1.3 Hydrostatic Forces

When a body or a structure is immersed in water, the body is subjected to forces exerted by the surrounding water. These forces are called "hydrostatic" forces. Hydrostatic forces are caused by water either above or below the ground surface that is essentially stagnant. A direct relationship exists between flood depth and amount of hydrostatic pressure. Greater depths of water exert greater pressures on a structure.

Hydrostatic pressures are equal in all directions and always act perpendicular to the surface on which they are applied. Hydrostatic pressures can lift a manufactured home off its foundation. This is particularly true for fast rising floodwaters where insufficient time exists for floodwaters to seep into a home and reduce buoyancy forces.

The lateral force of water acting against a surface is related to the water's depth and specific weight. During a flooding condition, water against a manufactured home creates a hydrostatic pressure distribution as follows:

$$p = w \; x \; h$$

where: p = pressure in pounds per square foot

w = specific weight of water – 62.4 pounds per cubic foot

h = depth of water in feet

The resultant lateral hydrostatic force acting per linear foot on the submerged portion of the manufactured home is the total area of the pressure distribution given by:

$$F_l = 1/2 p \; x \; h \quad = 1/2 \; w \; x \; h^2$$

where: F_l = lateral force in pounds per linear foot

h = water depth

Hydrostatic pressures create triangular loading on vertical surfaces. Lateral pressures range from 0 psf at the water surface to w*x*h psf at a depth of h feet. For analysis purposes, the triangular loading can be replaced with a point load acting at a point 2/3h down from the water surface. Table 5-1 lists the equivalent lateral forces (in pound per linear foot) and points at which the forces act (in inches) for various water depths.

Table 5-2. Lateral Forces (F_l)

	Depth of Water (inches)													
	1	**2**	**3**	**4**	**5**	**6**	**9**	**12**	**15**	**18**	**24**	**30**	**36**	**48**
F_l	0.22	0.87	1.95	3.47	5.42	7.80	17.55	31.20	48.75	70.20	124.80	195.00	280.80	499.20
c	0.67	1.33	2.00	2.67	3.33	4.00	6.00	8.00	10.00	12.00	16.00	20.00	24.00	32.00

F_l = ½ w x h ^{2} (pounds / linear foot)

w = 62.4 pounds / cubic foot

h = water depth in feet

c = Depth (inches) where equivalent force F_l acts (2/3h). Depth is measured down from the water surface.

5.1.4 Buoyancy

Any object, wholly or partially immersed in a liquid, is buoyed by a force equal to the weight of the fluid displaced by the object. This force is the buoyancy force. If a manufactured home is located below the BFE, in the event of flooding, the home floor will be subjected to buoyancy forces from the floodwater (see Figure 5-3).

If the floods create buoyancy forces that are greater than the weight of a manufactured home, the home will float off its foundation unless it is securely fastened to a foundation that can adequately resist the buoyant forces. Floods do not need to be deep to displace a home. During rapidly rising flood events when only minor amounts of water have time to seep into a home, flood depths of only 4 to 5 inches can float a home off of its foundation.

If a home is elevated above the BFE, it is unlikely that the home will be subjected to buoyancy forces during a 100-year flood design event. For this reason, care must be exercised in using the 3-foot rule. If the 3-foot rule is used in design, the floor and its foundation must be designed to resist buoyancy forces.

The walls and floors of manufactured homes (and most site built homes for that matter) are not designed to resist hydrostatic forces due to flooding. After the hydrostatic forces exceed the strength of a home's walls, floors, or foundations, they can cause extensive structural damage. Since floodwaters generally seep into a home relatively rapidly, structurally failure from hydrostatic forces generally only occurs during rapidly rising floodwaters. Once water is inside the building, floodwaters inside the structure equalize pressures from waters outside the structure and buoyancy forces are reduced.

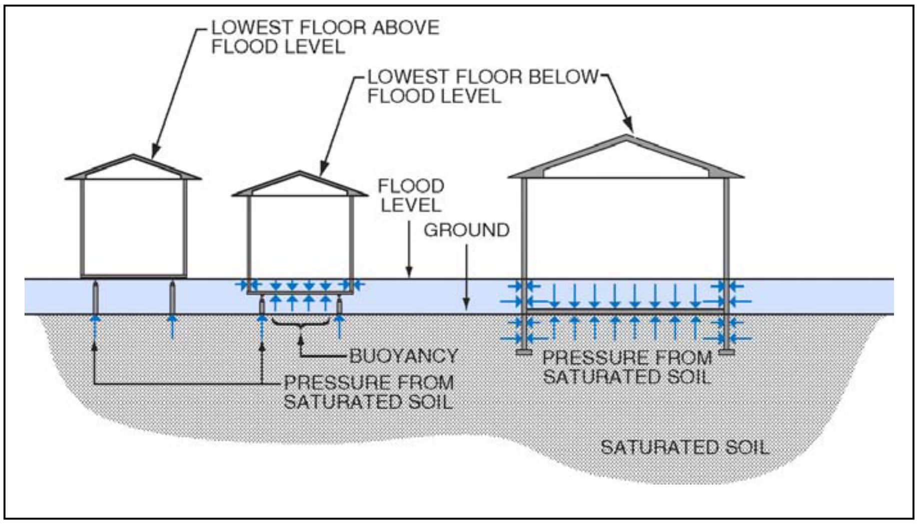


Figure 5-3. Buoyancy force acting on a structure.

Table 5-2 is the gross buoyancy force (F_b) exerted per foot length of the manufactured home due to a difference in anticipated water depth between the inside and outside of the home.

Buoyancy force is calculated by:

Fb = w x æh x W

where: qh = difference in water height inside and outside (ft)

w = density of water = 62.4 lb/cu. ft.

W = width of home (ft)

Table 5-3. Buoyancy Forces F_b (pounds per linear foot)

Home Width (ft.)	Difference in water height inside and outside the manufactured home (in.)												
	4	5	6	9	12	15	18	21	24	30	26	42	48
12	249.6	312.0	374.4	561.6	748.8	936.0	1123.2	1310.4	1497.6	1872.0	1622.4	2620.8	2995.2
14	291.2	364.0	436.8	655.2	873.6	1092.0	1310.4	1528.8	1747.2	2184.0	1892.8	3057.6	3494.4
24	499.2	624.0	748.8	1123.2	1497.6	1872.0	2246.4	2620.8	2995.2	3744.0	3244.8	5241.6	5990.4
28	582.4	728.0	873.6	1310.4	1747.2	2184.0	2620.8	3057.6	3494.4	4368.0	3785.6	6115.2	6988.8

As an example, Table 5-2 shows that 6 inches of flooding exposes a 24-foot wide double unit to about 750 pounds of buoyancy force for each linear foot of home. If the unit is 60 feet long, its foundation would need to resist 45,000 pounds of buoyancy (60 ft x 748.8 pounds/foot). With appropriate code required safety factors, it would require 300 cubic feet of concrete (about 11 cubic yards) to resist the buoyancy of only 6 inches of flooding.

This example illustrated the importance of placing the home above the BFE to prevent it from being exposed to buoyancy forces during a design event.

5.1.5 Hydrodynamic Forces

An important phenomenon to consider in the design of a manufactured home that may be subjected to flooding is the dynamic effects of moving water on the structure and its foundation. Forces due to the flow of floodwaters are called "hydrodynamic forces." The forces are lateral forces and include positive pressures on the upstream surface of the home, drag forces on the sides of the home, and suction forces caused by eddies on the downstream side of the home.

Hydrodynamic forces depend on the floodwater depth and floodwater velocity; the higher the depths and velocities, the greater the hydrodynamic forces.

Hydrodynamic forces can be extreme particularly in areas with high flood velocities. The extreme forces can cause foundation failure typically by pushing homes off of their foundations (sliding failure) or by lifting homes off of their foundations (often in conjunction with buoyancy forces) and allowing foundation elements to be toppled by moving floodwaters. In addition, moving floodwaters can cause erosion and scour around the foundation and can undermine foundation elements (see Figure 5-4).

When a body of water moves, the flood velocity depends on the slope and roughness of the terrain. For example, water moves faster along streams in steep mountains than streams in flatter areas, and water moves faster over a parking lot with asphaltic concrete surface as opposed to an area with dense vegetation or other obstacles. Riverine flood velocities also depend on the channel size. Smaller channels will typically experience higher flow rates. Flood velocities are not contained in FIRMs, but can be found in FISs for floodways where floodway studies have been performed. Mean flood velocities for floodways can be obtained from the FIS by matching the cross-section in the FIRM with the cross-section in the FIS. The floodway's mean velocity is not usually a good measure of the flood velocity within the flood fringe; floodwaters will generally move slower as they extend outward from the floodway. However, the floodway velocities can be used as a general measure to determine cross-section locations within the floodplain where floodwaters will move relatively faster or slower. One of the best source for flood velocities is records of past flood events. In addition to the FIS, a list of potential sources for documentation of past flooding is included in Table 5-1.

Coastal areas are particularly hazardous because flooding is often accompanied with high velocity flow (greater than 5 feet per second (fps)) associated with storm surge from coastal storms. Flow velocity can be further increased by manmade or natural obstructions channeling the flow.

Figure 5-4. A manufactured home destroyed by flooding.

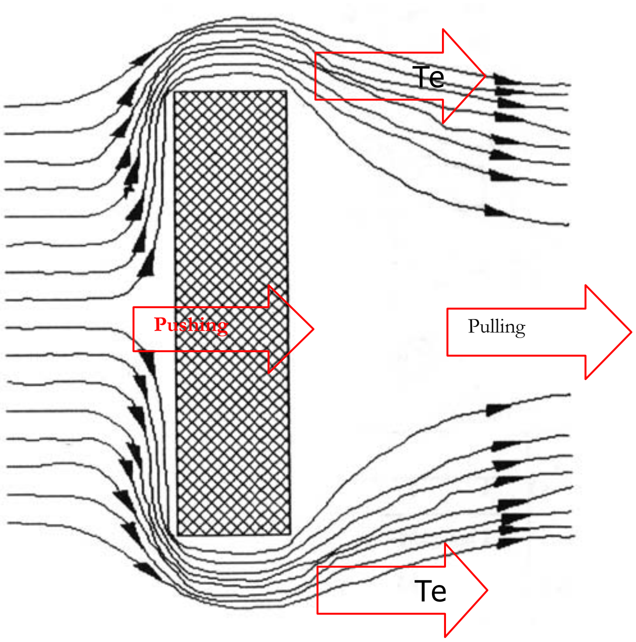


Figure 5-5. Hydrodynamic forces flowing around a building sited perpendicular to the flow.

Drag forces are calculated as follows:

$$F_d = \frac{C_d \; x \; A \; x \; \psi x \, V^2}{2}$$

where: F_d = drag force in pounds

C_d = coefficient of drag (not less than 1.25)

Ɉ = mass density of water

= Specific weight of water (ɔ)/ acceleration due to gravity (g)

V = floodwater velocity in feet per second

A = projected vertical area submerged in square feet, including the chassis I-beam

Table 5-3 provides the drag forces as a function of water velocity and water height.

Table 5-4. Drag Forces (F_d) (pounds per linear foot of home length)

V	Water Height (in.)													
(fps)	1	2	3	4	5	6	9	12	15	18	24	30	36	48
1.0	0.11	0.21	0.32	0.42	0.53	0.64	0.95	1.27	1.59	1.91	2.54	3.18	3.81	5.08
2.0	0.42	0.85	1.27	1.69	2.12	2.54	3.81	5.08	6.35	7.62	10.17	12.71	15.25	20.33
3.0	0.95	1.91	2.86	3.81	4.77	5.72	8.58	11.44	14.30	17.15	22.87	28.59	34.31	45.75
4.0	1.69	3.39	5.08	6.78	8.47	10.17	15.25	20.33	25.41	30.50	40.66	50.83	60.99	81.32
5.0	2.65	5.29	7.94	10.59	13.24	15.88	23.83	31.77	39.71	47.65	63.54	79.42	95.30	127.07
6.0	3.81	7.62	11.44	15.25	19.06	22.87	34.31	45.75	57.18	68.62	91.49	114.36	137.24	182.98
8.0	6.78	13.55	20.33	27.11	33.89	40.66	60.99	81.32	101.66	121.99	162.65	203.31	243.97	325.30
10.0	10.59	21.18	31.77	42.36	52.95	63.54	95.30	127.07	158.84	190.61	254.14	317.68	381.21	508.28
12.0	15.25	30.50	45.75	60.99	76.24	91.49	137.24	182.98	228.73	274.47	365.96	457.45	548.94	731.92
15.0	23.83	47.65	71.48	95.30	119.13	142.95	214.43	285.91	357.38	428.86	571.82	714.77	857.72	1143.63

An alternate approach to consider the dynamic effects of moving water is to use an equivalent hydrostatic load approach. When water velocities are less than 10 ft/sec, ASCE 7-02 permits adding an equivalent surcharge water depth to the design flood elevation to simulate the hydrodynamic load.

The equivalent surcharge water depth, d_h is determined by:

$$d_h = \frac{C_d V^2}{2g}$$

where: C_d = coefficient of drag (not less than 1.25)

V = average velocity of water in ft/sec

g = acceleration due to gravity, 32.2 ft/sec

Hydrodynamic loads are applied to any portion of the home or its foundation exposed to moving floodwaters. Elevating the home so its finish floor is at the BFE reduces hydrodynamic forces somewhat, but still allows hydrodynamic forces to act on the floor framing, the steel frames, and the home's foundation. Elevating the home so the bottoms of its steel frames are at the BFE nearly alleviates hydrodynamic forces since they only can act on portions of the foundation that are below the BFE

5.1.6 Erosion and Scour

Scour is the result of the erosive action of flowing water, excavating, and carrying away material from the bed and banks of streams and from around the piers and abutments of bridges. Different materials scour at different rates. Loose granular soils are rapidly eroded by flowing water; however, cohesive or cemented soils are more scour-resistant, but ultimate scour in cohesive or cemented soils can be as deep as scour in sand-bed streams. Under constant flow conditions, scour will reach maximum depths in sand- and gravel-bed materials in hours; cohesive bed material in days; glacial till, sandstones, and shale in months; limestone in years; and dense granite in centuries. Under flow conditions typical of actual bridge crossings, several floods may be needed to attain maximum scour.

Hydrodynamic forces can also remove soil from the ground surface (erosion) and from around objects that obstruct the flow (scour), such as foundation supports of a manufactured home. Scour under building foundations and around supporting columns and the erosion of elevating fill can result in failure of the manufactured home's foundation. For example, after Hurricane Opal struck Navarre Beach, Florida, in 1995, several homes were washed away due to scouring of their pile supports from the channeling and the increased velocity flow that resulted from the homes being sited between two larger engineered buildings.

Scour is an important consideration for the manufactured home elevated foundation. It is defined as the loss of earth or foundation materials caused by moving water. Scour erodes soils and can undermine shallow footings, and is particularly harmful in areas where flood velocities exceed 2 feet/second and where granular soils exist. As a reminder, flood velocities are not shown on FIRMs. The full FIS must be consulted to determine flood velocities in the floodways. In some SFHAs, flood velocities have not been determined and methods must be used to determine approximate flood flow rates.

Where achievable, scour can best be addressed by placing the bottom of the manufactured home's foundation below the predicted scour depth. In areas with deep frost depths, foundations set below the frost line may be inherently resistant to scour. In areas where frost depths are shallow, however, scour protection often controls in determining foundation depth.

Placing foundations below maximum scour depth is not always practical. In those cases, alternate scour projection methods are needed. One method is to add non-erodable soils around the foundation elements. Large aggregate stone can provide this protection.

Equations to predict scour depths for bridge piers, abutments, etc., have been developed by various researchers. These equations are for structures located at sites where there is constant water flow, like a river or streambed. Situations for manufactured homes are very different. A manufactured home foundation will typically only be exposed to the damaging effects of scour during a design flood event and design events can last as short as a few hours. Depending on soils present, that period often is insufficient for scour to reach its full potential. Therefore, using equations that have been developed for constant flow to predict scour depth for manufactured homes will provide very conservative results.

The following equation, developed for long slender foundation elements like circular and square piers, posts, and piles, and offering only limited accuracy for continuous foundations, can be used to predict maximum scour depth. The scour depth can be calculated as follows:

$$S = d\left[2.2\left(\frac{a}{d}\right)^{0.65} x \left(\frac{V}{\sqrt{gd}}\right)^{0.43}\right] K$$

where:

S = maximum localized scour depth in feet

d = design still water depth in feet (upstream of structure in feet)

a = diameter of post, pier, or pile in feet or half the width of the solid foundation perpendicular to the flood flow

V = average velocity of water approaching the structure in feet per second

g = gravitational constant – 32.2 feet/sec^2

K = factor applied for flow angle of attack = 1.0 for circular members

For rectangular footings, the above equation can be written as:

$$S = d\left[2.2\left(\frac{0.5}{12\,d}\sqrt{l^2 + w^2}\right)^{0.65} x \left(\frac{V}{\sqrt{gd}}\right)^{0.43}\right]K$$

where: l = length of footing in inches

w = width of footing in inches

K = 2.5

Results from using the above equations to predict scouring depth for circular members and 8 inches x 16 inches and 16 inches x 16 inches rectangular footings in 1-foot and 3-feet flood depths, respectively, are presented in Tables 5-4 and 5-5. These values can be used as a conservative estimate of the amount of scour that can be expected for the different conditions. These tables are for average soil conditions (2,000 – 3,000 psf bearing capacity). For loose sand and hard clay, the value may be increased and decreased , respectively; however, the assistance of a soils engineer should be sought where highly erodable soil conditions exist (e.g., loose sand). In reviewing the scour depths tables, note that their magnitude and potential impact on piers that are placed on grade. Because of uniform cross-section, the magnitude of local scour for thin circular members is not affected by the direction of flow.

Table 5-5. Depth of Scour (in feet) for Flood Depth of 1 Foot

Velocity (fps)	**Vertical Member Diameter (in.)**					**Rect. Footing**	
	4	**6**	**8**	**10**	**12**	**8" x 16"**	**16" x 16"**
1	0.51	0.66	0.80	0.93	1.04	2.15	2.51
2	0.69	0.90	1.08	1.25	1.41	2.90	3.38
4	0.93	1.21	1.45	1.68	1.89	3.91	4.55
6	1.10	1.44	1.73	2.00	2.25	4.65	5.41
8	1.25	1.63	1.96	2.27	2.55	5.26	6.13
10	1.37	1.79	2.16	2.49	2.81	5.79	6.74
15	1.64	2.13	2.57	2.97	3.34	6.90	8.03

Table 5-6. Depth of Scour (in feet) for Flood Depth of 3 Feet

Velocity (fps)	Vertical Member Diameter (in.)					Rect. Footing	
	4	6	8	10	12	8" x 16"	16" x 16"
1	0.59	0.77	0.93	1.07	1.21	2.50	2.91
2	0.80	1.04	1.25	1.45	1.63	3.36	3.91
4	1.07	1.40	1.69	1.95	2.20	4.53	5.27
6	1.28	1.67	2.01	2.32	2.61	5.39	6.28
8	1.45	1.88	2.27	2.63	2.96	6.10	7.11
10	1.59	2.07	2.50	2.89	3.26	6.72	7.82
15	1.90	2.47	2.98	3.44	3.88	8.00	9.31

An alternate, but less conservative equation to predict scour depth for a situation that is closer to that of a manufactured home is:

scour depth = 2 x diameter of the pile/pier or diagonal dimension of a rectangular footing

In this equation, flow velocity and flood depth will have no contribution to scour depth.

The determination of maximum potential scour is critical in designing an elevated foundation system to ensure that failure during and after flooding does not occur due to loss in bearing capacity or anchoring resistance around the posts, piles, or piers elevating the manufactured home. The anticipated scour depth must, therefore, be added to the pre-flood height above grade in determining the necessary post, pile, or pier design. Without the inclusion of the scour depth in elevated foundation design, failure and collapse of the foundation system is most likely after a flood.

In coastal areas, scour depth can be significant due to both localized scour as calculated above and area erosion resulting from the overall effects of storm surge. Because area erosion is difficult to predict, local regulatory officials should be contacted for further information and historical perspectives.

Based upon the water velocity and type of soil, scour and erosion would increase the height above grade of the vertical member since the grade level would be reduced due to scour and erosion. As this occurs, the depth of burial of the vertical member also decreases an identical distance. This can result in an elevated foundation failure because the loss of natural supporting soil would change the conditions under which the elevated foundation system was designed.

To account for this, the vertical member length used for the purpose of determining an acceptable design must be increased. The vertical member length is used in determining the size of vertical member needed to carry anticipated loading.

If acceptable to local authorities, scour protection can be provided by ensuring that soils around the foundation elements can not be eroded by moving floodwaters. Placing appropriately sized rip-rap around foundation elements is one method of preventing erosion.

5.1.7 Debris Impact Forces

Flood velocity also influences the magnitude of the debris impact forces. Floodwaters can pick up and carry objects of all types – from small to large, from light to heavy – including trees, portions of flood-damaged buildings, automobiles, boats, storage tanks, manufactured homes, and even entire houses. In cold climates, wintertime floods can also carry large pieces of ice. Dirt and other substances such as oil, gasoline, and sewage, and various types of debris add to the dangers of flooding. Even when flow velocity is relatively low, large objects carried by floodwaters can easily damage windows, doors, walls, and more importantly, critical structural components. As the flood velocity increases, so does the danger of greater damage from debris. If floodwaters carrying large amounts of dirt or hazardous substances enter a house, the cleanup costs are likely to be higher and the cleanup time greater.

Many of the impact damages observed to manufactured homes due to Hurricane Georges resulted from attachments to manufactured homes being torn off one home and then carried by the floodwaters and impacted into another home. Typical attachments such as decks, porches, or awnings should be minimized for manufactured homes in SFHAs. These homes are typically not designed to withstand loads to walls or floor systems that may be exerted by attached decks, porches, or awnings. Attachments should be designed and anchored to the same standards as the manufactured house. Site-built decks, porches, or overhead awnings must not be permitted except as standalone units. Additionally, if a standalone porch or deck is going to be added, design criteria for vertical foundation members on the addition should be equivalent to those for the foundation system of the main structure to prevent damage to the main structure from adjacent structures.

Figure 5-6. Manufactured home damaged by debris.

Impact forces are calculated as follows:

$$Fi = m \; x \; \frac{dVb}{dt}$$

where: Fi = impact force in pounds

m = mass of the water displaced by the object in slugs

Vb = velocity of the object in feet per second

t = time in second

$\frac{dVb}{dt}$ = acceleration (deceleration) of the object in feet per second squared

The impact force acts horizontally at the flood level and can be assumed to be the impact force produced by a 1,000-pound object traveling at the velocity of the floodwater acting on 1 square foot of the manufactured home or its elevated foundation.

5.2 Wind Hazards

High winds will impose forces on a manufactured home and the structural elements of its foundation. Damage potential is increased when the wind forces occur in combination with flood forces as in the coastal and mountainous areas. In addition, as the manufactured home is elevated to minimize the effects of flood forces, the loads on the elevated structure itself, due to wind, are increased. Figures 5-7 and 5-8 are examples of wind damage to a manufactured home

Figure 5-7. Example of a wind damaged manufactured home.

Figure 5-8. Another example of a wind damaged manufactured home.

The texture and roughness of the terrain, as well as its surface contours and topography, have a profound effect on the structural loads. A structure in open country outside a city is likely to see a substantially higher wind load than one situated in the center of the city. Similarly, a structure situated on a hilltop may be subjected to significantly greater loads that one on a flat terrain. All structures should be built to withstand the pressure and suctions caused by the strongest gust of wind that is likely to happen at the site.

The basic wind speed for the United States can be obtained from the map given in Figure 6-1 of ASCE 7-98 as well as ASCE 7-02. The wind speeds correspond to 3-second gust speeds in miles per hour at 33 feet (10 meters) above the ground for open terrain with scattered obstructions having heights generally less than 30 feet (9.1 meters), Exposure C category. This includes flat open country, grasslands, and all water surfaces in hurricane-prone regions.

5.2.1 3-second Gust versus Fastest Mile Wind Speed

The fastest-mile wind speed was used in ASCE 7-88 for determining design wind loads on a building. The fastest-mile wind speed is the average speed of 1 mile of wind as it passes over a given point. Since the 1995 issue of ASCE 7, the 3-second wind speeds at 33 feet (10 meters) above the ground for Exposure C are included in the wind speed map. The 3-second wind speed is the average wind speed for 3 seconds at a time. This change was made because the U.S. National Weather Service no longer collects fastest-mile wind speed data. The 3-second gust speed data are collected at a large number of stations in the country and provide a more consistent way to describe wind speed. It is important to note that all the wind coefficients and load factors in ASCE 7-98 and 7-02 can only be used with the 3-second gust wind speed.

The wind pressures specified in the HUD 3280 document are based on fastest mile wind speed given in ASCE 7-88 with additional modifications. These values can only be used with the ASCE 7-88 standard and cannot be used with the ASCE 7-98 or 7-02 standard.

In order to comply with ASCE 7-98 or 7-02, the fastest mile wind speed has to be converted to the 3-second gust wind speed. The easiest way is to identify the location and determine the wind speed from the ASCE 7-98 or ASCE 7-02 wind speed maps. A slightly more time consuming method is to use the curve in Figure C6.1 in ASCE 7-98 or Figure C6.2 in ASCE 7-02. This curve is only applicable to non-hurricane winds. Table 5-7 was developed using this method.

Table 5-7. Converting Fastest Mile Wind Speed to 3-second Gust

Fastest Mile (mph)	3-second Gust (mph)
80	100
90	110
100	120
110	130
120	140
130	150

5.3 Wind Forces on Structures

Wind will impose forces on a manufactured home and its foundation. If not properly designed, wind load can cause the manufactured home to overturn or have lateral movement (sliding). Structural components such as the walls and roof of the home must also be designed to withstand wind forces.

Wind pressure varies with the height and geometry of the structure. Figure 5-9 illustrates the variation of wind pressure with height. For a given manufactured home at a particular site, locating it on an elevated foundation to avoid flooding will introduce additional wind loads on the structure and its foundation.

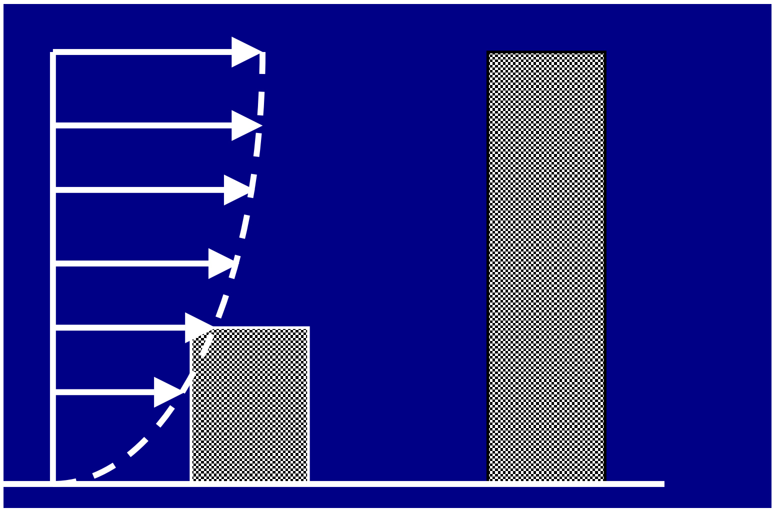


Figure 5-9. Variation of wind pressure with height.

When a building is subjected to wind forces, the wind will flow over and around the building. This will impose positive pressure on the windward side of the building and negative pressure (suction) on the leeward side and roof of the building. The wind pressure will be applied to the main wind force resisting system (MWFRS) and to the components and cladding (C&C). MWFRS is the assemblage of structural elements assigned to provide support and stability for the overall structure (e.g., joists, beams, columns, roof framing, and walls of the building). Elements of the building envelope that do not qualify as part of the MWFRS are identified as C&C (e.g., roof covering, fascia, windows, doors, parapets, chimneys, and roof overhangs). After the appropriate MWFRS and C&C wind pressure are determined for the building, they can be applied to the exterior wall and roof surfaces to establish wind loads for the structural and non-structural elements of the building. These wind loads should be included in the appropriate load combinations for the design of the building.

5.4 Earthquakes

5.4.1 Design Philosophy

The effect of earthquake loads on a structure is different from that of wind loads. In the case of wind load, the load is applied to the exterior of the envelope of the structure. Typically, internal building elements that are not part of the MWFRS of the building will not receive load unless there is a breach of the building envelope. Earthquake loads are based on force acceleration relationships. Any objects with mass will have loads. Therefore, all building elements and all non-structural components within and attached to the structure will be loaded. Consequently, all exterior and interior elements of a structure must be designed for seismically induced forces.

In the event of an earthquake, the structure will be subjected to vertical and horizontal accelerations simultaneously under earthquake loading. This will make it impossible to rely on gravity forces for the frictional resistance between the manufactured home and its foundation.

The assumed response of the structure is another major difference between earthquake and wind loadings. In the case of wind loading, the structure is assumed to remain elastic during a wind event. The structure is also assumed to remain elastic for a common earthquake event, one that may occur several times during the life of the structure. But, for the rare earthquake, the structure is allowed to go into the inelastic range (i.e., have permanent deformation and rotation, but no collapse). This is done to allow the building the ability to withstand the rare earthquake without the economic penalty of having to strengthen the building to accommodate the rare earthquake with no permanent deformation.

Seismic soil liquefaction is an important consideration for earthquake design because soil liquefaction is a major cause of damage in a seismic event. Liquefaction is defined as the significant loss of strength and stiffness due to cyclic pore pressure generation. It is the process where the soil becomes a viscous fluid, creating problems with any structure from bridges to buildings and to buried pipes and tanks. This phenomenon of liquefaction develops from repeated disturbances of saturated cohesionless soils and can cause excessive displacements of the ground. Building foundations can slide or unevenly settle, bridges can collapse, and empty fuel tanks buried under ground can rise to the surface. Clean sandy soil with relatively few fines and coarse, gravelly soils are potentially vulnerable to seismic induced liquefaction. It is, therefore, necessary to identify the presence of any liquefiable material in the foundation, compute the expected settlement, and design the foundation accordingly.

5.4.2 Design Standard

The regulations that currently govern the manufacture of manufactured homes do not specifically address seismic loads but rather specify loading requirements developed primarily to provide basic wind resistance. However, seismic requirements exist in most model codes and standards, and exemptions have not been provided for manufactured housing. Also, seismic requirements are being proposed for NFPA 225.

Historically, it was felt that the wind provisions provide adequate protection for seismic events. Although this may be true in the case of transverse loading (i.e., wind pressures acting on the long walls) where wind loads are high, it is often not the case with longitudinal loading where wind loads are low.

Studies list the following damages to manufactured homes during design earthquakes:

- Piers supporting the home topple and allow the home to fall to the ground
- Damage to floors from piers puncturing them
- Disruption of gas, water, and electrical lines from seismic motions of the home
- Fire resulting from damaged gas and electric lines

For a manufactured home installed on a foundation system, providing adequate resistance to lateral movement, uplift, and rotation is very important. It is also necessary to provide tensile connections between the main frame of the home and the piers supporting the home. The connections between the supporting piers and the main frame of the home must be adequately designed to resist all seismic forces. This typically involves perimeter foundation systems typical of site built homes or foundations consisting of reinforced piers and concrete footings.

Although they do not provide the protection of a seismic resistant foundation system, earthquake resistant bracing systems (ERBSs) can be installed to minimize damage to the home. ERBSs are secondary supports that do not resist seismic forces, but rather allow the home to fall from its primary supports and "catch" it before it hits the ground.

The State of California has had an ERBS certification program since 1987. To be certified, the ERBS must be able to limit seismic movement and limit vertical drop of the manufactured home to 2 inches. A list of certified ERBSs is available from the State of California, Department of Housing and Community Development, Division of Codes and Standards. The price range of ERBSs range from $2,000 to $5,000 and the average cost of an ERBS is about $2,500.

In providing a foundation for a manufactured home against seismic forces, it is also important to think of the construction of the home itself. A typically manufactured home tends to be more flexible than a conventional site built home. If the foundation for the manufactured home is very rigid (strong) compared to the home, in the event of an earthquake, the tendency is for the foundation to remain and for the home to be heavily damaged. Whereas, if the foundation is not as strong, the foundation and home may suffer some damage, but can be easily restored and available for occupancy in a few days.

5.5 Evaluation of Multihazards

Manufactured homes, as in other buildings, can be simultaneously subjected to many natural hazards at the same time. Although it is an unlikely event, the combined effect of the forces generated from these hazards must be considered. The different loads that must be considered in the design of a manufactured home and its foundation are:

- Dead load (D)
- Live load (L)
- Roof live load (L_r)
- Load due to lateral earth pressure, ground water pressure (H)
- Rain (R)
- Snow (S)
- Load due to fluids with well-defined pressure and maximum heights (F)
- Self-straining force (e.g. differential settlement), change in temperature of members (T)
- Loads from natural hazards, such as wind (W), flood, (F_a), and earthquake (E)

Load combinations are used in the design process to take into account the simultaneous occurrence of different hazards. Manufactured homes should be designed to the load combinations indicated by the applicable building code for the area. In the absence of a building code, the manufactured home should be designed in accordance with the load combination given in ASCE 7-98 or 7-02, Minimum Design Loads for Buildings and Other Structures.

5.5.1 Load Combinations (ASCE 7-02 and 7-98)

5.5.1.1 Strength Design (Load and Resistance Factor Design, LRFD)

Strength is defined as a method of proportioning structural members such that the computed forces produced in the members by the factored loads do not exceed the member design strength.

According to ASCE 7-02, the basic load combinations for strength design are:

1. 1.4 (D+F)
2. 1.2(D+F+T) + 1.6 (L+H) + 0.5(L_r or S or R)
3. 1.2D + 1.6(L_r or S or R) + (L or 0.8W)
4. 1,2D + 1.6W + L + 0.5(L_r or S or R)
5. 1.2D + 1.0E + L +0.2S
6. 0.9D + 1.6W + 1.6H
7. 0.9D + 1.0E + 1.6H

When a structure is located in a flood zone, the following load combinations must be considered:

In V-Zones or Coastal A-Zones, 1.6W in combinations (4) and (6) shall be replaced with $1.6W + 2.0F_a$.

In noncoastal A-Zones, 1.6W in combination (4) and (6) shall be replaced by $0.8W + 1.0F_a$.

The load factor on L for combinations (3), (4), and (5) is permitted to equal to 0.5 for all occupancies in which the maximum uniformly distributed live load, L_o, is less than or equal to 100 pound-force per square foot, with the exception of garages or areas occupied as places of public assembly.

The load factor on H shall be set equal to zero in combinations (6) and (7) if the structural action due to H counteracts that due to W or E. When lateral earth pressure provides resistance to structural actions from other forces, it shall not be included in H, but shall be included in the design resistance.

In the design of a manufactured home, it is necessary to investigate each relevant strength limit state. The effects of one or more loads not acting must be investigated. The most unfavorable effects from both wind and earthquake loads shall be investigated, where appropriate, but they need not be considered to act simultaneously. This is because the chance of maximum winds and maximum seismic activity occurring simultaneously is extremely rare.

There is no change in the load combinations between ASCE 7-98 and 7-02 for strength design.

5.5.1.2 Allowable Stress Design (also known as Working Stress Design)

Allowable stress design is defined as a method of proportioning structural members such that elastically computed stresses produced in the members by nominal loads do not exceed specified allowable stresses

According to ASCE 7-02, the basic load combinations for allowable stress design are:

1. D + F
2. D + H + F + L + T
3. D + H + F + (Lr or S or R)
4. D + H + F + 0.75(L + T) + 0.75 (Lr or S or R)
5. D + H + F + (W or 0.75E)
6. D + H + F + 0.75(W or 0.7E) + 0.75L + 0.75(Lr or S or R)

7. $0.6D + W + H$

8. $0.6D + 0.7E + H$

When a structure is located in a flood zone, the following load combinations must be considered:

1. In V-Zones or Coastal A-Zones, 1.5 F_a shall be added to other loads in combinations (3) and (4) and F shall be set equal to zero in (3).

2. In non-coastal A-Zones, $0.75F_a$ shall be added to combinations (3) and (4) and F shall be set equal to zero in (3).

With the exception of the last two load combinations, the load combinations given in ASCE 7-02 are different from those given in ASCE 7-98. There are a total of five load combinations in ASCE 7-98.

As in strength design, the most unfavorable effects from both wind and earthquake loads shall be investigated, where appropriate, but they need not be considered to act simultaneously. In addition, increase in allowable stress shall be used with these load combinations.

Either allowable stress design (ASD) or strength based design can be used for manufactured housing.

Chapter 6: Soils

Soil properties can have significant impact on manufactured homes exposed to flooding. For example, highly erodible soils are not desirable for use as fill in elevating a structure in a high velocity area because they can be washed away by moving floodwaters. Some soils loose strength when they become saturated. This can reduce the ability of a foundation to resist wind, flooding and seismic forces. This chapter discusses the effect of flooding on soil properties.

6.1 Bearing Capacity

Soil conditions typically vary with depth. The proper determination of soil type and soil bearing capacity is important for the selection and performance of the manufactured home foundation. It is recommended that a geotechnical engineer make these determinations. For preliminary design purposes, allowable bearing pressure can be established based on national model codes, local building codes, and soil surveys. Local officials may also have available information on soil types and soil bearing capacities.

The characteristic of soil in a flood area (i.e., soil bearing capacity) is important in determining an appropriate design. Bearing capacity is the capability of the soil to support load without failure. Bearing capacities of footings on cohesive soils (clays and silts) depend primarily on the shearing resistance of the soil. Bearing capacities of footings on granular soils (sands and gravels) depend on the frictional resistance between soils particles, the density of soils below the footing, and the weight of the surrounding soil surcharge or backfill.

Estimating the bearing capacity of soils in their saturated condition is difficult in that soil characteristics may be altered later due to a change in moisture content. Soil classifications of a general nature and a typical range of their maximum allowable bearing capacities are shown in Table 6-1. Soil bearing values for different soil types are also provided in the Model Manufactured Home Installation Standard, 2003 Edition.

Table 6-1. Soil Classification and Maximum Allowable Bearing Pressure

(NFPA 5000, 2003 Edition)

Soil Classification	Minimum Depth of Footing Below Adjacent Ground	Bearing Pressure Permitted if Footing is at Minimum Depth*	Maximum Pressure*
	(ft)	(psf)	(psf)
Compacted Fine Sand	1	1,000	5,000
Loose Sand	2	500	3,000
Medium Stiff Clay	1	2,000	6,000
Soft, Sandy Clay or Clay	2	1,000	2,000
Compact Inorganic Sand and Silt Mixture	1	1,000	4,000
Loose Inorganic Sand and Silt Mixtures	2	500	1,000

*These pressures are considered sufficient to prevent failure of the supporting ground, but not to prevent excessive foundation movement or settlement where unusual soil or moisture conditions are encountered.

6.2 Effects of Flood Duration and Frequency on Soil

The unit weight of granular soil like sands, whether dry, moist, or saturated, lies within a fairly narrow range and is not an important variable in determining the bearing capacity of a footing. However, if the sand is located below the water surface, only its submerged weight is effective in producing frictional resistance. The submerged weight is about half of the moist, dry, or saturated weight. The value of angle of internal friction is not appreciably changed by submergence. Therefore, it can be concluded that if the water table rises from a depth greater than the width of the footing to the top of the surcharge, as in the case of flooding, the bearing capacity of the soil would be reduced to one-half of its value for dry, moist or saturated sand (Peck, Hanson, and Thornburn, 1973).

For cohesive soil like clay, the shearing resistance will decrease with increase in porewater pressure, which is a function of the height of water above the surface. As the height of water increases during a flood, the porewater pressure increases. The decrease in shear resistance of the soil will lead to a decrease in bearing capacity.

6.3 Recommended Soil Testing and Criteria for MH Installations

When a general visual inspection and consultation with a geotechnical engineer is not sufficient to estimate the bearing capacity of the soil, subsurface investigations or, at a minimum, a load test should be conducted.

Subsurface investigations should be conducted to a minimum depth below the footing depth. This depth maybe established on the basis of approximate stress and settlement computations. The investigation will provide information on soil type and bearing capacity.

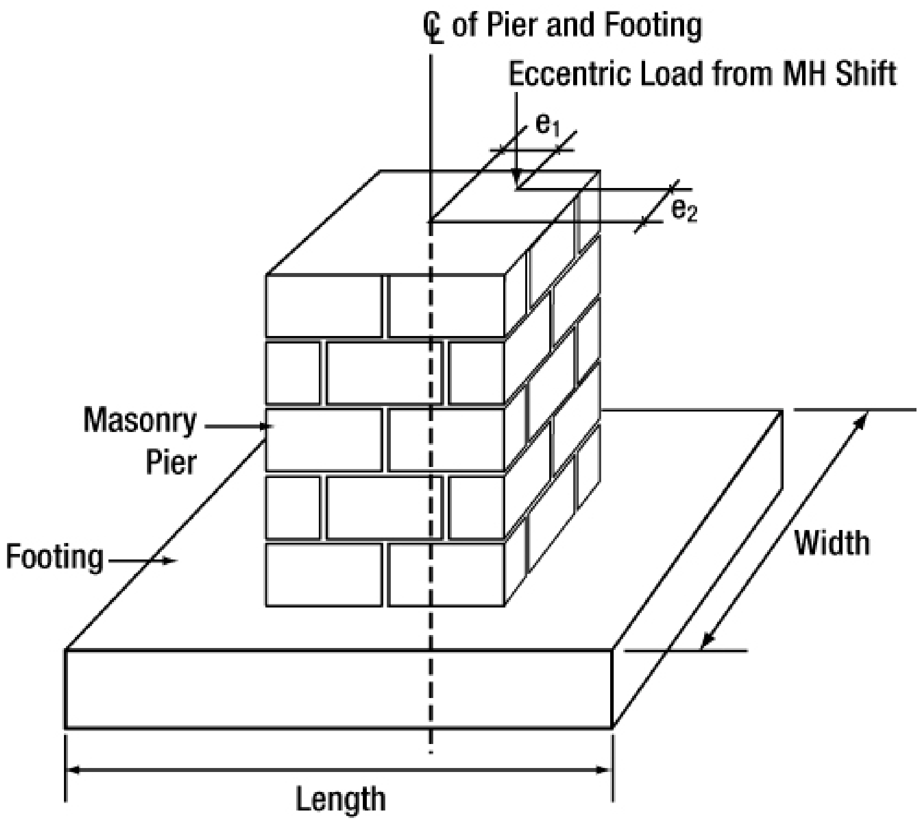
The load test should be conducted when the soil is wet. The load test will provide information on bearing capacity. After the soil bearing capacity is determined, that value can be evaluated against the maximum vertical member load to determine the required bearing area of the vertical member.

$$\frac{\text{Vertical Member Load (lb)}}{\text{Soil Bearing Capacity (psf)}} \mid \text{Bearing Area (sq. ft.)}$$

The size of the footing that will be needed to support the vertical member load can be determined from the required bearing area.

Some manufactured home foundations, most notably those using ground anchors, are inherently flexible and allow a home to shift on its foundation much more than conventional foundations. The shifting of a home on its foundation creates eccentric (off center) loading in the supporting soils that can lead to failure. To account for eccentric loading, it is generally acceptable to reduce the effective area of the foundation by twice the eccentricity. For a footing with dimensions of L and W exposed to an eccentricity in the L direction of e1 and e2 in the W direction, the effective footing area becomes:

$A_{eff} = (L-2e_1) * (W - 2e_2)$



The allowable loads of ground anchors are affected by soil saturation and how they are placed in the ground. Ground anchor tests conducted to develop design values for the pre-engineered foundations contained in this manual revealed that, in the granular soils present in the test site (they were generally Class 4a soils), saturation *decreased* the allowable loads on anchors with stabilizer plates, but *increased* the resistance of anchors pulled axially. The increase resulted from "apparent cohesion" that resulted from saturation.

Because continuously saturated conditions can generally not be relied upon, the soil condition (whether saturated or non-saturated) that produces the weakest strength needs to be used in design.

Chapter 7: Ground Anchors

Ground anchors are used extensively in manufactured home installations. They are inexpensive, can be installed with limited special equipment or training, and are readily available.

Ground anchors, however, have their drawbacks. One of their most significant drawbacks results from the way ground anchors interact with the surrounding soils to resist wind, flood, and seismic forces. By design, ground anchors are typically allowed to move up to 3 inches to develop the load required to resist those forces. When a manufactured home is secured with ground anchors, it too can move up to 3 inches when exposed to wind, flood, or seismic events. By comparison, convention foundations only move fractions of inches.

Because of this, foundations using ground anchors need to be inspected periodically particularly after high wind, flood, or seismic events; loose anchor straps need to be retightened, loose or failed anchors need to be reset or replaced, and, in extreme cases, homes need to be reset to center them on their supporting piers. If this maintenance is not performed, ground anchor foundations can fail and damage or destroy the home or surrounding properties.

Although tightening ground anchor straps typically costs a few hundred dollars or less, replacing anchors or resetting a home is estimated to cost at least $1,000.

7.1 Types of Anchors and Installed Configurations

7.1.1 Types of Anchors

There are anchors made to place directly into soil-earth anchors, as well as anchors made to place into concrete-concrete anchors.

7.1.1.1 Screw Augers

Ground anchors are designed to screw into the ground and are often referred as screw augers. Ground anchors typically consist of a shaft; at the top of the shaft is a head used for installing and tensioning. Toward the bottom of the shaft, there are typically one (single) or two (double) helical disks, referred to as heads that allow the anchor to be “screwed” into the soil. The diameters of the helix can be type A (less than 8 inches diameter, but no less than 6 inches) or type AA (no less than 8 inches diameter). Some anchors have a built-in stabilizer cap. Anchors with no stabilizer caps may be installed with stabilizer plates. Stabilizer caps and plates use the bearing strength of the soil under the cap or plate to help withstand forces in particular lateral forces.

Ground anchors come in typical lengths of 30, 36, 48, and 60 inches.

The following are types of single helix ground anchors:

- Single head
- Double head
- Type A (diameter of helix a minimum of 6 inches)
- Type AA (diameter of helix a minimum of 8 inches)

7.1.1.2 Concrete Anchors

Concrete anchors are used to connect the manufactured home to a concrete foundation. Some concrete anchors are designed to be cast in place, but others can be installed on an existing concrete structure.

Unlike ground anchors, concrete anchors do not interact directly with the soils and do not need to move several inches to develop their strength.

7.1.2 Anchor Construction and Capacity

Ground anchors are typically constructed with a circular shaft, with one or more helixes and a head to connect the anchor to the home’s frame and/or sidewalls with steel straps or cables. Anchor shafts are typically 5/8 inch to 3/4 inch in diameter and helixes range from 3 inches to 8 inches in diameter. Most anchors have one helix; some have two to four (see Figure 7-1). Most anchor heads are "U" shaped and contain connections for two knurled and slotted bolts. The bolts connect the anchor to the home’s frame or sidewalls with 1-inch anchor straps. Some anchors have heads with closed eyes for cable connections. The bolts in “U” shaped anchor heads can be used to pre-tension the anchor. Pre-tensioning an anchor with closed eye heads requires using other devices like turnbuckles.

Figure 7-1. Single and double helix ground anchors with strap connection and single helix anchor with a closed eye connection.

HUD currently requires anchoring equipment to be capable of resisting an allowable working load equal to or exceeding 3,150 pounds. Because anchor strength depends greatly on the soil properties, anchors are designed for the soils they are to be used in. Anchors with longer shafts and larger helixes are needed for poor soils. Shorter anchors with smaller helixes can be used in more capable soils. Ground anchors must develop their strength without their anchor head moving more than 3 inches horizontally or 2 inches vertically. To satisfy HUD criteria for ultimate strength, anchors and connecting hardware must also be capable of resisting a 50-percent overload condition (4,725 pounds) without failure.

Ground anchors are certified by architects, engineers, or nationally recognized testing agencies. Testing protocols for certification vary, but typically involve pre-loading tested anchors with 500 or 1,000 pounds, increasing loads in 500-pound increments, and recording the resulting displacements. The displacement caused by the pre-load, which can be several inches, is not considered in the displacement criteria.

Section 7.5.2.4.3 of the 2003 MHCC Installation Standards states:

"Each anchor shall be manufactured and installed in accordance with its listing by a nationally recognized testing agency, with its testing by a registered professional engineer, or as accepted by an AHJ, which shall list the anchor for use in a classified soil (Table 5.5.2.2) based on a nationally recognized testing protocol."

The 500- or 1,000-pound pre-load used during anchor certification does not replicate actual installations because most anchor manufacturers do not specify the same level of pre-loading in their installation instructions.

7.1.3 Anchor Selection

Ground anchors must be selected for the soils present where the manufactured home is placed. Shorter anchors with smaller helixes may be used in firm, well consolidated soils. Longer anchors or anchors with larger or multiple helixes are required to poorer soils.

Most anchors are selected based on standard torque probe tests conducted at the site. During those tests, a 5-foot long auger probe is screwed into the ground to the approximate depth of the anchor helix. A torque wrench is then used to measure the torque required to advance the probe. The resulting torque value is used to classify the soils and select an appropriate anchor based on anchor manufacturers' recommendations. Table 7-1 depicts how one anchor manufacturer classifies soils for anchor selection.

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Table 7-1. Soil Classifications for Torque Probe Tests

Soil Class	Test Value (in. lbs.)	Soil Description
1	N/A	Sound hard rock.
2	550 +	Very dense and/or cemented sands, coarse gravel, cobbies, preloaded silts, clays and coral.
3	350 to 550	Medium dense coarse sands sandy gravels very stiff silts and clays.
4a	275 to 350	Loose to medium dense sands, firm to stiff clays and silts, alluvial fill.
4b	175* to 275	Loose sands, firm clays and silts, alluvial fill.

** Below 175 in. lbs., a professional engineer should be consulted*

Tests conducted by the manufactured housing industry indicate that standard torque probe tests reasonably predict the effort required to install ground anchors, but provide little data on the working strength of the anchors. However, selecting anchors based on standard torque probe tests is consistent with the anchor selection criteria used during anchor certification.

7.1.4 Anchor Installation

Anchors can be machine-installed or hand-installed. Machine installation involves using portable torque equipment to “twist” anchors into the supporting soils. Figure 7-2 shows an electric installation device.

Figure 7-2. Portable anchor drive machine (courtesy of Tie Down Engineering).

Hand installation involves excavating holes for the anchors, placing the anchors into the holes, and then backfilling and compacting the removed soils. Hand installation disturbs significantly more soils than machine installation and reduces anchor strength. Manufacturers typically limit the depth of pre-drilling to two thirds the anchor length. They also recommend against hand installations in areas with poor soils.

In a conventional installation, anchors are installed vertically (or raked 15 degrees to facilitate installation) and stabilizer plates are installed 4 inches away from the shaft (see Figure 7-3). This allows anchors to be installed after the manufactured home is positioned and locates the exposed anchor heads behind the manufactured home’s skirting. Anchor straps are then installed to the manufactured home frames and, in HUD Wind Zones II and III, to the wall ties installed when the home is fabricated. When used in this configuration, stabilizer plates are installed to provide additional lateral resistance for the frame straps.

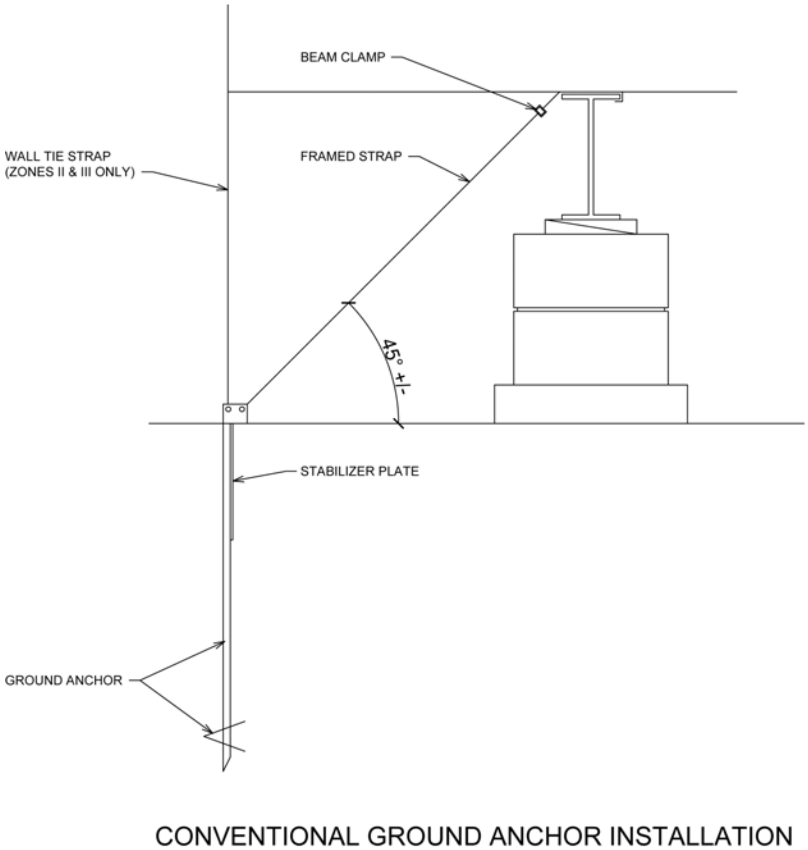

Figure 7-3. Conventional ground anchor installation.

When fastened to wall ties only, anchors are installed vertically and used without stabilizer plates. When ground anchors are used with some proprietary foundation systems, anchors can be installed 45 degrees to the horizon and loaded axially (see Figure 7-4).

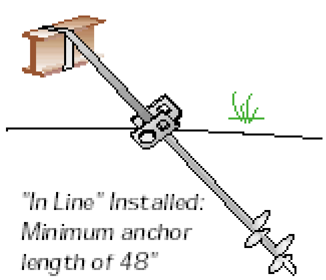

Figure 7-4. In-line ground anchor installation.

7.1.5 Anchor Performance

Ground anchors can produce working strengths of over 3,000 pounds and ultimate strengths over 7,000 pounds. Unfortunately, anchors must displace several inches to obtain these strengths particularly when used with stabilizer plates. Ground anchor tests performed in conjunction with preparation of this manual revealed that anchor heads needed to travel 4 to 12 inches to produce their rated resistance. Tensioning anchors during installation can pre-load the anchors and stabilizer plates and can greatly reduce the amount of movement required to achieve listed strengths. However, pre-loading anchors is not included in most anchor manufacturers' installation instructions. Also, even with pre-loading, anchor stiffness remains much lower than the stiffness provided by conventional structural components.

Anchor response curves for various anchor installation configurations were investigated during the anchor testing. Figure 7-5, a plot of anchor load (in pounds) as a function of anchor head displacement (in inches), shows the typical response for an anchor installed vertically and loaded axially. Figure 7-6 shows the typical response for anchors used with stabilizer plates.

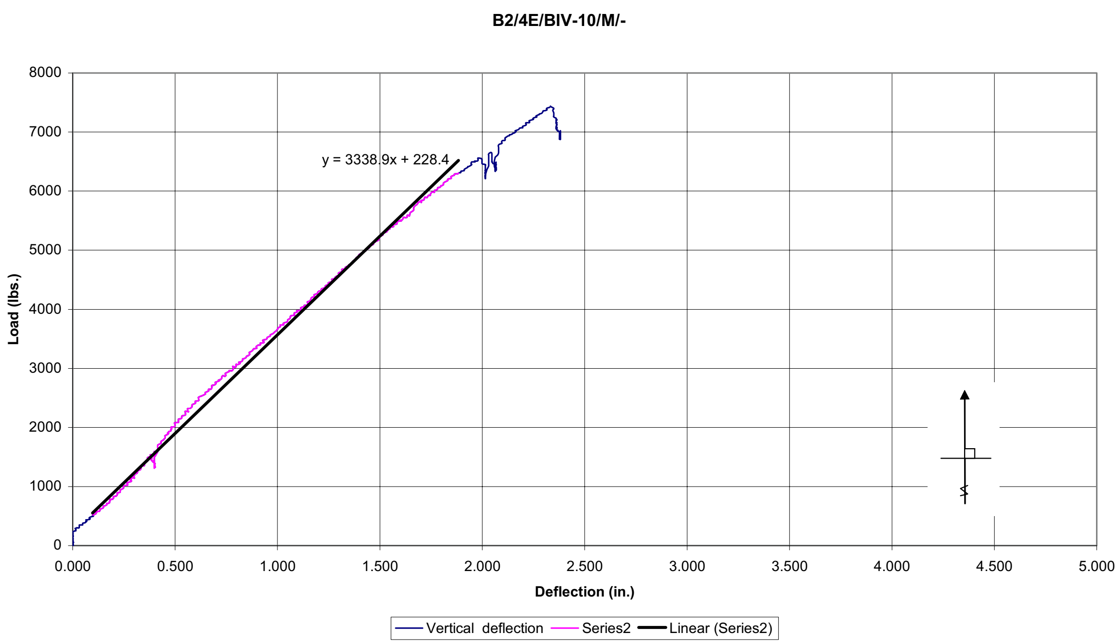

Figure 7-5. Typical response for an axially loaded anchor.

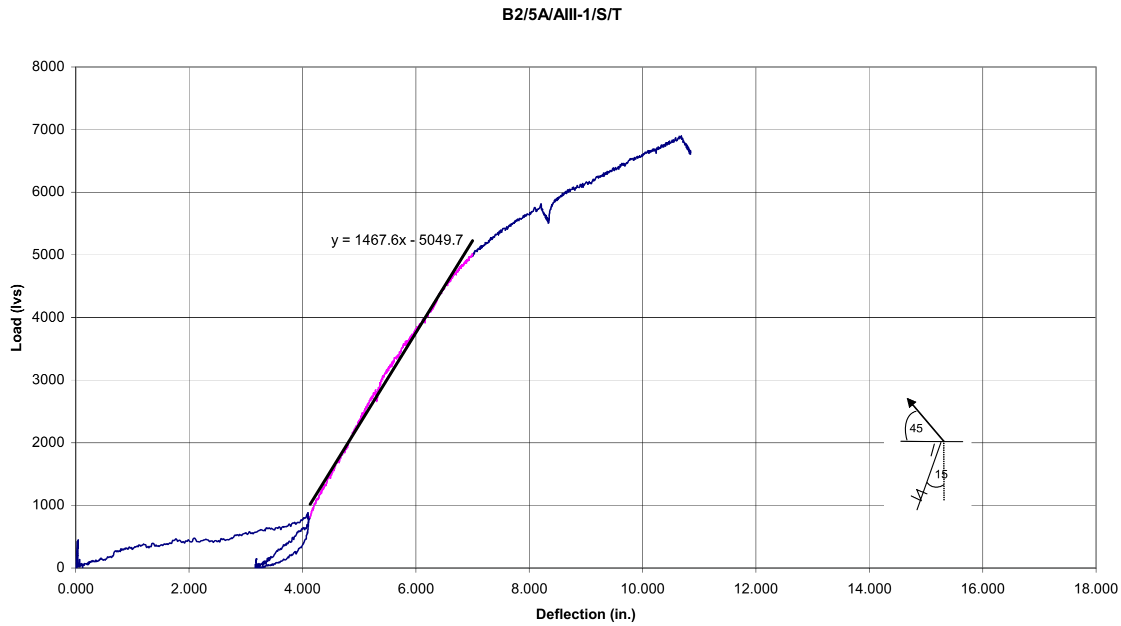

Figure 7-6. Typical response for an anchor used with a stabilizer plate.

Axially loaded anchors develop their strength immediately upon loading. Soils surrounding the helix resist movement and the anchor responds in a nearly linear fashion throughout its normal range of loading. The loads an anchor resists are proportional to the displacement of the anchor head. Axially loaded anchors can produce stiffness (the measure of load versus displacement) of over 3,500 pounds per inch. If loads are increased, the anchor eventually fails abruptly. Anchor failure typically results from weld failure between the anchor shaft and the anchor head, weld failure between the shaft and the helix, collapsing of the anchor helix, or metal tearing around the anchor head strap bolts.

Anchors used with stabilizer plates respond very differently than axially loaded anchors. During initial loading, the anchors provide little resistance to movement. The resistance is limited to that provided by the narrow anchor shafts tearing through the adjacent soils. Stiffness as low as 100 pounds per inch is typical.

After the anchor shaft contacts the stabilizer plate, the resistance of the plate comes into play as does the resistance of the helix trying to be pulled out of the subsurface soils. After the shaft contacts the stabilizer plate, stiffness increases to approximately 1,200 pounds per inch – significantly more than the pre-contact stiffness, but still much less than the stiffness provided by axially loaded anchors.

After contact, the anchor and plate combination responds in a nearly linear fashion until the soils around the stabilizer plate tear. A soil "slug" develops in the front of the plate and the slug plows through the adjacent soils with little increase in stiffness.

In saturated soils, the resistances of soil anchors are reduced significantly.

7.1.6 Anchors and Other Foundation Elements

In a conventional installation, ground anchors are used with masonry piers, wood posts, or steel jack stands. For satisfactory performance, all of those components must be able to function with the relatively large displacements anchors require to achieve their strength. Many foundation components can not do this. Piers, for example, can experience brittle failure in the masonry or ductile failure in the reinforcing steel when allowed to displace the 1 to 3 inches required for the anchors to develop their resistance. Although they may prevent collapse of the foundation system, their response, at best, is unpredictable.

Foundation systems that prevent failure in the piers can be used with ground anchors. These systems include lateral bracing or post tensioning to allow the foundation system to function as a rigid body.

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The large displacement required to develop anchor strength can be greatly reduced by effective pre-tensioning. Pre-tensioning involves loading the anchors after installation while they are fastened to the home or its foundation. Conceptually, pre-loading takes the "slack" out of the anchor and stabilizer plates assemblies and allows the anchors to develop required strengths with much less movement. Pre-tensioning can also increase the stiffness of the linear portion of the anchor response curve so that stiffness of 3,000 to 5,000 pounds per inch is achievable.

7.1.7 Anchors in Saturated Soils

During flood events, soils supporting manufactured homes become saturated particularly during long duration flooding. Soil saturation can reduce the strength of ground anchors, soften soils under foundation footings, and increase the potential for foundation failure.

Prior to 2001, little definitive data existed on the performance of ground anchors in saturated soils. That lack of data severely limited the ability to design foundations using ground anchors that would perform in a predictable fashion when exposed to design wind, flood, and seismic forces.

In 2002, 120 anchors were field tested to provide performance data used to develop pre-engineered foundation designs using ground anchors. Sixty anchors were tested in a saturated site and sixty were tested in an adjacent dry site.

A site in Kissimmee, Florida, was selected for the anchor tests. The site was specifically selected because:

- It offered nearly identical soils in both saturated and unsaturated states.
- The soils present on site are similar to soils found throughout many portions of the Southeast.
- Ground anchors placed in the soils would provide “lower bound” performance when compared to more capable soils.

Soils at the site were generally classified as loose to medium fine sand with some to little silt. Unified Soils Classification System designations were generally SP-SM to SM. N values at depths where anchor helixes were placed ranged from 3 to 11 blows per foot.

Standard Torque Probe tests, a soils classification system used only by the manufactured housing industry, generally rated the soils as Class 4b. Some torque tests rated the soils as below Class 4b, but because no correlation has been determined between Standard Torque Probe testing and anchor tests, the low torque values did not preclude testing in the site.

Five different anchor configurations were included in the tests:

- Five-foot anchors installed at 45^{o} to the horizontal and loaded axially
- Five-foot anchors installed vertically and loading axially
- Five-foot anchors installed 15^{o} vertical, provided with an 11-inch by 17-inch steel stabilizer plate and loaded 45^{o} from the horizontal
- Four-foot anchors installed 15^{o} vertical, provided with an 11-inch by 17-inch steel stabilizer plate and loaded 45^{o} from the horizontal
- Four-foot anchors installed 15^{o} vertical, provided with an 8-inch by 24-inch ABS stabilizer plate and loaded 45^{o} from the horizontal

7.2 Test Protocol

Ground anchors were tested using a consensus based protocol developed by the engineering community, the manufactured housing industry, and HUD and FEMA. The protocol was chosen to provide as much information on ground anchor response as possible.

Five ground anchor manufacturers supplied anchors for testing. They also provided their ground anchor installation instructions. Minor variations existed between the instructions (generally involving angle of installation on anchors used with stabilizer plates). For consistency, all anchors were installed per one set of installation instructions.

After installation, the anchors were allowed to set for a minimum of 60 days before loading. This was done to replicate real life conditions, assuming design events do not occur immediately after a home is set.

Anchors were equipped with load cells to measure anchor resistance (in pound force) and string potentiometers to measure both vertical and horizontal anchor head displacement. Where possible, anchor response was measured through to anchor failure. If anchors produced more than 6,000 pounds of resistance, the test was stopped to prevent damaging test equipment.

Load vs. displacement plots were developed for each anchor. Each anchor had a pseudo-linear portion of the response curve. For anchors loaded axially, the linear portion of the anchor response extended from the unloaded position to failure. For anchors used with stabilizer plates, the linear portion began only after the anchor shaft contacted the stabilizer plate.

The slope of each linear portion of the anchor response curve was determined graphically. The slope, with units of force/displacement (pounds/inch), was determined for each anchor.

Tables 7-2 and 7-3 contain the test results for dry site anchors and wet site anchors, respectively.

Table 7-2. Dry Site Anchor Data

	Anchor Stiffness (pound/inch)			
Anchor Style and Installation	**Min**	**Max**	**Average**	**Standard Deviation**
5-foot anchor installed at 45° and loaded axially	1,505	3,283	2,426	543
5-foot anchor installed vertically and loaded axially	1,774	6,639	3,801	1,394
5-foot anchor used with an 11-inch by 17-inch stabilizer plate	1,006	2,001	1,475	294
4-foot anchor with an 8-inch by 24-inch ABS stabilizer plate	1,019	2,612	1,721	497
4-foot anchor used with an 11-inch by 17-inch stabilizer plate	817	1,614	1,197	257

Table 7-3. Wet Site Anchor Data

Anchor Style and Installation	Anchor Stiffness (pound/inch)			
	Min	Max	Average	Standard Deviation
5-foot anchor installed at 45^{o} and loaded axially	2,874	9,019	5,506	1,829
5-foot anchor installed vertically and loaded axially	2,166	6,581	4,112	1,391
5-foot anchor used with an 11-inch by 17-inch stabilizer plate	833	1,412	1,094	193
4-foot anchor with an 8-inch by 24-inch ABS stabilizer plate	655	2,006	1,538	370
4-foot anchor used with an 11-inch by 17-inch stabilizer plate	1,024	1,894	1,319	300

7.3 Acceptable Performance and Design Values

Historically, design values were determined by dividing the mean value by a safety factor. In structural components, a safety factor of 4 or 5 was used, depending on the type of component application, type of loading (static, dynamic), etc.

Currently, a more statistical approach that utilizes probability concepts is typically used. In July 1991, the International Council of Building Officials (ICBO) adopted a significantly revised "AC01 Acceptance Criteria for Expansion Anchors in Concrete and Masonry Elements." The standard uses a fractile concept in calculating design loads. Similar approaches are used in ASTM standards. For example, a 5 percent fractile load for anchors is the load where 5 percent of anchors perform below that load and theoretically fail. Conversely, 95 percent of the anchors perform above that design load and theoretically would not fail.

Typically fractile loads are set at percent. In critical applications or where a single failure could cause disproportionate damage, a 1 percent fractile or even 0.1 percent fractile is often used.

The statistical approach to determining appropriate design values also involves a confidence factor. Simply stated, the confidence factor indicates the confidence of using test results from a finite sample (in our case 12 anchors) to predict future performance.

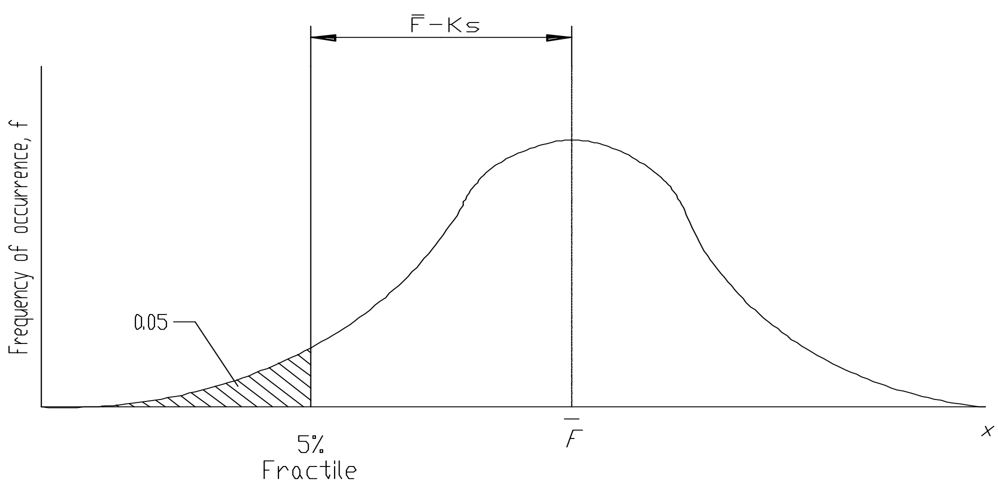
Both fractiles and confidence factors are used to scale the calculated standard deviation. The scaled standard deviation is then subtracted from the calculated mean to determine the design value.

Mathematically:

$$\text{Design} = F - Ks$$

Where K is tabulated and based on the desired fractile point and confidence for the number of data points used in the test.

Graphically:



7.4 Recommended Design/Performance Criteria

Anchor performance values were developed statistically. Anchor performance was assumed to follow a Normal (or Gaussian) Distribution function and design stiffness values were selected that provide a 90 percent confidence level that less than 10 percent of individual anchors would provide resistances less than design values. This level of statistical performance is less conservative, but similar to statistical performance levels applied to other structural materials like steel or concrete.

The lowest stiffness values from the dry and wet sites where selected for design. Generally, dry site values controlled for axial pull anchors and saturated site anchor values controlled for anchors used with stabilizer plates. Table 7-4 lists the recommended design stiffness for the anchors tested.

Table 7-4. Recommended Design Stiffness for Tested Anchors

Anchor Style and Installation	Anchor Design Stiffness (pound/inch)	Controlling Soils
5-foot anchor installed at 45^{o} and loaded axially	1,200	dry
5-foot anchor installed vertically and loaded axially	1,010	dry
5-foot anchor used with an 11-inch by 17-inch stabilizer plate	675	wet
4-foot anchor with an 8-inch by 24-inch ABS stabilizer plate	708	wet
4-foot anchor used with an 11-inch by 17-inch stabilizer plate	659	wet

With a 3-inch displacement, the axially loaded anchors provide working loads greater than the 3,150 pound loads required by HUD (e.g., 1,200 /inch x 3 inches = 3,600 pounds). However, the anchors with stabilizer plates provide only two thirds of the HUD required capacity.

Chapter 8: Methods for Mitigating Flood Hazards

The ideal site to locate a manufactured home is one where there is little or no danger of flooding. For structures already installed in flood-prone areas, the best way to avoid damages and safety issues posed by flooding is to relocate them outside of the flood-prone area.

If a manufactured home is to be located in a flood-prone area, it will be necessary to decide the best course for mitigating flood damage to the structure. A new manufactured home located in a floodplain must be elevated above the base flood elevation and should be sited in an area where access to and from the structure will be minimally affected by flooding. Similarly, for retrofitting manufactured homes installed in the floodplain prior to a community's participation in the NFIP (pre-FIRM), elevating the home above the BFE will help to meet post-FIRM building requirements.

8.1 Elevation

8.1.1 Elevation on Fill

When permitted under applicable Federal, state, and local laws, ordinances, and regulations, earthern fill is sometimes placed in Special Flood Hazard Areas to reduce the flood risk to the filled area. Under certain conditions, when engineered earthern fill is placed within an SFHA to raise the surface of the ground to or above the BFE, a request may be submitted to FEMA to revise the FIRM to indicate that the filled land is outside of the SFHA. When such revisions are warranted, FEMA usually revises the FIRM by issuing a Letter of Map Revision based on the fill (LOMR-F).

Although a structure built on a site that has been elevated by the placement of fill may be removed from the SFHA by FEMA, the structure may still be subject to damage during the base flood and higher-magnitude floods. Constructing the entire structure at or above the level of the BFE will minimize the flood risk from the base flood and is therefore the most prudent approach to constructing on fill.

The NFIP prohibits the use of structural fill for support of buildings in V-Zones. In addition, it is recommended that structural fill not be used to elevate buildings constructed in A-Zones in coastal areas. The NFIP will not remove land from the floodplain based on placement of fill in alluvial fan flood hazard areas.

Placement of fill in a SFHA can result in an increase in the BFE by reducing the ability to convey and store floodwaters. This can result in increased flood damage to both upstream and downstream properties. To prevent these possible results, some communities prohibit fill, require compensatory storage for filled areas, and/or identify a more restrictive floodway.

Placing the manufactured home on fill, to elevate the lowest floor or lowest level above the flood level, is generally an acceptable flood mitigation technique. However, if floodwater velocities are expected to exceed 10 feet per second, erosion of fill becomes a major concern. Therefore, this technique should not be used where high floodwater velocities are expected. An example of this technique being used is shown in Figure 8-1.

Figure 8-1. Manufactured home installed on earth fill elevated building pad.

[Note - this picture is probably not of adequate quality for publication production – 134KB jpeg. Try using graphic in j:\env\2800 TARC\021 Image Database\Images\247.]

Using fill allows the manufactured home to be placed a short distance from the ground, which facilitates easy access to the home. In some cases, it also allows the site to be "tied-in" to higher ground, improving the accessibility to and from the site during a flood event.

Care must be exercised in the installation of ground anchors in earthern fill sites. The ground anchor manufacturer's installation manual recommends that at least 1/3 of the ground anchor should be in undisturbed soil. For earthern fill sites, the height of the fill must be taken into account in selecting the proper length of the anchor for the home. In addition, since consolidation of fill material will occur, it maybe necessary to periodically tightened the anchors after the home has been installed.

Before placing earth fill on the site where the manufactured home is to be installed, the area to be filled and a zone of 5 feet on each side of this area should be cleared of standing trees and snags, stumps, bush, down timber, other vegetation, and all objects on or above the ground surface or partially buried. The area should also be stripped of topsoil and debris.

The safest methods of constructing a home on filled land removed from SFHA are those that result in the entire home being above the BFE. Methods that place the lowest floor of the home at, rather than above, the BFE is at greater flood risk, and methods that result in the lowest floor below the BFE have the highest flood risk of all.

The earth fill material must be homogeneous and isotropic. There must be a granular drainage layer beneath the floor slab. The fill should be placed in layers not to exceed 8 inches in depth with each layer being compacted with rollers or vibrating compacting equipment. Each layer of fill should be compacted to at least 95 percent of Standard Laboratory Maximum Dry Density (Standard Proctor), according to ASTM Standard D-798. Fill selection and placement should consider the effects of saturation from floodwaters on slope stability, uniform and differential settlement, and scour potential. Soil saturation and anticipated velocity of floodwaters will also have to be given careful consideration when earth fill is selected and placed. The minimum distance from any point of the building perimeter to the edge of the fill slope should be either 5 feet or twice the depth of the fill at that point, whichever is greater.

Slopes for granular fills should be no steeper than 1½ feet horizontal to 1 foot vertical, unless data justifying steeper slopes are developed. For slopes exposed to flood velocities of less than 5 feet per second, grass, vine cover, weeds, bush, and similar vegetative undergrowth will provide adequate scour protection. For velocities up to 10 feet per second, stone or rocks slope protection should be provided. Fill should not be used in areas subjected to velocities higher than 10 feet per second. Additionally, fill should not be used where it will constrict the flow of floodwater and cause increased flood elevations or velocity. In order to use it as a means of building elevation, the fill must be adequately compacted and graded. If earth fill is to be considered in conjunction with individual sewage systems, the local building department should be consulted, because additional fill will affect the absorption rate of the system.

8.1.2 Elevated Foundations

Elevated foundations allow a manufactured home to be placed in the SFHA and at the same time to be protected from floodwaters by preventing the actual structure from being exposed to floodwaters. However, the foundation itself is exposed to flooding and floodwater forces and must therefore be designed to withstand flooding.

8.1.2.1 Pier/Column Foundation

This type of foundation consists of the use of brick, concrete masonry units, or cast-in-place concrete with steel reinforcing bars for both the pier/column and the below-grade footing. Piers are an effective foundation technique for areas with flood depths of up to 10 feet. Piers can withstand lateral wind and water forces due to the reinforcing within the piers themselves, bracing attached to the piers, conventional anchoring, and below-ground embedment. Reinforcing bars must be continuous from the footings to the I-beam connections. However, because the ground around pier footings can be highly susceptible to erosion and scour, the footings must be embedded below the anticipated scour and erosion depth.

[Figure 8-2. Insert picture of pier/column foundation MH?? Try using graphic in j:\env\2800 TARC\010 Rewrite FEMA 85\Graphics\Georges Mfg Homes\5-27.]

8.1.2.2 Pile Foundation

Pile foundations provide protection for the broadest range of flooding conditions. This foundation system consists of the pile supports, horizontal beams, longitudinal support under the manufactured home, and foundation bracing for additional resistance to lateral wind and water loads. A properly designed pile foundation can withstand high wind and water velocities, and can resist scour and erosion around its base if embedded to an adequate depth. Saturated soils with low bearing capacity are less of a stability problem for a pile foundation than for a pier foundation and thus pile foundations are preferable in coastal areas. The design of pile foundations requires determining the number, size, length, and location of piles appropriate to the particular manufactured home, soil conditions, and flooding situation at the site. A pile design methodology is provided in FEMA's *Coastal Construction Manual* (June 2000) that requires input parameters, including soil property and loading information.

[Figure 8-3. Insert picture of pile foundation MH?? Use graphic in j:\env\2800 TARC\021 Image Database\Images\1 and 158.]

8.1.2.3 Extended Foundation Walls

A less-frequently-used elevation technique is to raise the manufactured home on extended foundation walls, often creating the appearance of a conventionally built home. The walls are usually either reinforced concrete block or poured concrete perimeter walls. This technique is permitted for manufactured homes in A-Zones under the NFIP as long as the foundation contains openings as required in 44 CFR 60.3 (c) (5) to equalize internal and external water pressures during flood conditions. It is very important that the extended foundation walls be sitting on a firm foundation. This elevation technique should not be used in high-velocity or highly erosive flood conditions (such as V-Zones). An example of this technique is provided in Figure 8-4.

Figure 8-4. A manufactured home elevated using the extended foundation wall technique.

[Note - this picture is probably not of adequate quality for publication production – 222KB jpeg. Use graphic in j:\env\2800 TARC\021 Image Database\Images\175 and 247.]

8.1.3 3-foot Pier Rule

The current floodplain management regulations covering manufactured home installation in flood hazard areas culminate a long history of coordination among FEMA, the manufactured housing industry, owners of manufactured homes and manufactured home parks, state floodplain managers, and local permit officials. FEMA's intent throughout the evolution of the regulations has been to minimize the potential damages to manufactured homes in flood hazard areas, while accommodating the concerns of park owners and individual homeowners.

From 1976 to 1986, manufactured homes placed in parks or subdivisions existing prior to the locality's adoption of floodplain management regulations were "grandfathered" into the NFIP, and thus were not required to be elevated to the BFE. The grandfather provision was rescinded in 1986 due to a new awareness of the high susceptibility of these housing types to damage from even low-level flooding, and increased knowledge of low-cost elevation techniques for manufactured housing.

Vigorous opposition to the removal of the grandfather provision resulted in the suspension of the 1986 rule while the effects of the provision's removal on homeowners, the industry, and the NFIP were investigated. The investigation culminated in a report to Congress in September 1988, *National Flood Insurance Program: Report on Existing Manufactured Home Parks and Subdivisions*. In this report, FEMA concluded that other actions could be taken to reduce losses of life and property that would have considerably less impact on owners and residents of existing manufactured home parks. FEMA proposed the 36-inch or 3-foot rule as an alternative to elevation to the BFE. The rule took effect on November 1, 1989.

The 3-foot rule was chosen for the following reasons:

- 36 inches is the maximum foundation height that a number of states allow without requiring an "engineered" foundation.

- Elevating homes to 36 inches provides additional flood protection with minimal impact on manufactured home and home park owners.

- Elevating to 36 inches should not result in financial or physical hardships for homeowners and park owners and park residents.

- Elevating to 36 inches protects an estimated 75 percent of manufactured homes vulnerable to 100-year floods.

As indicated above, many manufactured homes elevated only 3 feet above grade remain susceptible to flooding and flood damages from the 100-year flood event, as well as flood events with even higher frequencies.

Therefore, the NFIP and FEMA continue to strongly recommend elevating structures to the level of the BFE or higher.

8.2 Design Considerations

The 36-inch foundation height should be measured from the grade adjacent to the manufactured home to the top of the foundation pier where the manufactured home chassis is attached. If the site is uneven or sloped, the lowest adjacent grade is to be used to limit the maximum height of the piers to 36 inches. The 36-inch foundation combined with the manufactured home chassis and floor system will place the top of the floor approximately 4 feet above the lowest grade at the site. This is illustrated in Figure 8-5.

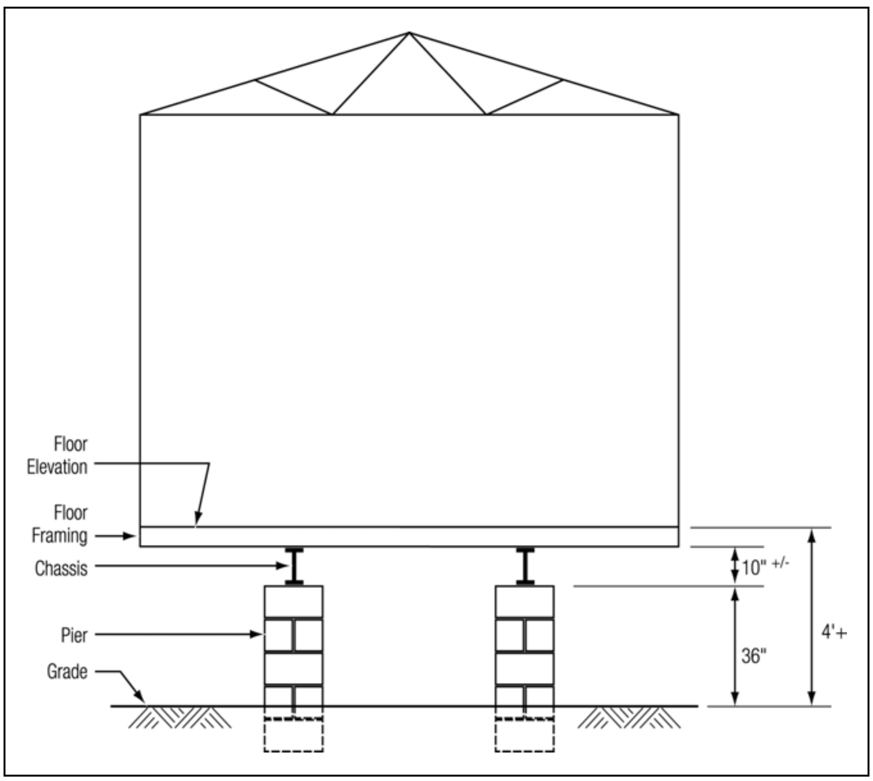


Figure 8-5. The 3-foot rule generally places a manufactured home's floor approximately 4 feet above grade.

8.3 Existing Homes

Clearly, the best way to prevent damage to structures and to prevent loss of life and injury during a flood is to install manufactured homes outside of flood-prone areas. For those manufactured homes that are currently situated within the SFHA or adjacent flood-prone areas, retrofitting measures can be implemented to help to drastically reduce the flood vulnerability of the structures. For manufactured homes, relocation of the structure out of the floodplain is a viable option.

Manufactured homes are typically relatively easy to transport and can be moved from areas prone to flooding, to sites located outside of the flood hazard area. This not only allows the homeowner to prevent damage from occurring to the structure, but also provides peace of mind concerning safety risks and property damages due to flooding, as well as eliminating the requirement to have flood insurance.

Some issues to consider when evaluating relocation as a mitigation option are:

- Will it be cost-effective (cost of incurring damages vs. cost of preventing damages)?
- Is the structure in good enough condition for transporting it?
- Is the removal of existing utility connections easily done prior to transportation?
- Is there a suitable new site for relocation?
- Are utilities with similar connections available at the new site?
- Is there a moving route that will provide adequate clearance for transporting the structure?

Some issues that might be prohibitive to relocation for other structures, but are not generally things manufactured housing owners have to be concerned with, are listed below:

- Is there adequate space around the structure to allow for access for moving it?
- Is the structure transportable (size and shape can be prohibitive)?

The relocation process consists of nine steps that are fairly clear, but include many design considerations.

- Step 1. Selection of a house moving contractor
- Step 2. Analysis of existing site and structure
- Step 3. Selection, analysis, and design of new site

- Step 4. Preparation of the existing site
- Step 5. Analysis and preparation of the moving route
- Step 6. Preparation of the structure
- Step 7. Moving the structure
- Step 8. Preparation of the new site
- Step 9. Restoration of the old site

More information on relocation as a retrofitting technique can be found in FEMA's *Homeowner's Guide to Retrofitting* (June 1998) and *Engineering Principles and Practices of Retrofitting Floodprone Residential Structures* (June 2001).

Chapter 9: Foundation Systems

9.1 Introduction

When properly designed and constructed, manufactured home foundations can significantly reduce the potential for damages from flooding. Many styles of foundations are available for supporting manufactured homes. Continuous perimeter walls, constructed of concrete, masonry, or treated wood; concrete or masonry piers; wood posts; and pilings are some of the options available to a manufactured home owner and installer.

To be effective, manufactured home foundations must:

- Support the weight of the home, its contents, and its occupants
- Resist anticipated loading from natural events like wind, snow, seismic events, and moving floodwaters
- Elevate the home sufficiently to prevent losses from anticipated floodwaters

Elevated foundations can be classified as enclosed or open foundations. As the name implies, enclosed foundations enclose the basement or crawl space below the home. Perimeter masonry, concrete, or sheathed wood foundations are enclosed styles. Open foundations consist of a system of individual members that support the house only at discrete locations. Pier, post, and pile foundation systems are considered open systems. Many open foundations have non-structural skirting to enclose the space below the home. Because the skirting is non-structural, adding skirting does not create an enclosed foundation.

Selection of an appropriate foundation system depends on a number of variables, including hydrological factors, siting, cost, loading conditions, availability of materials, soil characteristics, and local construction practices. Whatever foundation system is chosen, the NFIP requires a foundation to resist flotation, collapse, or lateral movement during a design event to prevent damages to the home and surrounding structures.

With few exceptions, the NFIP does not allow basements to be constructed in floodplains. Also, because homes located in Coastal V-Zones are exposed to breaking waves over 3 feet high, foundations in V-Zones must be open style and any skirting or other materials installed to enclose the space below the home must be designed and constructed as breakaway walls. FEMA 55*, The Coastal Construction Manual*, contains information on designing and constructing breakaway walls.

In Coastal A-Zones and in areas exposed to riverine flooding, enclosed foundations are not prohibited. However, because they can still be exposed to scour, hydrodynamic forces, hydrostatic forces, and, in the case of Coastal A-Zones, breaking waves, enclosed foundations must be heavily reinforced to resist those phenomena. Because the loads on an open foundation are substantially less, open style foundations style should be selected in Coastal A-Zones and all areas exposed to fast moving floodwaters.

Proprietary systems are also an option for the manufactured home owner. Proprietary systems are not covered by this manual, but if a proprietary system is chosen, the system must meet the design and performance criteria described in Chapter 11 and the design should be sealed by a registered architect or engineer.

More information proprietary foundations are contained in the Manufactured Housing Research Alliance's (MHRA) publication *Guide to Foundation and Support Systems for Manufactured Homes* available at http://www.research-alliance.org/pages/foundations_guide.htm.

9.2 Enclosed Foundations

The perimeter wall foundation consists of continuous walls on continuous footings enclosing an area below the living space of the home (see Figure 9-1). Perimeter wall foundations can not be used in V-Zones characterized by high-velocity and/or wave action. This system is permitted for homes in A-Zones under the NFIP as long as the foundation contains openings to allow automatic entry and exit of floodwaters as required in 44 CFR 60.3 (c) (5) to equalize internal and external hydrostatic pressures during flood conditions.

Perimeter walls are commonly constructed of wood, concrete, or steel. Continuous wall foundations must be designed to withstand soil hydrostatic pressures as well as hydrostatic forces caused by standing water, which may require added reinforcement in the walls. This technique is permitted for homes in A-Zones under the NFIP as long as the foundation contains openings to allow automatic entry and exit of floodwaters as required in 44 CFR 60.3 (c) (5) to equalize internal and external hydrostatic pressures during flood conditions. This elevation technique can not be used in V-Zones characterized by high-velocity and/or wave action.

By regulation, homes placed outside of V-Zones may use enclosed foundations. However, in areas where floodwaters have velocity, the additional strength required to resist hydrodynamic forces may make enclosed foundation wall construction impractical.

Figure 9-1. Manufactured home with a perimeter wall foundation.

9.3 Open Foundations

The NFIP regulations require open foundations for buildings constructed in V-Zones. Buildings in A-Zones may be constructed on any foundation system. However, because of the history of observed damage in Coastal A-Zones, and the magnitude of the flood and wind forces that can occur in these areas, this manual recommends that only open foundation systems be constructed in Coastal A-Zones. Open foundations experience cyclic fluid impact and drag forces especially where breaking waves pass them. The waves flow peaks at its crest, just as the wave breaks. Although the flow creates drag on the foundation, most of the flow under the building is undisturbed. Open foundations become somewhat resistant to wave actions. This also makes pile and column foundations a manageable design. In a V-Zone, any enclosures constructed around the foundation must be designed as breakaway walls.

9.3.1 Pier Systems

A pier system consists of vertical structural members that typically rest on footings placed below the design frost level or, in areas exposed to moving floodwaters, below the anticipated scour depth (see Figures 9-2 and 9-3). Pier systems are typically placed under the manufactured home chassis supports, under large openings in exterior load bearing walls and under point loads along the marriage wall line.

Piers require footings to transfer the loads into the underlying soil. In conventional construction, piers are designed as independent supports primarily for vertical loading, to hold the weight of the house. They are not normally designed to resist large horizontal forces such as those associated with moving floodwater, waves, impacts from flood-borne debris, wind, and earthquakes. As a result, pier foundations are generally used where the risks of wave action and high-velocity flow are low and the potential for earthquake is low. To achieve a higher resistance to lateral and uplift forces, pier systems are often anchored or braced.

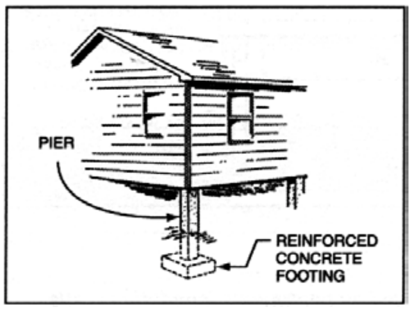


Figure 9-2. Manufactured home with a pier system foundation.

Figure 9-3. Manufactured home with a pier system foundation.

In areas exposed to moving floodwater, special consideration must also be given to controlling scour around the pier foundations elements. Moving floodwaters can dislodge all soils. Fine cohesionless soils like sands are particularly vulnerable.

Floodwaters with higher flow rates and floodwaters that are turbulent cause more scour than low laminar flood flow. Because of this, scour is particularly damaging where floodwaters converge or abruptly change direction. Scour is generally greatest around discrete interior piers and the corners of continuous foundations.

Scour can undermine foundation elements and destroy the load bearing capacity of the affected foundation elements. If scour only affects one or two supports, damage may be limited to localized settlement in the home. If multiple supports are compromised, total collapse can occur.

When foundation elements support vertical loads only, mitigation for scour can be as straightforward as placing foundation elements below the maximum predicted scour depth. When foundation elements must provide a moment connection (e.g., like a flagpole), foundation elements must be placed even deeper so that not only is foundation undermining prevented, but sufficient soil cover remains to prevent piers from toppling after moving waters have washed away the upper layers of soil.

Piers are commonly constructed of brick, reinforced or unreinforced concrete masonry units (CMUs), or cast-in-place concrete. When the piers must provide moment or uplift resistance, the piers must be grouted and firmly attached to the supporting footings.

9.3.1.1 Reinforced Piers

Reinforced piers typically have steel reinforcements placed inside of the piers. The vertical reinforcing helps to prevent overturning, sliding and uplift due to wind, seismic, or flood forces. Reinforced pier systems are commonly constructed of CMUs, pre-cast concrete, and cast-in-place concrete (see Figure 9-4).

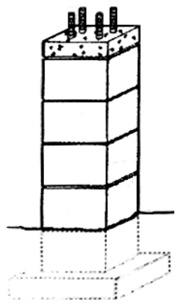
Even when grouted and reinforced, piers, by themselves, provide only limited resistance to lateral forces. In high-wind areas and in areas exposed to seismic or hydrodynamic loads, piers may require much larger footings or methods to laterally brace the piers may be required.

Adequate connections between the piers and the manufactured home are also necessary so that the manufactured home and its foundation will resist lateral and uplift loads from flood, wind, and earthquakes. Generally, multiple fastener bolted connections are needed to connect the top of the piers to the manufactured home frames when the piers must transfer moments. If the piers must resist only uplift loads, fastening requirements may be simplified. Regardless of the complexity of the connection, the manufactured home manufacturer must be consulted to ensure the factory built components are not overloaded.

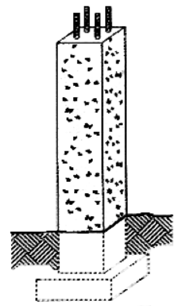
Figure 9-5 shows a method used to fasten a home’s steel frames to reinforced masonry piers using nuts, steel plates, and bolts grouted into the piers.

CMU Reinforced Piers

Depending on their size, reinforcement, and soil conditions, CMU piers are generally effective for elevations up to 10 feet, as long as adequate lateral and uplift resistance can be provided. Height should generally be limited to a maximum of ten times the smallest dimension of concrete. block piers.



Reinforced Masonry Pier



Reinforced Concrete Pier

Figure 9-4. Reinforced piers.

(Modify figure to show MH frame - similar to Figure 6.2.3.2.1.1 (a) of MHCC Installation Standards)

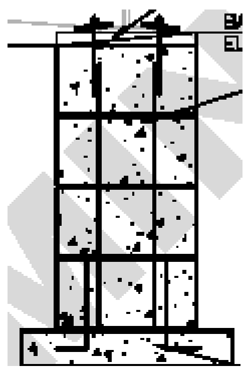


Figure 9-5. Bolted connection between frame and reinforced pier.

9.3.1.2 Unreinforced Pier Systems

Unreinforced brick or CMU pier systems have no reinforcing steel and therefore have only limited resistance to overturning and shearing. Many styles of unreinforced piers are used to support manufactured homes; the styles provide varying degrees of strength to resist loads on the home. These systems can be constructed without mortar (called dry stacked masonry), with dry stacked block lightly secured with a surface bonding material, with mortared block, or with fully grouted mortared block.

Dry stacked block piers (see Figure 9-6) offer relatively good strength for vertical loads, but are inherently weak in resisting lateral loads. Because of this, dry stacked piers should only be used when other foundation components (like ground anchors) are in place to resist lateral loads. Even when used with other foundation components, dry stacked piers remain vulnerable to damage from moving floodwaters and therefore should only be used in areas exposed to limited flood depths and velocities. When placed directly on concrete footings or pads, 3-foot tall piers constructed with dry stacked blocks can only resist flood velocities of approximately 1½ feet per second.

Applying surface bonding materials strengthens the piers slightly by increasing their shear resistance. However, surface bonding does almost nothing to improve their resistance to bending moments from lateral loads so surface bonded piers still need to be used with other foundation components. The increased shear resistance allows 3-foot tall piers to resist hydrodynamic loads from floodwaters moving at approximately 2½ feet per second. This resistance to moving floodwaters can only be achieved when the surface bonding materials not only bond the individual pier blocks to each other, but also the pier to the concrete footing below.

Figure 9-6. Manufactured home with an unreinforced pier foundation. Try using graphic in j:\env\2800 TARC\010 Rewrite FEMA 85\Graphics\Georges Mfg Homes\5-18.

Mortared block and fully grouted mortared block are much stronger than dry stacked and surface bonded piers, but their strengths still do not approach that of even a lightly reinforced pier. Mortared and fully grouted piers usually require other foundation components (like shear walls) to resist lateral loads.

Reinforced piers (constructed by introducing reinforcing steel to fully grouted piers) can be made to resist lateral and vertical loads when used with other foundation components like large concrete footings.

Piers exposed to moving floodwaters need to resist the shear forces caused by hydrodynamic loading. Because dry stacked block only resists shear forces through friction, they should not be exposed to moving floodwaters that create lateral forces greater than friction forces and should only be used in areas exposed to nearly stillwater flooding.

All unreinforced piers (even fully grouted piers) should not be used in V-Zone and Coastal A-Zones and are only appropriate in areas with low to moderate floodwater velocity.

9.3.2 Posts

Posts are set in holes and their ends are usually encased in concrete, or supported on concrete bearing pads (see Figures 9-7 and 9-8). Posts are set in hand and/or machine excavated holes. Machine excavation is generally required when holes are deeper than 6 feet. In order to allow for proper backfilling, post holes should be a minimum of 8 inches larger than the greatest dimension of the post. The bearing pad should have a diameter at least twice the post diameter and be one post diameter thick. It is recommended that a minimum of 8 inches in thickness be used for post diameter.

Posts are generally used where risks of wave action and high-velocity flow are low to moderate.

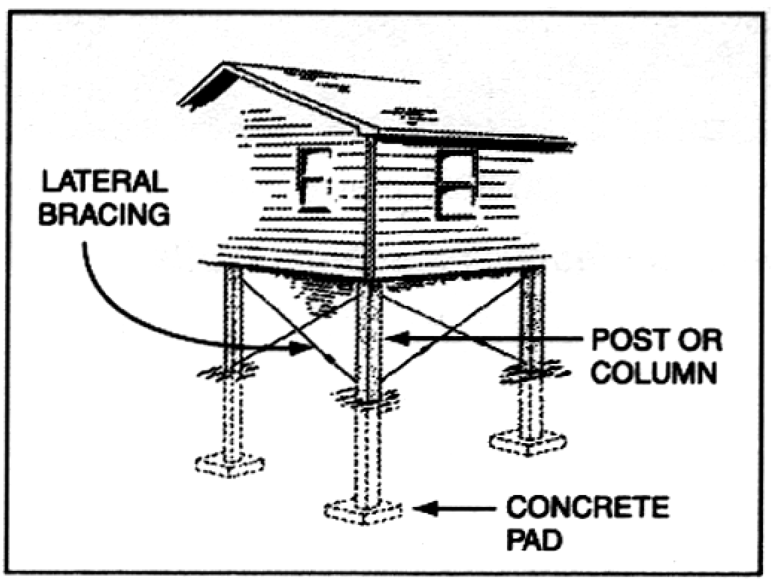


Figure 9-7.

Figure 9-8. Manufactured home with a post foundation.

9.3.3 Pilings

Pile foundation systems typically consist of the pile supports, horizontal framing members to support the manufactured home, and lateral bracing for additional resistance to floodwater, lateral wind, and seismic loads.

Pilings are vertical supports similar to posts, but differ in the method and depth of placement. Pilings are typically embedded deeper in the ground than posts and do not rest on footings (see Figure 9-9). Instead the pilings are driven until they rest on a solid support layer, such as bedrock, or until they are embedded enough that the friction between the ground and the pilings will enable them to resist the loads that are expected to act on them.

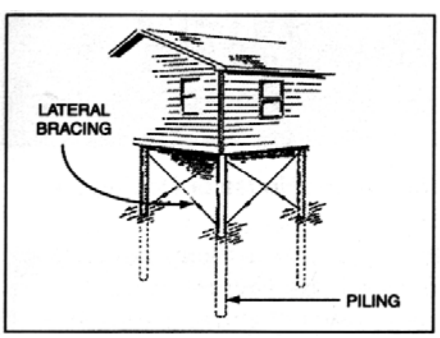


Figure 9-9. Piling foundation.

Piles are made of wood, steel, or reinforced concrete; the most common type is the elevated wood pile foundation. Piling foundations are primarily used in areas where other elevation methods are not feasible, such as oceanfront areas where floodwaters are deep and risks of wave action and high-velocity flow are great (see Figure 9-10).

Figure 9-10. Manufactured home with a piling foundation.

A major consideration in the effectiveness of pile foundations is the method for installing the piles into the ground, which can influence the pile load capacity.

Piles are placed into the ground by impact driving, water jetting, augering, or some combination of these methods (see Figure 9-11). Piles are often driven by a mechanical single- or double-acting hammer. Pile driving is an excellent method due to the strength of the pile and the ability of the pile and its earth interface to resist vertical and horizontal loads.

Wood piles can be damaged by driving the piles into the ground.

A less desirable method, which is frequently used, is "jetting." Jetting is a method of inserting piles into sandy soil and involves forcing a high-pressure stream of water through a pipe along the side of the pile. The stream of water will force a hole in the sand, while the pile is continuously pushed or dropped to the desired penetration. The result of jetting is a lower load capacity due to loose soils, which creates decreased friction between the piles and the surrounding soil. Jetted piles must be inserted deeper into the ground than driven piles in order to achieve the same load capacity.

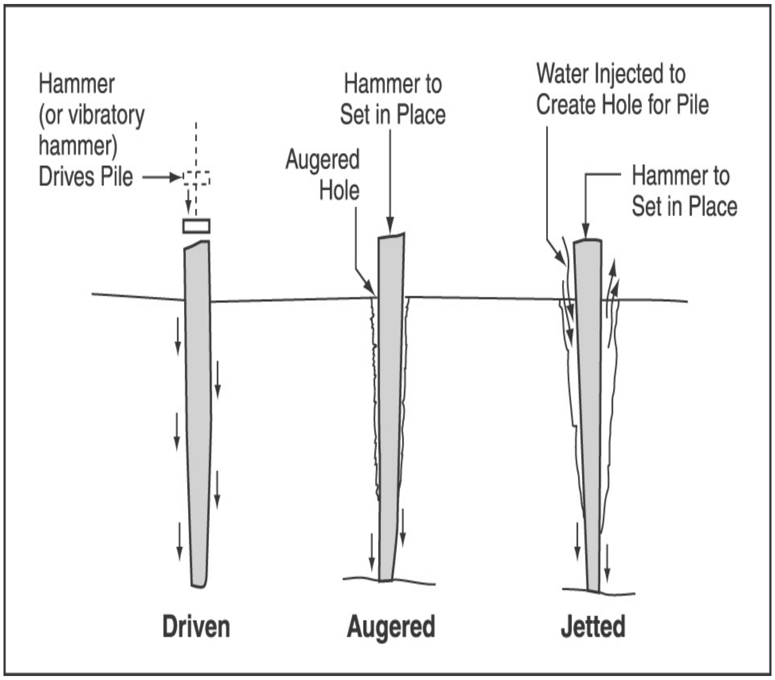


Figure 9-11. Pile driving methods.

Another method is the use of an auger to create holes for piles. If the soil is composed of sufficiently clay or silt, the use of an auger to create holes for piles is sufficient. Additionally, some sands may contain enough clay or silt to permit the use of an auger. This method can be used by itself or in conjunction with pile driving.

Table 9-1 lists advantages and considerations for each pile installation method.

Table 9-1. Advantages and Disadvantages of Various Pile Installation Methods

Pile Installation Method	Advantages	Special Considerations
Driven	• Well suited for friction pile • Common construction practice • Pile capacity can be determined empirically	• Difficult at times to reach terminating soil strata, which is not necessary for friction piles • Difficult to maintain plumb during driving and thus maintain column lines
Augered	• Economical • Minimal driving vibration to adjacent structures • Well suited for end bearing • Visual inspection of some soil stratum possible • Convenient for low headroom situations • Easier to maintain column lines	• Requires subsurface investigation • Not suitable for highly compressible material • Disturbs soil adjacent to pile, thus reducing earth pressure coefficients k_{HC} and k_{HT} to 40 percent of that for driven piles • Capacity must be determined by engineering judgment or load test
Jetted	• Minimal driving vibration to adjacent structures • Well suited for end bearing • Easier to maintain column lines	• Requires subsurface investigation • Disturbs soil adjacent to pile, thus reducing earth pressure coefficients k_{HC} and k_{HT} to 40 percent of that for driven piles • Capacity must be determined by engineering judgment or load test

Pile driving, jetting, and, to a lesser extent, auguring places piles in inexact locations. Also irregularities in the piles and soil will often prevent the piles from being driven perfectly plumb. In site built construction, those inherent irregularities are easily addressed by modifying floor framing. When using pilings to support manufactured housing, wood frames are typically site built and secured to the pilings and the home itself is then secured to the site built frames.

9.4 Foundation Enclosures and Breakaway Walls

When a wave hits a solid wall, a pocket of air is trapped and compressed by the wave when the crest of a breaking wave impacts a vertical surface. As the air pocket compresses, it exerts a high-pressure burst on the vertical surface, centered at the stillwater level. These extremely high loads make the design of solid foundation walls impractical in areas subject to the effects of breaking waves. Breakaway walls are designed and constructed to fail under the loads imposed by floodwaters. Because such enclosures will fail under flood forces, they will not transfer additional significant loads to the foundation (see Figure 9-12).

Figure 9-12. Breakaway walls.

9.5 Bracing

Bracing distributes lateral loads, such as flood, wind, and seismic loads, to the vertical support members by tying various members together. They are there to provide additional stability to the system. The two most common bracing techniques used are diagonal bracing and knee bracing.

Diagonal bracing runs diagonally from one vertical supporting member to another, stiffening the vertical supporting members and increasing their strength and lateral stability (see Figure 9-13). Unfortunately, the cost of greater strength is a larger exposure to wave and debris impact. Diagonal bracing is typically too slender to resist compressive forces and is typically only designed to carry tension forces. This technique of bracing is especially beneficial in higher elevated homes.

Figure 9-13. Manufactured home with diagonal bracing.

Steel rods can be used to diagonally brace wood posts or piles. The rods are fitted through drilled holes filled with wood preservative and fastened with nuts and cast beveled washers. Welded connections or drilled holes can be used to provide rod bracing in steel post or pile foundations.

Knee bracings are short diagonal braces that run from a vertical support member to a horizontal support member (see Figure 9-14). Unlike diagonal bracing, knee bracing is designed to resist both tension and compression loads. Their advantage over diagonal bracing is they provide less obstruction to floodwaters, waves (in coastal construction), and debris.

Figure 9-14. Knee bracing.

9.6 Footings

The size of a pier footing is a direct function of soil bearing capacity and loading. The depth of the footings depends on local frost levels and expected scour depths (whichever is greater). Specific requirements for the size and depth of footings based on local soil conditions may be provided by local codes.

9.7 Anchoring

Anchoring is intended to ensure that the manufactured home does not become dislodged from the elevated foundation due to uplift or lateral loading. Anchoring is most typically used for pier system foundations. There are two general methods for anchoring: anchoring into the ground or anchoring into a concrete mass. Techniques and considerations for anchoring are covered in Chapter 7.

9.8 Foundation Materials Selection

The use of flood-resistant materials below the BFE is covered in FEMA NFIP Technical Bulletin 2.

As stated in Section 60.3(a)(3) of the NFIP regulations, all structural and non-structural materials at or below the BFE must be flood-resistant. A flood-resistant material is defined as any building material capable of withstanding direct contact with floodwater for 72 hours without sustaining significant damage (i.e., damage requiring more than low-cost cosmetic repair, such as painting). In addition, materials should be resistant to decay and corrosion and be durable.

Some flood-resistant foundation material choices include:

- Pressure-treated lumber
- Naturally decay-resistant lumber (only for applications above grade)
- Concrete – 5,000 lb/in^2 minimum compressive strength recommended in coastal environments, with a 0.4 water-cement ratio
- Masonry – reinforced and fully grouted in coastal environments
- Steel – must resist corrosion
- Closed-cell foam insulation
- Other flood-resistant materials approved by local building officials

The most commonly used foundation materials are wood, concrete, steel, and masonry. Their properties, advantages, and special considerations are discussed below. Additional information on materials durability can be found in FEMA's *Coastal Construction Manual* (June 2000), and trade organization publications.

9.8.1 Wood Foundations

Wood is a very workable material and one of the most cost-effective. Wood is susceptible to decay, insect infestation, marine borers, and weathering, and must be adequately maintained to ensure the foundation's integrity (see Figure 9-15). All wood used in foundation piles, girders, beams, braces, and walls must be pressure-preservative-treated or, when allowed and not in direct contact with the ground, naturally decay-resistant wood. No wood with natural resistance to decay is considered to have sufficient decay resistance for ground contact or partial water immersion.

Wood exposed to the ground and exterior elements should be pressure-preservative treated to increase its resistance to infestation and decay. The degree of resistance depends on the treatment chemical and the amount of retention in lb/ft^3 of wood.

The preservatives commonly used in pressure treating wood are:

- Waterborne arsenicals, such as copper chromium arsenic (CCA) and ammoniacal copper zinc arsenate (ACZA)
- Waterborne products without arsenic compounds, such as alkaline copper quaternary (ACQ)
- Oil-borne products such as copper napthenate and copper-8 quinolinolate
- Oil-borne pentachlorophenol
- Creosote

Designers and builders considering the use of ACQ- or ACZA-treated wood should consider using stainless steel hardware and fasteners or obtain the latest information on the chemicals' interaction with hardware due to reports of alleged problems with corrosion of galvanized framing hardware and nails in contact with wood treated with these chemicals.

Figure 9-15. Wood foundation.

9.8.2 Concrete Foundations

Concrete is a very economical and workable foundation material and extremely good at resisting compressive loads. Concrete can be reinforced to increase its ability to withstand tensile loads that often result from flood, wind, and seismic activity. Corrosion of the reinforcement and the cracking of the concrete weaken the concrete structural element, reducing its ability to resist loads. Providing adequate concrete cover to reinforcement is the best defense against corrosion. Consult the latest version of ACI 318 for minimum concrete cover requirements. Additional protection from corrosion can be achieved by using epoxy coated reinforcement.

Section 7.7 of the ACI Building Code Requirements for Structural Concrete, ACI 318-02 (ACI 2002), specifies minimum amounts of concrete cover for various construction applications.

Proper placement, mixing, and curing are essential for durable concrete. During placement, concrete will normally require vibration to eliminate air pockets and voids in the finished surface. The vibration must be sufficient to eliminate the air, but not to separate the concrete or water from the mix. The International Building Code (IBC) gives requirements for more durable concrete mixes with lower water-cement ratios and higher compressive strengths to be used in a salt water environment. The concrete mix water-cement ratio required by the IBC or by the design should not be exceeded by the addition of water at the site. Appropriate freeze protection may be needed if pouring is done in cold temperatures. Concrete placed in cold weather takes longer to cure, and the uncured concrete may freeze, which will adversely affect its final strength. Methods of preventing concrete form freezing during curing include the following:

- Heating adjacent soil before pouring
- Warming the mix ingredients before batching
- Placing insulating blankets over and around the forms after pouring
- Selecting a cement mix that will shorten curing time

Because the environmental impact of salt-laden air and moisture make the damage potential significant for concrete, this manual recommends that all concrete construction in and near coastal flood hazard areas (both V- and A-Zones) be built with the more durable 5,000-pounds per square inch (psi) minimum compressive strength concrete regardless of the purpose of the construction and the design loads.

[Insert Graphic for Concrete Foundations for MH]

9.8.3 Steel Foundations

Prefabricated steel stands are available for use in supporting manufactured housing. Like unreinforced masonry piers, steel stands have little resistance to overturning and should only be used in conjunction with other foundation components like ground anchors or perimeter shear walls. Metal stands should also be firmly secured to the homes frames.

9.8.4 Masonry Foundations

Open masonry foundations in earthquake hazard areas require special reinforcement detailing and pier proportions to meet the requirements for increased ductility.

The combination of high winds and moist (sometimes salt-laden) air can have a damaging effect on masonry construction by forcing moisture into the smallest of cracks or openings in the masonry joints and can cause cracking and spalling of the masonry. The entry of moisture into reinforced masonry construction can lead to corrosion of the reinforcement and additional cracking and spalling of the masonry. Moisture resistance is highly influenced by the quality of the materials and the quality of the masonry construction at the site. For CMUs, choosing Type I "moisture controlled" units and keeping them dry in transit and on the job will minimize shrinkage and cracking. For optimum crack control use, Type S mortar should be used for below-grade applications and Type N mortar used for above-grade applications. The IBC specifies grout proportions by volume for masonry construction.

Reinforced masonry has much more strength and ductility for resisting large flood, wind, and earthquake forces than unreinforced masonry. It is recommended that permanent masonry construction in and near coastal flood hazard areas be fully or partially reinforced and grouted solid regardless of the purpose of the construction and the design loads.

Chapter 10: Pre-engineered Foundations

Six pre-engineered foundations suitable for use in many Special Flood Hazards Areas in the United States are presented in this manual. These pre-engineered foundations can be used for sites in A-Zones with low to moderate floodwater velocities and depths. They are not suitable for V-Zones, Coastal A-Zones, and home sites in floodways or other high velocity areas.

Although the designs can be used in many flood areas, they are not "all inclusive" and do not provide a "one-size-fits-all" design. Because natural loads vary greatly from site to site, any single design may either be overly conservative in some areas, but would provide inadequate protection in other areas.

Criteria used in the design of the pre-engineered foundations were selected to provide a balance between cost and applicability. Homes placed in areas where anticipated events exceed the design criteria used will require custom designed foundations.

10.1 Design Criteria

The following criteria were used in developing the pre-engineered foundations. A professional engineer should design the foundation for sites that have design criteria in excess of those listed below:

- Maximum flood depths of 36 inches above finished grade with floodwaters not rising above the bottom flanges of the home's I-beam.
- Maximum flood velocities of 5 feet per second with no breaking wave forces.
- Wind speeds of 90 mph, 125 mph, and 140 mph (3-second gusts) corresponding to HUD's wind zones I, II, and III.
- Manufactured home widths of 14 feet for single units and 28 feet for double units, and lengths of 60 feet for both single and double units.
- Manufactured home eave heights up to 8 feet 2 inches.

- Manufactured home frame spacing 96 inches or greater.

- Maximum ground snow loads of 40 psf.

- Manufactured homes weighing more than 25 psf.

- The designs specifically exclude V-Zones, Coastal A-Zones, and home sites in floodways and where flood velocities exceed 5 feet per second.

- The designs are applicable for manufactured homes located in areas with seismic spectral acceleration constants S_S less than 0.5g or S_1 less than 0.15g. S_S is defined as the mapped maximum considered earthquake, 5 percent damped, spectral response acceleration at short periods as defined in Section 9.4.1.2 of ASCE 7-02. S_1 is defined as the mapped maximum considered earthquake, 5 percent damped, spectral response acceleration at a period of 1 second as defined in Section 9.4.1.2 of ASCE 7-02. g is the acceleration due to gravity.

All foundations have been designed to resist loads calculated using ASCE 7- 02, Minimum Design Loads for Buildings and Other Structures. ASCE 7-02 is a nationally recognized state-of-the-art engineering standard and is referenced by most model building codes, including the International Building Code, the Standard Building Code, the Uniform Building Code, and NFPA 5000. Where additional design guidance was needed, other documents have been used, including FEMA 55, *The Coastal Construction Manual.*

A brief description of each design follows:

10.1.1 Reinforced Masonry Perimeter Foundation Walls (Drawing Numbers: M-1 - M-4)

The reinforced masonry (RM) foundation consists of reinforced masonry walls constructed over continuous poured concrete strip footings. The foundation encloses the underside of the manufactured home and creates a crawl space for mechanical equipment. The RM foundation is similar to foundations constructed for site-built homes. Footings, somewhat larger than those found under site built homes, are used to provide the necessary weight to adequately resist overturning.

Flood vents, required by the NFIP, are spaced throughout the foundation walls. The flood vents are designed to open automatically to allow floodwater to enter the crawl space. Floodwaters entering a crawl space equalize hydrostatic pressures on the home, which reduces lateral forces on the foundation walls and buoyancy on the walls and home. The flood vents also provide ventilations for crawl space moisture control. Two significant differences exist between vents installed for floodwater and moisture control ventilation and vents installed only for moisture control. One, flood vents must automatically open to allow floodwaters to flow. Typical crawl space vents must be manually opened. And two, flood vents must be installed near the bottom of the foundation wall (the NFIP requires the bottom of the vent to be within 1 foot of grade). Vents for moisture control are typically installed at the top of the foundation wall.

The RM foundation is ideal for a foundation that requires little or no maintenance. It is also ideal for installations where replicating site-built housing is desired. In most areas, RM foundations will be the most expensive of the pre-engineered foundations that have been developed.

The difficulties of properly grouting the masonry wall cores after a home is placed will likely require homes to be crane set on the RM foundation. Crane setting allows the entire foundation walls to be constructed and reinforced prior to placing the home.

The RM foundation wall requires some custom features to be built into the home. The steel outriggers that extend outward from the home's I-beam frames must be fabricated shorter than for standard set homes to prevent interferences with the foundation wall. Also, provisions must be made to allow the perimeter of the home to be site connected to the foundation. These connections may be provided for having a pressure treated sill plate fabricated with the home and providing adequate connections between the sill and the rest of the structure to resist vertical and lateral forces. An alternate method of connecting the home to the foundation is to site-install the sill plate and use galvanized framing clips to connect the site-installed sill to the factory fabricated band joist. That connection method is best made by waiting until the home is placed before installing the lower two to three rows of siding.

Final connections between the factory-built home and the site-built foundation are made by bolting the home to the foundation wall anchor bolts (if an adequately attached pressure treated sill plate is provided with the home) or by anchoring a pressure treated sill to the foundation wall and installing framing clips between the site installed sill plate and the home's band joist (if a pressure treated sill is not provided with the home).

10.1.2 Wood Framed Perimeter Foundation Walls (Drawing Numbers: WF-1 – WF-4)

The wood framed (WF) foundation consists of 2 by 6 treated framing sheathed with plywood that is treated to resist rot and wood destroying insect damage.

The wood frame foundation walls are constructed over continuous poured concrete strip footings. Like the masonry foundation, the WF foundation encloses the underside of the home to create a crawl space and flood vents are required to equalize hydrostatic loads and provide for crawl space moisture control. Because wood framed walls resist less shear per unit length than masonry, the WF foundation design requires interior shear walls to adequately resist lateral (wind, flood and seismic) loads. In higher wind zones, plywood sheathing is needed on both sides of the shear walls.

Unlike the RM foundation wall design, the WF foundation was designed to enable “building to the box.” Crane installations should not be necessary unless lots are relatively steep or other site complexities exist. Footings can be poured prior to placing the home (they can be constructed slightly wider to provide installation tolerance), the home can be rolled onto the sites, and the walls can be constructed between the factory-built home and the site-built foundation.

A home destined to be placed on a wood framed perimeter foundation will require some fabrication modifications. Most notable is the need to shorten outriggers to avoid interferences with the foundation wall. Shear reinforcement may be necessary to adequately transfer lateral loads from the home to the foundation.

10.1.3 Braced Masonry Pier Designs (Drawing Numbers: BM-1.1 – BM-2.2)

The braced masonry pier (BMP) designs utilize materials developed for ground anchors and materials found in more conventional foundations. The results are a foundation system that provides stiffness and strength approaching that of conventional foundations without the relatively high cost of conventional foundations.

The BMP designs use metal straps and masonry piers found in ground anchor foundations. But instead of using ground anchors to resist vertical and lateral loads, the weight of continuous concrete footings resist uplift and soil pressure, and friction forces resist lateral loads.

The BMP designs are intended to utilize conventional installation methods. The concrete footings must be poured prior to setting the home. The designs for all wind speeds offer flexibility in the placement of frame straps and piers and allow strap anchors to be cast into the concrete footings under the frames. The 125- and 140-mph designs require vertical ties to be placed where manufacturers install connection points. These can be cast into the perimeter concrete or, if site conditions prevent precise placement, anchors with expansion shields or epoxy set anchors can be used.

Masonry piers provide vertical support and their weight contributes to uplift resistance. Pier construction varies with flood velocity. With low flood velocities, piers can be dry stacked and adhered with surface bonded mortar. For increased flood velocities, piers with greater lateral strength are needed to ensure that they do not become dislodged under the combined effects of wind (or seismic) loads and flood loads. High flood velocities require that the masonry piers be reinforced, fully grouted, and anchored to the footings.

The metal straps are an integral component in the braced masonry foundation. Failure of any strap will force loads to be redistributed to adjacent portions of the foundation. If straps are loaded to their maximum working load, load redistribution can lead to progressive strap failure and home collapse. To reduce potential for progressive failure, redundant straps have been included in the designs.

10.1.4 Wood H-frame Designs (Drawing Numbers: HF-1.1 – HF-2.2)

The wood H-frame designs are similar to piling foundations used to elevate structures in coastal areas. The greatest difference between the H-frame designs and the coastal piling home foundations is that the weight of concrete footings is used to resist uplift and lateral forces instead of the friction between earth soils and pilings.

The designs are intended to allow setting the manufactured home on the site and constructing the H-frames from below. This "building to the box" provides flexibility in site construction, but some installers have expressed concerns regarding the amount of work required to be performed under the home. Temporary piers or metal jack stands can support the home during construction or all H-frames can be built and the home can be set with a crane.

A critical component to the H-frame designs is the post bases used to connect the vertical posts to the concrete footing. The design specifies cast in place bases that require they be accurately positioned during the concrete pour.

The fasteners used to construct the frames are sized to resist uplift and lateral forces only. They are not sized to support all gravity loads. Because of this, the posts must be constructed tight to the bottoms of the I-beam frames or provided with shim pairs that transfer gravity loads.

10.1.5 Ground Anchor Designs (Drawing Number: GASP90-1.1 – GASP125/140-2.2 and GA90-1.1 – GA125/140-2.2)

In many areas of the United States, ground anchors have historically been used to help manufactured homes resist wind and seismic forces. Anchors are inexpensive, easily installed in many soils, and readily available in many portions of the United States.

Although they have the advantages of ease of installation and low cost, ground anchors have several shortcomings from a performance standpoint. They simply do not perform nearly as well as conventional foundations.

Most of these shortcomings result from the fact that shallow earth anchors are relatively weak and their performance is highly variable, and foundations using ground anchors lack the structural stiffness that conventional foundations materials provide.

To develop the strength needed to resist loads, homes secured with ground anchors must move several inches (typically up to 3 inches laterally or 2 inches vertically). This is particularly true for homes secured with ground anchors using stabilizer plates. To resist equivalent loads, ground anchors with stabilizer plates must move nearly twice as much as axially loaded anchors. Conventional foundations, on the other hand, only allow homes to move at most tenths of inches to resist applied loads.

The lack of stiffness in ground anchor foundations limits the effectiveness of these foundations to resist design loads. It also necessitates periodic maintenance not required with other foundations. Ground anchors, particularly those with stabilizer plates, tend to loosen. A recent study (2001) by the Blue Sky Foundation of North Carolina found that 93 homes out of 100 inspected had straps securing manufactured homes to ground anchors that were loose or improperly installed.

As a minimum, ground anchors need to be retightened following wind or seismic events. If the anchors are fully loaded, some homes will need to be lifted and re-centered on their foundations.

Two pre-engineered foundation designs using ground anchors have been developed. One design uses ground anchors with stabilizer plates. The ground anchor/stabilizer plate design is similar to a "standard set," but includes additional aspects required to resist flood forces and flood damage.

The second ground anchor design has been developed using ground anchors installed for axial (in-line) loading. In-line anchors offer superior performance to anchors used with stabilizer plates. Fewer anchors are needed for the same level of performance. More importantly, in-line anchors are less prone to becoming loose and can withstand repeated loading better than anchors used with stabilizer plates.

One drawback of in-line anchors is that they may need to be installed prior to home placement. This requires additional advanced planning of home placement and may require using qualified installers.

Both ground anchor designs utilize masonry piers for vertical support. Pier construction varies with flood velocity. Dry stacked block is acceptable for areas with low flood velocities. With higher flood velocities, surface bonded mortar can be used and with even higher velocities, fully grouted and reinforced piers are needed.

For flood depths of 3 feet or less, dry stacked block can be used for piers placed on concrete footings for flood velocities up to 1.5 feet per second. Applying 1/8 inch thick surface bonded mortar to the piers (and between the bottom pier and the concrete footing) allows dry stacked block to be used in areas exposed to flood velocities of 2.5 feet per second.

If additional ground anchors are installed (to limit lateral movement and reduces eccentric loads on the footings), acrylonatrile butadiene styrene (ABS) pads can be used instead of concrete footings for flood velocities below 1 foot per second.

For increased flood velocities, piers with greater lateral strength are needed to ensure that they do not become dislodged under the combined effects of wind (or seismic) loads and flood loads. High flood velocities require that the masonry piers be reinforced, fully grouted, and anchored to the footings.

10.2 Summary

A summary of the different pre-engineered foundation systems proposed in this manual, and a comparison of these six proposed systems, is given in Table 10-1.

Table 10-1. Summary of Pre-engineered Foundations

Type of Foundation	Advantages	Disadvantages
Reinforced masonry	∉# Similar to site built home ∉# Little or no maintenance ∉# Most permanent of all the foundation concepts discussed here	∉# Need crane to set home ∉# Expensive ∉# Need custom feature built into home to accommodate foundation wall ∉# Shear reinforcement needed
Wood framed	∉# Crane installation not necessary ∉# Considered a permanent	∉# Need modification to home to accommodate foundation wall

	foundation	∉# Shear reinforcement needed
Braced masonry pier	∉# Conventional installation methods	∉# Adjustment of straps needed after a design event ∉# Likely movement of home after a design event
Wood H-frame	∉# Similar to conventional pile foundation	∉# Need crane to set home ∉# Amount of work under Manufactured home ∉# Accurate placement of vertical posts at concrete footings
Ground anchors with stabilizer plate	∉# Inexpensive ∉# Readily available ∉# Easy to install ∉# Anchors installed after home is in place	∉# Not as strong as conventional foundation ∉# Human intervention needed after a design event ∉# Likely movement of home after a design event ∉# Home may need to be lifted and re-centered on foundation
Ground anchor – in-line	∉# Better performance than anchors with stabilizer plate – use fewer anchors and less movement ∉# Anchors readily available	∉# Adjustment of straps after a design event ∉# Anchors need to be accurately installed prior to placement of home ∉# Possible movement of home after a design event

10.3 Design Drawings

The design drawings included in this manual are listed in Table 10-2.

Table 10-2. Pre-engineered Foundation Drawings

Drawing No.	**Title**
GN-1.0	Pre-engineered Foundation – General Notes
M-1	Single Unit Masonry Foundation Plan
M-2	Double Unit Masonry Foundation Plan
M-3	Masonry Wall Foundation Detail
M-4	Masonry Wall Shear Wall Detail
WF-1	Single Unit Wood Framed Foundation Plan
WF-2	Double Unit Wood Framed Foundation Plan
WF-3	Wood Framed Foundation Detail
WF-4	Wood Framed Shear Wall Detail
BM-1.1	Single Unit Braced Masonry Pier Foundation Plan
BM-1.2	Single Unit Braced Masonry Pier Detail
BM-2.1	Double Unit Braced Masonry Pier Foundation Plan
BM-2.2	Double Unit Braced Masonry Pier Detail
HF-1.1	Single Unit Braced Wood H-Frame Pier Foundation Plan
HF-1.2	Single Unit Wood H-Frame Detail
HF-2.1	Double Unit Braced Wood H-Frame Pier Foundation Plan
HF-2.2	Double Unit Wood H-Frame Detail
GASP90-1.1	Single Unit Ground Anchor with Stabilizer Plate Foundation Plan (90 mph)
GASP90-1.2	Ground Anchor with Stabilizer Plate and Pier Detail (Single Unit) (90 mph)

	Detail (Single Unit) (90 mph)
GASP90-2.1	Double Unit Ground Anchor with Stabilizer Plate Foundation Plan (90 mph)
GASP90-2.2	Ground Anchor with Stabilizer Plate and Pier Detail (Double Unit) (90 mph)
GASP125/140-1.1	Single Unit Ground Anchor with Stabilizer Plate Foundation Plan (125/140 mph)
GASP125/140-1.2	Ground Anchor with Stabilizer Plate and Pier Detail (Single Unit) (125/140 mph)
GASP125/140-2.1	Double Unit Ground Anchor with Stabilizer Plate Foundation Plan (125/140 mph)
GASP125/140-2.2	Ground Anchor with Stabilizer Plate and Pier Detail (Double Unit) (125/140 mph)
GA90-1.1	Single Unit In-Line Ground Anchor Foundation Plan (90 mph)
GA90-1.2	In-Line Ground Anchor and Pier Detail (Single Unit) (90 mph)
GA90-2.1	Double Unit In-Line Ground Anchor Foundation Plan (90 mph)
GA90-2.2	In-Line Ground Anchor & Pier Detail (Double Unit) (90 mph)
GA125/140-1.1	Single Unit In-Line Ground Anchor Foundation Plan (125/140 mph)
GA125/140-1.2	In-Line Ground Anchor and Pier Detail (Single Unit) (125/140 mph)
GA125/140-2.1	Double Unit In-Line Ground Anchor Foundation Plan (125/140 mph)
GA125/140-2.2	In-Line Ground Anchor and Pier Detail (Double Unit) (125/140 mph)

Chapter 11: Design and Performance Criteria for Manufactured Home Foundations in SFHA

11.1 Performance Criteria

Foundation systems that fall outside of the pre-engineered criteria for siting, loads, etc., should meet the following performance criteria:

> Foundations supporting manufactured homes in the SFHA must be designed and constructed to resist all loads imposed on them by their "normal" use as well as all environmental loads expected to occur during the life of the building. The manufactured home must be adequately anchored to prevent flotation, collapse, or lateral movement resulting from hydrodynamic, hydrostatic, and buoyancy loads. Foundations should to be constructed of materials resistant to flood damage and by methods and practices that minimize flood damages.

11.2 Design Criteria

To meet the performance requirements, more specific criteria must be established: the design criteria. The design criteria identify the anticipated loads, design loads, the structure is expected to experience. Design loads can be classified into two groups: normal and environmental loads.

Normal loads are dependent on the characteristics of the structure, such as construction materials and contents, or the structure's function. For example, minimum live loads in single-family residences are typically 30 psf in sleeping areas and 40 psf in other habitable areas. Roof loads are typically 20 psf for small flat or low sloped roofs and less for larger or steeper roofs. The most common normal loads that act on manufactured homes are dead loads and live loads.

Dead loads depend on the weight of the manufactured home, its foundation, and any accessory supported by the structure, such as tanks, piping, electrical service panels and conduits, and HVAC equipment.

Live loads depend on the weight of occupants, furnishings, and non-fixed equipment, and the function of the building or specific space.

Environmental loads are typically based on projected worst case loading for a 50-year recurrence interval (for a critical facility, 100-year intervals are often specified) and vary with locality. Wind loads (which are proportional to the square of the design wind speed) can exceed 80 psf near coastal areas, while those inland can be as low as 15 psf. Snow loads are non-existent in much of the southern U.S., but can be as high as 30 psf in northern and mountainous regions. The most common environmental loads that act on manufactured homes and foundations include:

Flood loads, such as hydrodynamic, hydrostatic (including buoyancy) and floating debris impact loads, depend on flood depth, velocity, wave effects, elevation of the building in relationship to expected flood conditions, and surrounding topography and exposure.

Wind loads depend on roof shape and pitch, siting, topography and exposure, and building geometry (particularly height) and orientation.

Seismic loads depend on the mass (includes building mass and additional loads that the building may occasionally support such as snow load), elevation, location, soil conditions, and building geometry and distribution.

Snow loads depend on roof geometry and building orientation.

After the design loads are identified, the interaction of these loads with the structures can be assessed.

Most model building codes contain requirements on estimating the normal and environmental loads on a structure.

11.3 Design Process

After the performance criteria are established, the design process can begin. The design process involves the following steps:

Step 1: *Determine design criteria.*

Step 2: *Select a design methodology and assess load combinations and failure modes.*

Step 3: *Select foundation type and materials.*

Step 4: *Determine forces at connections and on foundation components*

Step 5: *Specify connection and framing methods along with component dimensions to satisfy load conditions.*

Step 6: *Note all design assumptions and details on drawings.*

Each step of this process is described below. The entire design process is based on the fundamental premise that anticipated normal and environmental loads can and must be transferred through the manufactured home to the foundation in a continuous path to the supporting soils. Any weakness in that continuous path is a potential point of failure of the building, and any failure creates the possibility for large property losses and the loss of life.

This manual does not cover all of the almost endless number of combinations of loads, materials, building shapes and functions, hazard risks, and elevations. The designer will find that engineering judgment will need to be applied to a range of problems during the design of a manufactured home foundation located in a SFHA. Therefore, the intent of this manual is to provide sufficient background so that designers can effectively design manufactured home foundations for forces and issues encountered when sited in a SFHA.

11.3.1 Step 1: Determine design criteria

The minimum design criteria are typically determined by the adopted local building code and floodplain regulations. In the case where there is no adopted building code it is suggested that the current International Residential Code (IRC) published the International Code Council (ICC) be used to determine the minimum design criteria. Best practices refer to construction methods or use of materials that go beyond the minimum requirement and the result is safer and more damage-resistant structures. This manual provides best practices (listed below) and the FEMA website has additional resources.

Best practices:

- Design for a flood elevation above the BFE.
- Take the lowest finished floor elevation to be the lowest point on the lowest structural member. Incorporate scour protection.
- Use fully grouted masonry (CMU) piers.
- Use a foundation type that does not require extensive repairs, such as resetting a home, following an event.

11.3.2 Step 2: Select a design methodology, assess failure modes and load combinations.

11.3.2.1 Design methodology

The two predominant design methods being used in the engineering practice today are allowable or working stress design (ASD) and load factor and resistance design (LRFD). ASD (sometimes referred to as elastic design) is based on the calculated stress in members due to service loads. LRFD design (also known as limit state or strength design) is based on ultimate loads (i.e., the load that will cause a member to fail) and the mode associated with the failure. Because ASD uses service loads and not ultimate loads, the additional strength in a member after its behavior exceeds the elastic range is not taken into account. With LRFD design, the designer is designing for a particular mode of failure. This can ensure a ductile failure as opposed to a brittle failure. For this reason, LRFD design is considered the preferable method of analysis.

11.3.2.2 Load combinations

After the design criteria are determined, the possibility of more than one hazard occurring at the same time must be considered for all modes of failure as must the possibility of imposed loads counteracting gravity loads. For example, it is common in some coastal areas to expect simultaneous flooding with high winds during hurricane events. In similar situations, uplift forces due to the high winds from hurricanes can counteract gravity loads. Load combinations are used to assess the probability of more than one hazard occurring simultaneously and the probability of imposed loads exceeding gravity loads. ASCE7-02 addresses the various load combination possibilities for both the ASD and LRFD design methodologies. The associated nomenclature used in the load combinations from ASCE 7-02 is given in Table 11-1. The LRFD load combinations from ASCE 7-02 are given in Table 11-2. All load combinations should be checked and the governing load combination is the one that produces the most unfavorable effect on the structure.

Table 11-1. Load Combination Nomenclature (ASCE 7-02)

Nomenclature	Load description
D	Dead load
L	Live load
F	Load due to fluid with well-defined pressures and maximum heights
F_a	Flood loads
H	Load due to lateral earth pressure, groundwater pressure, or pressure of bulk materials
T	Self-straining force
L_r	Roof live load
S	Snow load
R	Rain load
W	Wind load
E	Earthquake load

Table 11-2. LRFD Load Combinations (ASCE 7-02)

	Load Combinations for LRFD Design
1	1.4(D + F)
2	1.2(D + F + T) + 1.6(L + H) + 0.5(L_r or S or R)
3	1.2D + 1.6(L_r or S or R) + (0.5 L or 0.8W)
4*	1.2D + (0.8W + 1.0F_a)* + 0.5L + 0.5(L_r or S or R)
5	1.2D + 1.0E + 0.5L + 0.2S
6*	0.9D + (0.8W + 1.0F_a)* + 1.6H
7	0.9D + 1.0E + 1.6H
*	Load combinations given are for non-coastal A-Zones. In V-Zones or Coastal A-Zones, (0.8W + 1.0F_a) should be replaced by (1.6W + 2.0 F_a).

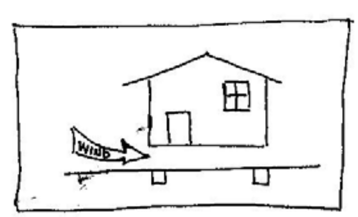
The *Commentary* in ASCE 7-02 states "Wind and earthquake loads need not be assumed to act simultaneously. However, the most unfavorable effect of each should be considered in design, where appropriate. In some instances, forces due to wind might exclude those due to earthquake, while ductility requirements might be determined by earthquake loads."

It is important to note that the load combinations discussed in this section must be resolved directionally, so that all loads in a given combination are acting in the same direction, either vertically or horizontally.

All design loads create forces in and on the building. All forces acting on the manufactured home must be transferred through the foundation and into the soil that supports the structure. The foundation designer must ensure integrity of this load path. The primary failure modes in load path integrity include: uplift failure, overturning, and sliding.

11.3.2.3 Primary failure modes

Uplift failure occurs when vertical forces caused by wind or buoyancy exceed the weight of the structure and the strength of the soil anchorage. The building fails by being lifted off its foundation or because the foundation pulls out of the soil.



Uplift failure mode is particularly likely when the 3-foot pier rule is used in areas where the BFE is greater than 3 feet above the ground elevation. In this situation, the connections and foundation must be designed for the additional buoyancy forces to prevent uplift and flotation of the manufactured home. Once water is allowed to enter the manufactured home, the home may be significantly damaged.

However, the home must still be connected to the foundation to prevent the home from becoming floating debris that could impact and damage surrounding structures (see Figure 11-1).

Figure 11-1. The lack of connections between this home's structure and the foundation allowed hydrostatic forces to lift the home off of its foundation.

Overturning failure occurs when the applied moments caused by wind, waves, earthquake, and buoyancy forces exceed the resisting moments of the building's weight and anchorage. The building fails by rotating off its foundation or because the foundation rotates out of the soil (see Figure 11-2).

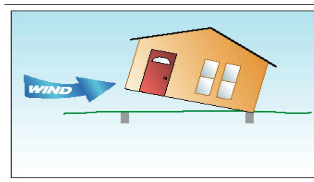
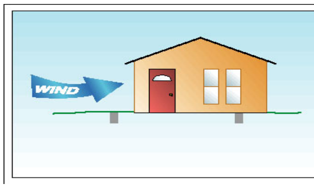


Figure 11-2. An inadequate foundation allowed hydrodynamic forces to overturn this manufactured home.

Sliding or shearing failure occurs when horizontal forces exceed the friction force or strength of the foundation. The building fails by



sliding off its foundation, shear failure of components transferring loads to its foundation, or the foundation sliding.

These failure modes can result in all levels of damage, from minor damage, such as loosening of the anchor straps to catastrophic damage, such as structural collapse.

It is important to emphasize that these load combinations and failure modes are not all-inclusive, and expert judgment should be exercised in any situations not covered by this manual.

11.3.3 Step 3: Select foundation type and materials

After loads are determined and failure modes are assessed, a foundation type and materials must be selected. Foundation types and materials are described in Chapter 9. Chapter 9 also lists advantages and special considerations for foundation types and materials to help with the selection process.

11.3.4 Step 4: Determine forces on connections and on foundation components

The loads on components and at connections must be determined to design an adequate foundation. Some examples of critical points of the load path include:

- Vertical support components
- Lateral support components
- Connection for lateral support to vertical members
- Connection of vertical support components to structure
- Connection of vertical support components to footings
- Anchoring capacity to resist uplift and lateral loads
- Connections between anchoring and foundation
- Footings and soil capacity (appropriate for soil bearing strength)

11.3.5 Step 5: Specify connections and framing methods along with component dimensions to satisfy load conditions

The loads determined in step 4 are used in the design and detailing of connections, foundation components, and anchoring. The loads at connections will be used to design the connections (i.e., number of bolts, or nails, size of clip angles). The reactions at the support will be used to design the foundations (i.e., size of piers and footings, amount of reinforcement, and spacing between piers and ground anchors).

Components and connections design should meet the requirements of the appropriate standard listed according to material in Table 11-3.

Table 11-3. Design Standards and Publishers

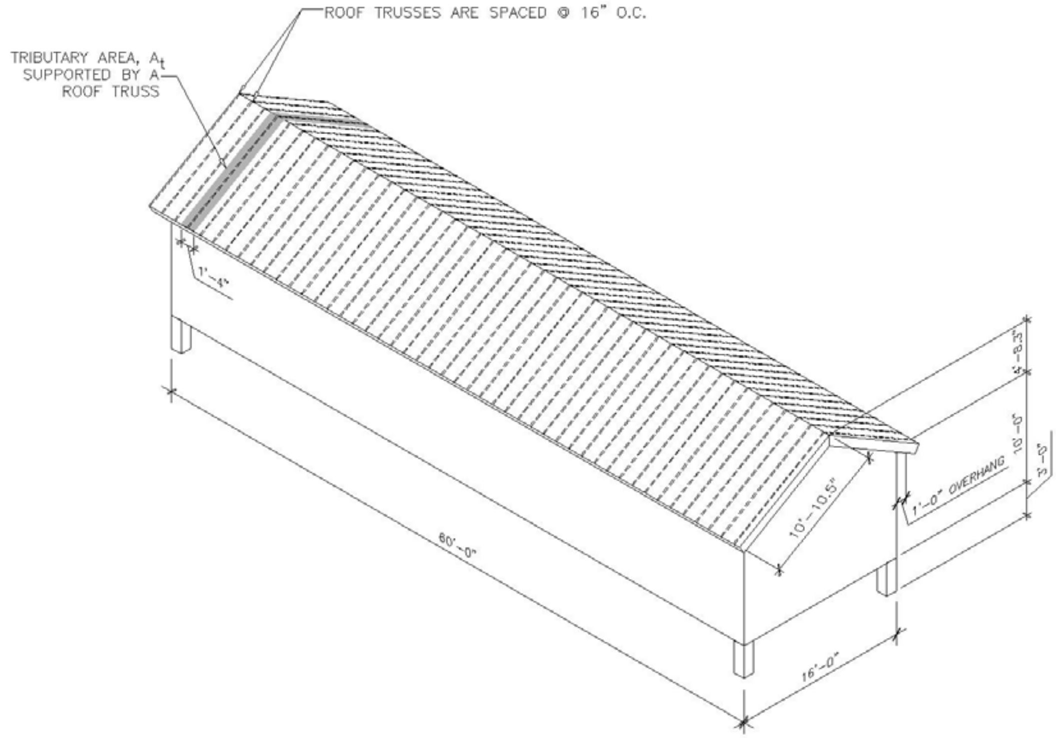
Building Material	Standard and Publisher
Wood	*National Design Standard (NDS)* published by American Forest and Paper Association/American Wood Council
Steel	*Manual of Steel Construction* published by American Institute of Steel Construction (AISC)
Concrete	*Building Code Requirements for Reinforced Concrete (ACI 318)* published by American Concrete Institute (ACI)
Masonry	*Building Code Requirements for Masonry Structures (ACI 350)* published by ACI

11.3.6 Step 6: Note all design assumptions and details on drawings

To ensure a quality design and installation, all assumptions, calculations and details should be clearly documented or noted on the construction documents so that installers and floodplain managers clearly understand the design and design assumptions.

Example

Design a concrete masonry unit (CMU) pier and ground anchor foundation for a manufacture home to be placed in a SFHA in Lewis, DE, with a BFE of 2 feet and a flood velocity of 2 ft/s. The home is sited in a hurricane-prone region less than 1 mile from the coastal mean high-water level. The manufactured home's glazing is not protected or designed to resist wind-borne debris impact. Therefore, the building must be classified as partially enclosed. The manufactured home is a single unit, 16 feet wide and 60 feet long with a 30-degree gable roof with a 1-foot overhang. Roofing members are spaced 16 inches on center. The manufactured home weighs 20 psf. Assume a NFPA 5000 soil classification of soft, sandy clay or clay. Use ASCE 7-2002, Minimum Design Loads for Buildings and Other Structures to calculate loads. (Note: At this location, wind loading is greater than earthquake loading, therefore only wind load calculations are given.)



Step 1: Determine design criteria.

Normal Loads

Dead Load

Dead Load, D — Given in the Example Statement

D = 20psf

Live Load

Live Load, L

L = 40psf

L is based on Residential, Dwellings (one- and two family), and all other areas except stairs and balconies.

Roof Live Load

Roof Live Load, Lr

$L_r = 20R_1R_2 = 20(1)(0.85) = 17psf$

$R_1 = 1$ *for* $A_t \le 200\ ft^2$

$R_2 = 1.2 - 0.05(7in) = 0.85$ *for* $4 < F < 12$

$$A_t = 2(9.2ft)(16in)\left(\frac{1ft}{12in}\right) = 24.5ft^2$$

F = number of inches of rise per foot

ASCE 7-02 Reference

Table 4-1

Section 4.9
Eq. 4-2

$$F = 1ft\left(\frac{12in}{1ft}\right)\tan 30° = 7in$$

Note that the roof live load falls between the limits given:
$12 \le L_r \le 20$

Environmental Loads

ASCE 7-02 Reference

Wind Loading

Section 6.2

Structure is a regular shape, located in a wind-borne debris region, with terrain classification of Exposure C and surrounded by flat terrain.

Mean roof height, h,

h = 3ft+10ft+0.5(4ft) =15ft

h < 16ft (least horizontal dimension)

Calculations are for a foundation system which is a main wind force resisting system (MWFRS).

Velocity Pressures

Section 6.5

Velocity pressures are determined using Method 2: Analytical Procedure.

Velocity Pressure Coefficient, q_z — Section 6.5.10

$q_z = 0.00256K_zK_{zt}K_dV^2I$ — Eq. 6-15

$q_z = 0.00256(0.85)(1)(0.85)(110)^2(1) = 23$ psf

$K_z = 0.85$ — Section 6.5.6.6

$K_d = 0.85$ — Section 6.5.4.4

Basic Wind Speed, V

V = 110 mph (3-second gust) — Figure 6-1

I = 1 (Category II building: Table 1-1 (ASCE 7-02)) — Table 6-1

ASCE 7-02 Reference
Section 6.5.11.1
Figure 6-5
Section 6.5.11.2.1
Figure 6-10
Figure 6-10
Section 6.5.8
Eq. 6-17

Design Pressures for MWFRS

Internal Pressure Coefficient, GC_{pi}

$GC_{pi} = \pm 0.55$

External Pressure Coefficients, C_p

Table 11-4. External Wall Pressure Coefficients

Surface	Wind Direction	L/B	C_p
Windward Wall	n/a	n/a	0.8
Leeward Wall	γ to roof ridge	$\frac{60\,ft}{16\,ft}$ | 3.8	-0.2
Leeward Wall	|| to roof ridge	$\frac{16\,ft}{60\,ft}$ | 0.27	-0.5
Side Wall	n/a	n/a	-0.7

Table 11-5. External Roof Pressure Coefficients

Surface	Wind Direction	h/L	C_p
Windward Roof	γ to roof ridge	$\frac{15\,ft}{16\,ft}$ | 0.94	-0.3 0.2
Leeward Roof			-0.6
Distance From the Windward Roof Edge	|| to roof ridge	$\frac{15\,ft}{60\,ft}$ | 0.25	
0 to h (0-15ft)			-0.9 -0.18
h to 2h (15ft-30ft)			-0.5 -0.18
> 2h (30ft-60ft)			-0.3 -0.18

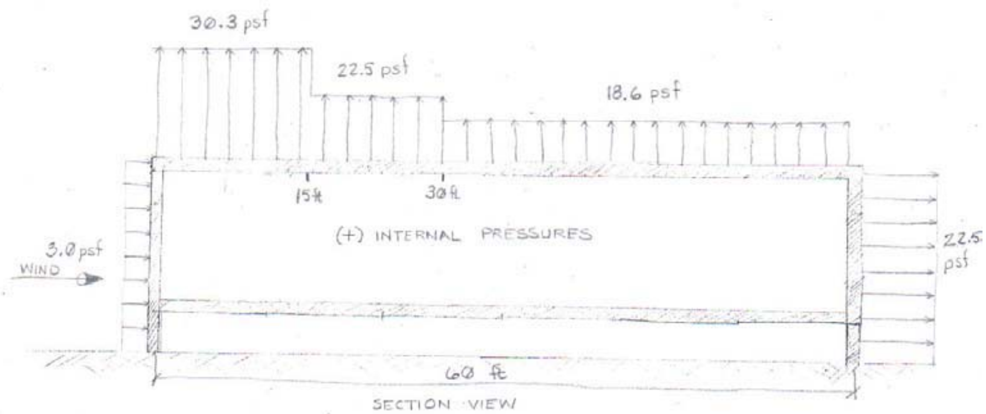
Foundation systems are considered rigid and therefore G = 0.85

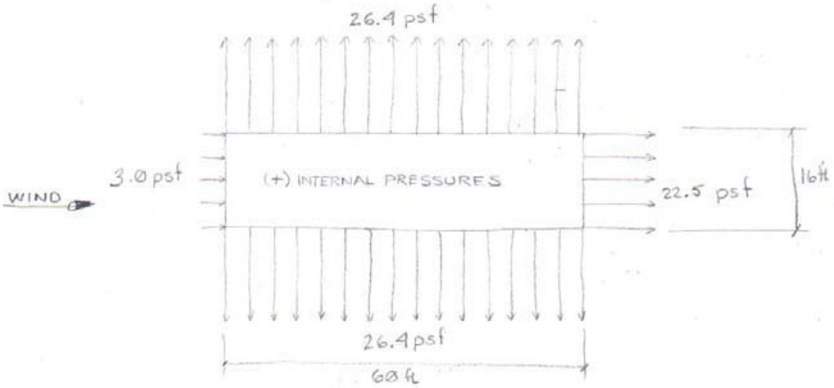
Design Pressure, p

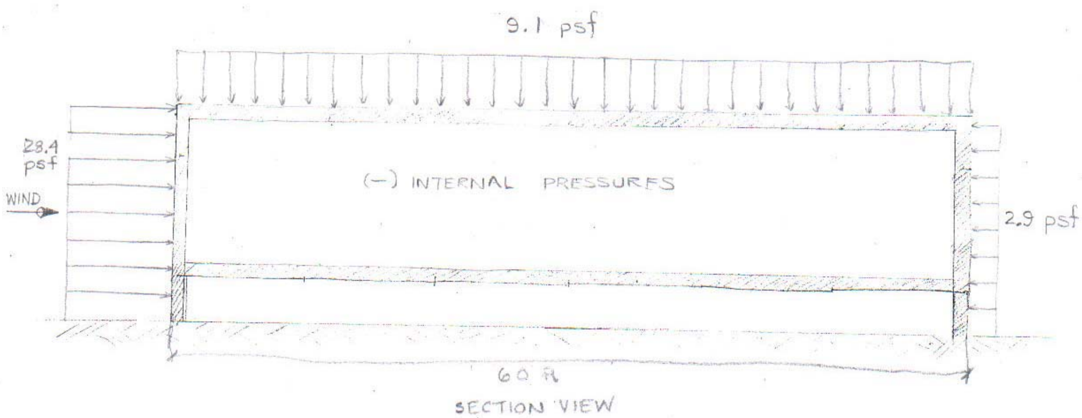
$p = qGC_p - q_i(GC_{pi})$

Table 11-6. Design Pressures for Wind Parallel to the Roof Ridge

Surface	Design Wind Pressure	(+) internal pressure (psf)	(-) internal pressure (psf)
Windward Wall	p = 23 psf(0.85)(0.8) – 23 psf(±0.55) p = 15.7 psf ± 12.7 psf	3.0	28.4
Leeward Wall	p = 23 psf(0.85)(-0.5) – 23 psf(±0.55) p = -9.8 psf ± 12.7 psf	-22.5	2.9
Side Walls	p = 23 psf(0.85)(-0.7) – 23 psf(±0.55) p = -13.7 psf ± 12.7 psf	-26.4	-1.0
Distance From the Windward Roof Edge			
0 to h (0-15ft)	p = 23 psf(0.85)(-0.9) – 23 psf(±0.55) p = -17.6 psf ± 12.7 psf	-30.3	-4.9
	p = 23 psf(0.85)(-0.18) – 23 psf(±0.55) p = -3.6 psf ± 12.7psf	-16.3	9.1
h to 2h (15ft-30ft)	p = 23 psf(0.85)(-0.5) – 23 psf(±0.55) p = -9.8 psf ± 12.7psf	-22.5	2.6
	p = 23 psf(0.85)(-0.18) – 23 psf(±0.55) p = -3.6 psf ± 12.7 psf	-16.3	9.1
> 2h (30ft-60ft)	p = 23 psf(0.85)(-0.3) – 23 psf(±0.55) p = -5.9psf ± 12.7psf	-18.6	6.8
	p = 23 psf(0.85)(-0.18) – 23 psf(±0.55) p = -3.6 psf ± 12.7psf	-16.3	9.1


30.3 psf
22.5 psf
18.6 psf
15ft
30ft
(+) INTERNAL PRESSURES
3.0 psf
WIND
22.5 psf
60 ft
SECTION VIEW


26.4 psf
WIND
3.0 psf
(+) INTERNAL PRESSURES
22.5 psf
16ft
26.4 psf
60 ft


9.1 psf
28.4 psf
WIND
(−) INTERNAL PRESSURES
2.9 psf
60 ft
SECTION VIEW

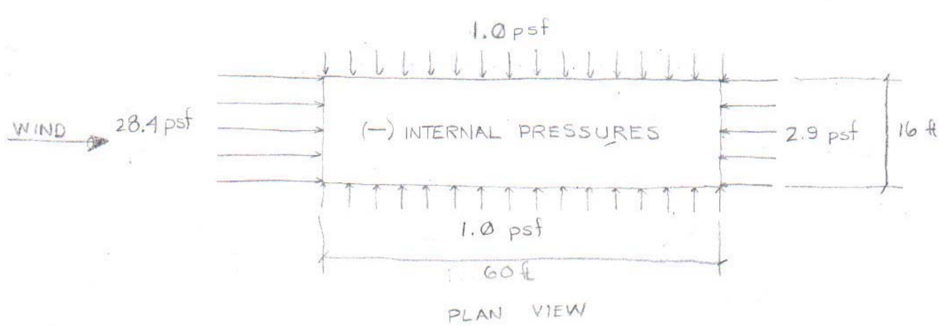

1.0 psf
WIND
28.4 psf
(−) INTERNAL PRESSURES
2.9 psf
16 ft
1.0 psf
60 ft
PLAN VIEW

Table 11-7. Design Pressures for Wind Perpendicular to the Roof Ridge

Surface	Design Wind Pressure	(+) internal pressure (psf)	(-) internal pressure (psf)
Windward Wall	p = 23 psf(0.85)(0.8) – 23 psf(±0.55) p = 15.7 psf ± 12.7 psf	3.0	28.4
Leeward Wall	p = 23 psf(0.85)(-0.2) – 23 psf(±0.55) p = -4.0 psf ± 12.7 psf	-16.7	8.7
Side Walls	p = 23 psf(0.85)(-0.7) – 23 psf(±0.55) p = -13.7 psf ± 12.7 psf	-26.4	-1.0
Windward Roof	p = 23 psf(0.85)(-0.3) – 23 psf(±0.55) p = -5.9 psf ± 12.7 psf	-18.6	6.8
	p = 23 psf(0.85)(0.2) – 23 psf(±0.55) p = 4.0 psf ± 12.7 psf	-8.7	16.7
Leeward Roof	p = 23 psf(0.85)(-0.6) – 23 psf(±0.55) p = -11.8 psf ± 12.7 psf	-24.5	0.9

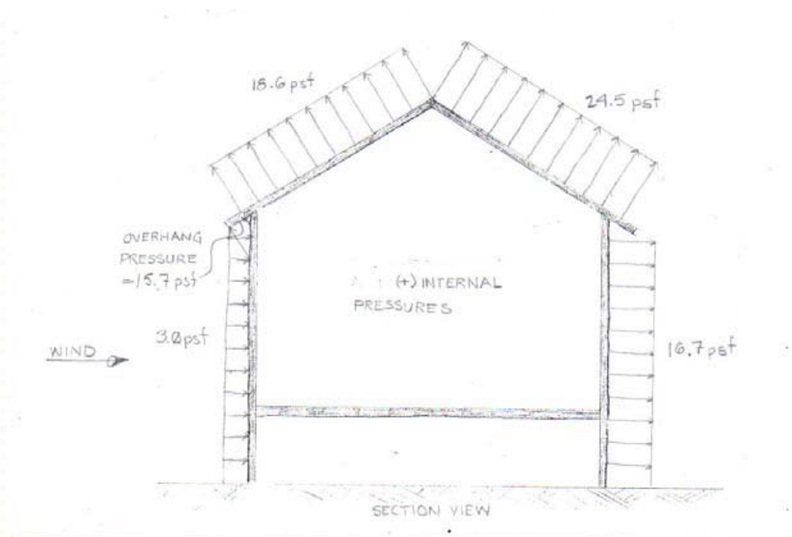
ASCE 7-02 Reference

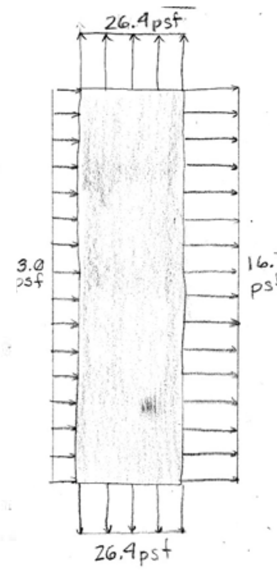
Section 6.5.11.4.1

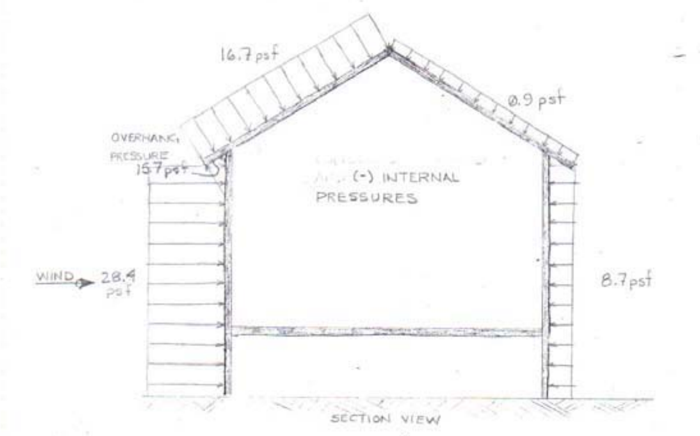
MWFRS Roof Overhang Pressures

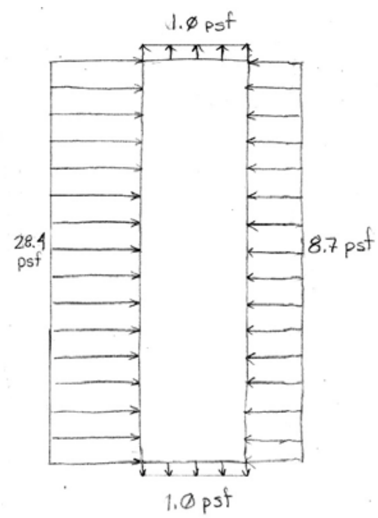
ASCE 7 only addresses the windward overhang: specifying the use of a positive pressure coefficient of C_p = 0.8. For the leeward overhang the coefficient for the leeward wall (C_p = -0.5) could be used, but the coefficient has been conservatively taken as 0.

p = 23 psf(0.85)(0.8) = 15.7 psf


18.6 psf
24.5 psf
OVERHANG
PRESSURE
=15.7 psf
(+) INTERNAL
PRESSURES
WIND
3.0psf
16.7 psf
SECTION VIEW


26.4psf
3.0
psf
16.7
psf
26.4psf


16.7 psf
0.9 psf
OVERHANG
PRESSURE
15.7psf
(-) INTERNAL
PRESSURES
WIND
28.4
psf
8.7psf
SECTION VIEW


1.0 psf
28.4
psf
8.7 psf
1.0 psf

ASCE 7-02 Reference

Section 7.2
Figure 7-1
Section 7.3
Eq. 7-1
Section 7.3.1
Table 7-2
Section 7.3.2
Table 7-3
Section 7.3.3
Table 7-4
Section 7.4
Eq. 7-2
Section 7.4.1
Figure 7-2
Section 7.6
Section 7.6.1

Snow Loading

Ground Snow Load, p_g

$p_g = 20$ psf

Flat Roof Snow Load, p_f

$p_f = 0.7C_eC_tIp_g$

$p_f = 0.7(1.0)(1.0)(1.0)(20) = 14$ psf

Exposure Coefficient, C_e

$C_e = 1.0$ (partially exposed roof)

Thermal Factor, C_t

$C_t = 1.0$

Importance Factor, I

I = 1.0 (Category II building: Table 1-1)

Sloped Roof Snow Load, p_s

$p_s = C_sp_f = (1.0)(14\text{ psf}) = 14$ psf

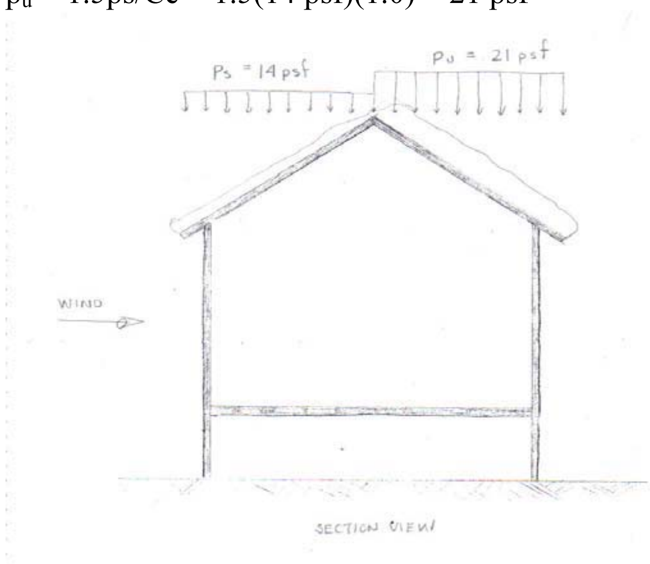
Warm Roof Slope Factor, C_s

$C_s = 1.0$ (asphalt shingle not slippery)

Unbalanced Roof Snow Load, p_u

Since the roof's eave to ridge distance Ò20 ft an unbalance uniform snow load shall be applied to the leeward side equal to:

$p_u = 1.5ps/Ce = 1.5(14\text{ psf})(1.0) = 21$ psf



Flood Loading

Hydrostatic Load, F_h

Since the manufactured home is elevated above the BFE and venting must be provided in all manufactured homes placed in SFHA, the hydrostatic forces will cancel each other out. But the hydrostatic load is calculated because it is used in the hydrodynamic load calculation.

$$F_h \mid \frac{1}{2} P_h H$$

insert equation # from ch. 5

Hydrostatic Pressure, P_h

$P_h = \gamma H$ *insert equation # from ch. 5*

Specific Weight of Fresh Water, γ

$\gamma = 62.4\,pcf$

Floodproofing Design Depth, H

H = 2ft (base flood depth) + 1 ft

A 1 ft freeboard is added to the design depth to provide a protection above the BFE.

Hydrodynamic Load,

The hydrodynamic load is calculated by converting it to an equivalent hydrostatic load by increasing the flood depth. The increase in flood depth is referred to as d_h.

$$d_h = \frac{C_d V^2}{2g} = \frac{2.0\left(2\,{}^{ft}\!/_{s}\right)^2}{2\left(32.2\,{}^{ft}\!/_{s^2}\right)} = 0.13\,ft$$ *insert equation # from ch. 5*

FEMA 55, *The Coastal Construction Manual* recommends a value of 2.0 for square or rectangular piles and 1.2 for round piles. For additional guidance regarding drag coefficients, refer to Volume II of the U.S. Army Corps of Engineers *Shore Protection Manual* (USACE 1984), FEMA 55, and FEMA 259.

Drag Coefficient, C_d

$C_d = 2.0$

Acceleration Due to Gravity, g

g = 32.2 ft/s^2

Therefore the $F_{h/ad}$ adjusted to include hydrodynamic effects becomes:

$$F_{h/ad} = {}^1\!/_2\, P_{hydr} = {}^1\!/_2(8.2\,psf) = 4.1\,{}^{lb}\!/_{ft}$$

with a hydrodynamic pressure of:

$$P_{hydr} = \gamma(d_h) = 62.4\,pcf(0.13\,ft) = 8.2\,psf$$

Since piers are 16 inches wide, the total hydrodynamic force on the pier is:

$$= 4.1\frac{lb}{ft}16in\frac{1\,ft}{12in} = 5.5\,lbs \text{ per pier}$$

Step 2: Select a design methodology and assess load combinations and failure modes.

Detailed calculations for each failure modes and all load combinations can be found in Appendix G. Table 11-8 shows a load matrix for the failure modes and associated load combinations.

Table 11-8. Load Combinations for Example Problem

Failure Modes	Load Combinations						
	1	2	3	4	5	6	7
Uplift	448 lbs	1,503 lbs	752 lbs	865 lbs	n/a[1]	-37 lbs	n/a[1]
Sliding	n/a[2]	n/a[2]	232 lbs	232 lbs	n/a[1]	232 lbs	n/a[1]
Overturning	1,792 ft-lb	6,244 ft-lb	-2,188 ft-lb	-1,982 ft-lb	n/a[1]	-2,059 ft-lb	n/a[1]

Step 3: Select foundation type and materials.

The Example statement specified a CMU pier and ground anchor foundation type. Since the flood velocity is 2 ft/sec, CMU piers must have surface bonded mortar that meets ASTM C887-79a (2001) and ASTM C946-91 (2001) and maintain bonding between CMUs (refer to Chapter 10, *Pre-engineered Foundations*).

Step 4: Determine forces at connections and on foundation components.

CMU piers transfer the compressive loads from the manufactured home into footings and then into the ground. The masonry piers are not considered to provide any lateral or uplift resistance. The governing load combination for downward forces is the uplift failure mode - load combination 2, which produces a total downward force form the manufactured home equal to:

(downward force)(length of manufactured home)
(1,503 lbs)(60 ft) = 90,180 lbs

[1] For this location, wind loading is greater than earthquake loading.
[2] There are no lateral loads for this load combination.

This downward force governs the number of footings and, therefore, piers needed to transfer the downward load into the ground.

Following the braced masonry pre-engineered foundation design for flood velocities over 2 ft/s specification given in Chapter 10 of the use of a dry stack 16-inch by 8-inch block pier with a minimum of an 1/8-inch thick surface bonded mortar and a 24-inch square, 10-inch deep footing, calculate the number of footings needed to adequately transfer the downward loads to the ground.

Required footing area = $\dfrac{compressive\_load}{ultimate\_soil\_bearing\_capacity}$

Required footing area = $\dfrac{90180 lbs}{2000 psf} \approx 45.1 ft^2$

Something in the soils or anchors chapter should address using a factor of safety of 2-3 to convert from allowable to ultimate soil bearing capacity

Individual footing area = (24 in x 24 in.) $\left(\dfrac{1 ft^2}{144 in^2}\right)$ = 4 ft^2

Number of footings = $\dfrac{total\_required\_footing\_area}{individual\_footing\_area}$

Number of footings = $\dfrac{45.1 ft^2}{4 ft^2}$ = 12 footings/piers, therefore 6 pier per side of the manufactured home.

Pier spacing = $\dfrac{manufactured\_\text{hom}e\_length}{number\_piers\_per\_side}$

Pier spacing = $\dfrac{60 ft}{6\_piers}$ = 10 ft

The maximum spacing of the piers is set to 8 feet to provide effective flood-borne debris protection. To protect against flood-borne debris, it is assumed that 1 pier will be lost due to flood-borne debris.

Minimum number of piers = $\dfrac{60 ft}{8 ft}$ = 7.5 piers, say 8 piers per side spaced at 7.5 ft.

Therefore the home will be supported by a total of 16 piers (8 piers on each side) spaced at 7.5 ft.

Lateral wind loads are resisted by the strapping and ground anchors. Since we have computed the number of piers, the total lateral load, including hydrodynamic forces, must be determined for the sliding failure mode-load combination 4 (refer to Table G-5).

Lateral Load Combination 4	
4	$0.8W + 1.0F_a$ wind γ to the roof ridge ***(- internal pressures*** 0.8[232 lbs(60 ft)] + [16 piers][5.5 lbs] = 11,224 lbs

Calculate the number of anchors needed to resist sliding failure.

The recommended design stiffness of the anchors in Table 7-4 of Chapter 7 in this manual is given for 5 foot anchors installed at 45° and axially loaded is 1,200 lb/in (Figure 7.#). The horizontal component of the ground anchors strength is equal to:

(1,200 lbs/in)(cos45°) = 848 lb/in.

The manufactured home industry gives an allowable lateral manufactured home movement of 3 in. So the total lateral strength of a ground anchor is (3 in.)(848 lbs) = 2,544 lbs.

Number of ground anchors needed = $\dfrac{lateral\_load}{anchors\_lateral\_capacity}$

Number of ground anchors needed = $\dfrac{11224 lbs}{2544 lbs}$ = 5 anchors per side

Calculate ground anchor spacing = $\dfrac{60\,ft}{5\_anchors}$ = 12 ft.

The anchor strapping should attach into a wall stud, therefore anchor spacing must be adjusted to 16-inch increments.

Both uplift and overturning failure modes are resisted by the vertical strength of ground anchors. The uplift forces will be resisted by all the ground anchors and the overturning moment will be resisted only by the windward ground anchors.

For the uplift failure mode, load combination 6 (refer to Table

G-3) governs, resulting in a total uplift of 2,175 lbs. Since uplift is resisted by all anchors the total vertical load each anchor will have to resist is:

$$\frac{uplift\_load}{number\_anchors} = \frac{2{,}175 lbs}{10\_anchors} = 217 \text{ lbs per anchor}$$

For the overturning failure mode, load combination 3 (refer to Table G-7) governs for wind parallel to the roof ridge with positive internal pressures. Overturning moment is only resisted by the windward anchors. Therefore, the total vertical load each anchor will have to resist is:

$$\frac{\dfrac{(overturning\_moment)(length\_of\_home)}{moment\_arm}}{number\_of\_anchors\_per\_side} = \frac{\dfrac{(2188 ft \cdot lbs)(60 ft)}{12 ft}}{5\_anchors}$$

= 2,188 lbs per anchor

The vertical component of the anchor stiffness equals:

(1,200 lbs/in)(cos45) = 848lb/in.

The manufactured home industry gives an allowable vertical movement of 2 inches. This results in a vertical strength per anchor equal to:

(2 in)(848lbs/in) = 1,697 per anchor.

This is less than the strength needed by each anchor to resist the overturning moment. Therefore, the number of anchors will be increased to 7 per side, a total of 14 ground anchors. Checking the overturning load per anchor with 7 anchors per side gives:

$$\frac{\dfrac{(overturning\_moment)(length\_of\_home)}{moment\_arm}}{number\_of\_anchors\_per\_side} = \frac{\dfrac{(2188 ft \cdot lbs)(60 ft)}{12 ft}}{7\_anchors}$$

= 1,563 lbs per anchor

The vertical strength of the ground anchors (1,697 lbs) is sufficient to resist the overturning moment load per anchor (1,563 lbs).

Anchor spacing must be recalculated.

Calculate ground anchor spacing = $\dfrac{60\,ft}{7\_anchors}$ = 8.5 ft.

The anchor strapping should attach into a wall stud, therefore anchor spacing must be adjusted to 16-inch increments. Therefore, place anchors at each end of the home and space at 72 inches.

Step 5: Specify connection and framing methods along with component dimensions to satisfy load conditions.

The CMU pier and ground anchor foundation will consist of 16 dry stack 16-inch by 8-inch block piers with a minimum of an 1/8-inch thick surface bonded mortar and 24-inch square, 10-inch deep footings. Ground anchors will be placed at 45° angle at each end of the manufactured home and spaced at 72 inches.

Step 6: Note all design assumptions and details on drawings.

Refer to pre-engineering foundation design drawings and specifications presented in Chapter 10 of how to adequately document assumptions and detail drawings.

Chapter 12: Additional Design Considerations

Construction considerations that must be considered in implementing a selected elevated foundation design include such items as utilities, location of mechanical equipment, access/egress, jacking, and attachments such as carports, decks, and porches.

12.1 Utility Service

Water, sewer, and gas services enter manufactured housing under the floor and originate from grade beneath the home. To connect the manufactured home to these services, utility pipes must extend from grade to the floor of the manufactured home. This location makes them extremely susceptible to flood inundation (leakage) and damage from flood-borne debris. To minimize damage to these pipes, they should be placed in waterproof risers that are located adjacent to the elevated foundation member on the downstream side of the flood flow.

Underground telephone and electric service should also be enclosed in a waterproof riser and protected as above for other utility services. If electrical and telephone service is supplied from overhead lines, the service connection to the manufactured home must be located above anticipated flooding.

Applicable codes and regulations must also be followed when designing and installing utility service. These provisions may also require waterproofing of all connections, backflow preventors on water and sewage service, and the use of certain specific waterproof materials in and for these services.

Another important consideration that must be given in installing utility service to a manufactured home is the likelihood that the home will have some displacement in a design wind event. By design, the ground anchors that are used to hold down many homes will displace a few inches in a design wind event. This displacement will be in the order of 2 to 3 inches. Therefore, some flexibility must be provided in the utility lines to accommodate for any potential movements in the manufactured home.

Propane and fuel oil tanks used to supply energy for heating or other services should be located in a waterproof enclosure or elevated above the anticipated flood level.

Methods to support these tanks above grade include separate elevated foundation systems for support from a platform built off the manufactured home foundation system. To minimize the potential for debris impact and damage, tanks and their supporting foundation should be located on the downstream side of the manufactured home.

12.2 Mechanical Access

Heating and air-conditioning equipment installed inside the manufactured home will generally be located directly under or on the floor. Elevation of the manufactured home above potential flood elevation will, therefore, prevent them from being damaged. Where external components, such as outdoor compressor/evaporator units are installed, they must also be elevated above anticipated flood elevation. These components, as with utility service tanks, are best located adjacent to the manufactured home on a separate platform supported by the elevated structure.

12.3 Access and Egress

Access and egress are important during flooding to ensure that building occupants can evacuate and that emergency and critical services can continue to be provided. A clear access and egress path to the manufactured home must be provided to allow evacuation and rescue efforts necessitated by a flood. Access and egress should be addressed during the evaluation of a potential site to ensure that feasible alternates exist. Necessary considerations may also include bridges, walkways, and areas of safe refuge, which allow safe evacuation during flooding.

12.4 Jacking

Hydraulic jacks are the most commonly used equipment to elevate the manufactured home onto its foundation. Equally spaced hydraulic jacks are located under the steel frame adjacent to the planned foundation supports, which are then moved under the home. For stability, a minimum of eight jacks should be used. For strength, additional jacks may be needed, depending on the jack capacity. The location of the jacks must be pre-determined by the home manufacturer. The following formula will help determine the number of total number of jacks needed.

$$\text{Jacks required} = \frac{\text{W x L x 20 lb/ft}^2}{C}$$

where: W = Width of home (ft)

L = Length of home (ft)

C = Jack working capacity (lb)

This formula assumes that the dead load of the manufactured home is 20 pounds per square foot. If this is not the case for the manufactured home in question, replace 20 in the formula with the appropriate number.

Maximum jack extension is also a consideration. Where the elevation height exceeds the jack extension, a multi-step procedure consisting of jacking, blocking, and jacking on top of elevated pads may be required. Temporary steel beam supports are then run perpendicular to and underneath the home's I-beams. They extend across the actual foundation site and are supported on both sides. The home is then moved across these beams, and lowered onto and secured to the elevated foundation.

Stability of jacks is a major safety concern, especially for high lifts. It is very important to ensure that the jacks are placed on level ground and that they are properly secured prior to placing the home on top of the jacks.

Where jacking cannot be used to raise the manufactured home to the required elevation, the use of a crane should be considered.

12.5 Attachments – Carports, Decks, and Porches

Carports, decks, and porches are often added after the manufactured home has been installed. They are typically located on a separate foundation. It is important that these attachments be designed to the same standard and their foundations subjected to the same considerations as the manufactured home. These attachments should be structurally independent of the manufactured home in order to reduce collateral damage between the home and the attachments.

12.6 A-Zone Requirements – Design of Openings, Skirting, and Other Requirements

It is important that foundations, such as perimeter walls or other enclosures, contain openings that will permit the automatic entry and exit of floodwaters. These openings allow floodwaters to reach equal levels on both sides of the walls and thereby lessen the potential for damage from hydrostatic pressures. Although not a requirement for existing buildings built prior to a community's joining the NFIP, NFIP regulations require these openings for all new construction and substantial improvements of existing buildings in SFHAs. Refer to FEMA Technical Bulletin 1-93 for discussion on openings in foundation walls.

The minimum criteria for design of these openings are as follows:

- A minimum of two openings shall be provided on different sides of each enclosed area, having a total net area of not less than 1 square inch for every square foot of enclosed areas subject to flooding. This is not required if openings are engineered and certified

- The bottom of all openings shall be no higher than 1 foot above grade.

- Openings must be equipped with screen, louvers, valves, or other coverings or devices that permit the automatic entry and exit of floodwaters.

When vinyl or aluminum skirting is attached as a covering between the ground and the bottom of the manufactured home, openings are not required. These materials are strictly cosmetic and will not prevent floodwaters from entering. However, the use of this type of skirting can result in debris problems as skirting is easily damaged and detached during flooding.

12.7 V-Zone Requirements – Design of Breakaway Walls and Other Requirements

The NFIP does not allow continuous foundations in V-Zones. The standard for V-Zones requires the lowest portion of the structural members supporting the lowest floor to be elevated by pilings or other columns to or above the BFE. Within V-Zones, the NFIP allows enclosures below the BFE, but only if they are constructed of breakaway walls, insect screening, or lattice work. Areas below the BFE must be free of obstruction and can only be used for parking, building access, or storage.

Breakaway walls are designed and constructed to fail under the loads imposed by floodwaters without jeopardizing the structural support of the building. Loads from floodwaters and water-borne debris are critical considerations in designing breakaway walls. Because such enclosures will fail under flood forces, they will not transfer additional significant loads to the foundation. Insect screening and lattice work both allow waters to enter enclosed areas and are likely to be damaged or destroyed in a flood. Buildings in a V-Zone must be certified by a registered architect or engineer.

Although the use of breakaway walls, insect screening, and lattice work allows for the automatic entry and exit of floodwaters within enclosures, the fact that they are designed to fail in a flood, or in the case of screening and lattice work, are likely to be damaged, means that they will become debris. Debris is a serious concern during and after flooding as water-borne objects can cause damage to structures and create safety issues, and post-flood recovery efforts can be prolonged and exacerbated by excessive debris removal needs. Detailed discussions on design and construction for breakaway walls can be found in FEMA Technical Bulletin 9-99.

Chapter 13: Costs

Costs associated with developing a site and elevating a manufactured home on the site are important factors in selecting an elevation strategy. These costs consist of those necessary to improve the site, erect the elevated foundation design developed, and properly secure the manufactured home on that foundation.

This chapter presents a format and guidance for estimating the first costs associated with those site design options found acceptable from a technical standpoint. Cost ranges are provided from which a general estimate for a particular design can be developed. The variance in labor rates, distance to the site, cost of material, etc., makes it difficult to develop a firm fixed cost for each elevation technique. For comparison purposes, cost estimates using conventional design are also included in this chapter.

13.1 Pre-engineered Foundation Systems

The six pre-engineered foundation systems incorporated in Chapter 10 are:

- Masonry foundation
- Wood framed foundation
- Braced masonry pier foundation
- Wood H-frame foundation
- Ground anchor foundation (ground anchors with stabilizer plate)
- Ground anchor foundation (in-line anchors)

The average cost for siting and placing a manufactured home is estimated to be $2,200. Maximum costs the "free market" will bear for site preparation and complete installation, without enclosure protection (breakaway siding), are $10,000 and $20,000 for single and double-wide homes, respectively.

13.2 Site Preparation

The cost for site preparation for any design is very site-dependent. Every site has its own unique conditions. The need to clear the site, accessibility to the site, the amount of material involved, and the distance to haul the debris are all factors that will determine the total cost of site preparation. Site preparation cost is best estimated on a site-specific basis.

Major components that will constitute the total cost of site preparation are:

- Cost to clear and grub the site

- Cost to grade and level the site
- Cost to trench and install utility lines

For a given site, the cost of these components is basically the same for each of the six pre-engineered foundation systems. In general, site preparation cost for a manufactured home is probably in the $1,000 to $2,000 range.

13.3 Earth Fill

Prices for earth fill work vary considerably due to the distance from sources of fill, quality of fill, and cost of fill material. Earth fill can be used to elevate a manufactured home in areas where flood velocity is not greater than 10 feet per second. Price for any site work can vary considerably due to the current condition of and need to clear the site, distance from source of fill, quality of fill, and cost of the fill material. The cost of earth fill material has increased by a significant percentage over the years. The cost of earth fill material is generally in the range of $15.00 to $25.00 per cubic yard, not including any additional site work required. The estimated amount of earth fill in cubic yards required for various length single and double section manufactured homes is provided in Table 13-1. The cost of earth fill can be estimated by multiplying the quantity of earth fill required from the tables with the cost per cubic yard of material as obtained from the local excavating and hauling contractors.

Table 13-1. Earth Fill Quantity (Cubic Yards)

Depth of Fill (feet)	Manufactured Home Width (feet)	Manufactured Home Length (feet)								
		32	**40**	**48**	**52**	**56**	**60**	**66**	**72**	**76**
1	12	35	41	48	52	55	58	64	69	72
	14	38	45	53	56	60	64	69	75	79
	24	54	64	74	80	85	90	98	106	111
	28	60	72	83	89	95	101	109	118	124
2	12	79	93	108	116	123	130	141	153	160
	14	85	101	117	125	133	141	153	165	173
	24	119	140	162	173	184	195	212	228	239
	28	132	156	180	193	205	217	235	253	265
3	12	133	157	181	193	205	217	235	253	265
	14	143	169	195	208	220	233	253	272	285
	24	195	230	265	282	299	317	343	369	386
	28	216	254	293	312	331	350	379	407	426
4	12	198	232	267	284	301	318	344	370	387
	14	212	249	286	304	323	341	369	396	415
	24	285	334	382	407	431	455	492	528	552
	28	314	367	421	447	474	501	541	581	607
5	12	275	321	367	390	413	436	470	505	528
	14	294	343	392	416	441	465	502	539	563
	24	389	452	516	548	580	611	659	707	739
	28	426	496	566	600	635	670	722	774	809

13.4 Installation

A conventional installation (without consideration of flooding) consists of piers on which the manufactured home rests and ground anchors to secure the manufactured home on top of the piers. The piers will generally be 2 feet in height and located under the manufactured home in accordance with the manufacturer's installation instructions. Ground anchors will generally be installed every 10 feet along the length of the manufactured home.

The cost for a conventional installation 2 feet to the bottom of the chassis I-beam will generally be as follows:

Cast-in place concrete piers	\$150-\$225/pier
Built-up unreinforced masonry piers	\$75-\$150/pier
Jacking and placement	\$300-\$450/section
Ground anchors and tie-downs	\$50-\$112/anchor

Conventional installation costs, not including miscellaneous clearing, grubbing work, steps, utility connections, etc., are shown in Tables 13-2 and 13-3 for various length single and double section manufactured homes, respectively.

These cost ranges may not represent local conditions, labor, and material rates, as well as conventional installations that may not utilize piers and ground anchors. It is important to note that, as the height above grade increases, the increment cost for each additional foot of elevation decreases. This can be largely attributed to labor and other fixed costs that are essentially the same regardless of height. Therefore, additional elevation will provide a relatively low cost safety factor against unusually high flooding.

Table 13-2. Conventional Installation Costs for Single Section (dollars)

	Manufactured Home Length (feet)						
	48	**52**	**56**	**60**	**66**	**72**	**76**
Concrete Piers	1,500-2,250	1,500-2,250	1,800-2,700	1,800-2,700	2,100-3,150	2,100-3,150	2,400-3,600
Masonry Piers	750-1,500	750-1,500	900-1,800	900-1,800	1,050-2,100	1,050-2,100	1,400-2,400
Ground Anchors	525-1,125	525-1,125	630-1,350	630-1,350	735-1,575	735-1,575	840-1,800
Jacking	300-450	300-450	300-450	300-450	300-450	300-450	300-450
TOTAL COST	1,575-3,825	1,575-3,825	1,830-4,500	1,830-4,500	2,080-5,180	2,080-5,180	2,340-5,850
Cost /Foot Length	32.81-79.69	30.29-73.56	32.68-80.36	30.50-75.00	31.52-78.48	28.89-71.94	30.79-51.32

Table 13-3. Conventional Installation Costs for Double Section (dollars)

	Manufactured Home Length (feet)						
	32	**40**	**48**	**52**	**56**	**60**	**66**
Concrete Piers	2,400-3,600	2,400-3,600	3,000-4,500	3,000-4,500	3,600-5,400	3,600-5,400	4,200-6,300
Masonry Piers	1,200-2,400	1,200-2,400	1,500-3,000	1,500-3,000	1,800-3,600	1,800-3,600	2,100-4,200
Ground Anchors	420-900	420-900	525-1,125	525-1,125	630-1,350	430-1,350	735-1,575
Jacking	600-900	600-900	600-900	600-900	600-900	600-900	600-900
TOTAL COST	2,220-5,400	2,220-5,400	2,625-6,525	2,625-6,525	3,030-7,650	3,030-7,650	3,435-8,775
Cost /Foot. Length	69.38-168.75	55.50-135.00	54.69-135.94	50.48-125.48	54.11-136.61	50.50-127.50	52.05-132.95

13.5 Anchors

13.6 Jacking

The placement of jacks and jacking of a manufactured home are based on the desired height above grade. Table 13-4 provides a general estimate based on height above grade.

Table 13-4. Jacking Costs (dollars)

	Height Above Grade (ft.)							
	3	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Single Section	375-525	450-600	525-675	600-750	675-825	750-900	825-975	900-1050
Double Section	750-1,050	900-1,200	1,050-1,350	1,200-1,500	1,350-1,650	1,500-1,800	1,650-1,950	1,800-2,100

13.7 Summary of Total Costs

Appendix A: Bibliography

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Marshall, Richard D., and Yokel, Felix Y., "*Recommended Performance-Based Criteria for the Design of Manufactured Home Foundation Systems to Resist Wind and Seismic Loads,"* U.S. Department of Commerce, National Institute of Standards and Technology, August 1995.

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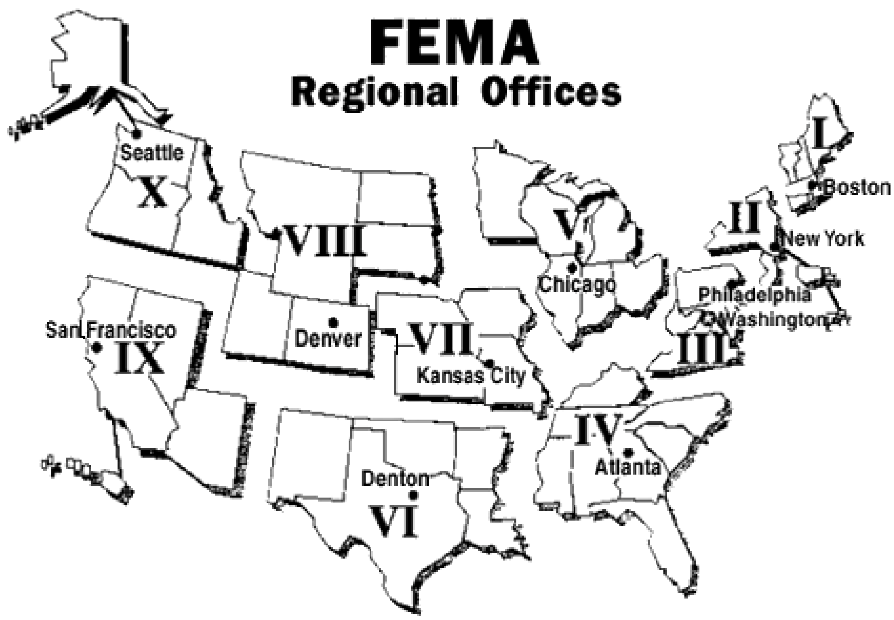
Appendix B: Federal and State Contacts

FEMA Regional National Flood Insurance Program Contacts

(Insert HUD information in Final document)



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Cheyenne, WY 82003

Appendix C: Sources for Flood Information

To develop an effective manufactured home installation strategy applicable to a flood hazard area, several hydrological factors must be evaluated. These include the regulatory floodplain boundaries and the anticipated flooding characteristics for the site such as, location of floodway depth, velocity, duration, rate-of-rise, and frequency. Various sources of this information are available. Also, there are methods by which portions of such information can be individually developed.

As part of its National Flood Insurance Program (NFIP), FEMA develops Flood Insurance Studies (FISs), which often contain the most current and detailed information that is available for a community. Such studies can include a Flood Insurance Rate Map (FIRM) and a Flood Boundary and Floodway Map (FBFM). If the study was completed prior to 1986, they stopped making these separate from FIRMs in 1986; however, many communities still have pre-1986 studies and a FIS report, from which the following information can be obtained:

- Floodplain and floodway boundaries
- Stream profiles that show the elevations of the 100-year or "base" flood (the flood that has a 1 percent chance of being equaled or exceeded in any given year) and other flood events
- Mapped base flood elevations which, in combination with other data, can be used to develop flood depths for a specific site
- Flood velocity data
- Flood frequency data
- Flood discharge data
- Historical flood information

FISs can be extremely valuable sources for much of the information necessary to evaluate a potential manufactured home site. The specific hydrologic data elements, and ways to obtain them, are described below.

C.1 Map Modernization

FEMA developed a plan in 1997 to modernize the FEMA flood mapping program. The plan outlined the steps necessary to update FEMA's flood maps for the Nation to digital format and streamline FEMA's operations in raising public awareness of the importance of the maps and responding to requests to revise them. Since that time, the plan has continually evolved as new products, processes, and technical specifications have been developed and implemented within present funding levels, which have not approached the levels necessary to fully update the national map inventory.

The goal of FEMA's Map Modernization Plan is to upgrade the 100,000 panel flood map inventory by:

- Developing up-to-date flood hazard data for all flood-prone areas nationwide to support sound floodplain management and prudent flood insurance decisions

- Providing the maps and data in digital format to improve the efficiency and precision with which mapping program customers can use this information

- Fully integrating FEMA's community and state partners into the mapping process to build on local knowledge and efforts

- Improving processes to make it faster to create and update the maps

- Improving customer services to speed processing of flood map orders and raise public awareness of flood hazards

C.2 Flood Study Software Programs

FEMA has developed several programs to support the NFIP. These programs are listed in the following table and are available for download from the FEMA web site.

FEMA Software

Program	Download	Tutorial	User's Manual / Guide	Additional Guidance	Sample Data Sets
CHAMP, Version 1.1	☐	☐	☐	☐	☐
CHECK-2	☐	☒	☒	☒	☒
CHECK-RAS, Version 1.1	☐	☐	☐	☐	☐
FAN	☐	☒	☐	☒	☒
FISPLOT	☐	☒	☒	☒	☒
NFF, Version 3.1*	☐	☐	☐	☐	FUTURE
Quick-2, Version 1.0	☐	☐	☐	☒	☒
Quick-2, Version 2.0	☐	☐	☐	☒	☐
RASPLOT, Version 2.1.0	☐	☐	☐	☐	☐
RUNUP, Version 2.0	☐	☒	☐	☒	☒
WHAFIS, Version 3.0	☐	☒	☐	☒	☒

☑ Available (Click to view) ☑ In Progress ☒ Not Planned

* U.S. Geological Survey software package.

Other programs that are available are the HEC programs and the WRAS-HEC-RAS Conversion Program. The HEC programs were designed by the USACE and are available free of charge. The programs are used for hydrologic engineering and planning analysis and procedures. WRAS is a conversion program developed by the Natural Resources Conservation Service (NRCS) that takes existing WSP2 data sets and converts them to HEC-RAS format for import into HEC-RAS.

C.3 Flood Hazard Boundaries

Boundaries for the different degrees and types of flooding, including floodways, floodway fringe areas, coastal high hazard areas, coastal fringe areas, and shallow flooding areas must be identified. Flood hazard boundaries are significant because they determine the specific flood hazard zones that are part of a proposed development site or that will influence development in the site. In addition, boundaries indicate where floodplain management regulations and flood insurance requirements, apply to the site. Flood hazard boundary data can be obtained from FBFMs, FIRMs, and floodplain maps or can be developed from topographic maps, zoning maps, aerial photographs, and related hydrologic data.

C.4 Flood Depth

Flood depths are determined by the difference between water surface elevation at times of flooding and normal ground surface elevations. This information is important both in determining the elevations at which flood waters will likely cause damage and in defining the appropriate elevations for flood insurance and floodplain management regulations. Flood depths also influence the hydrostatic forces that are in effect during flooding, including the horizontal loads that can cause lateral displacement or overturning, and the vertical loads that can cause uplift and flotation. Flood depths can be derived by using a FIRM showing base flood elevations in combination with a topographic map depicting ground elevations for a particular site. Flood depth data are also available from various technical studies that include flood elevations, water surface profiles, or stream and coast cross-sections. In the absence of official reports, information on flood depths can be obtained from site surveys and historical records.

C.5 Flood Water Velocity

The average and maximum velocity of floodwater is important in determining the hydrodynamic forces, which influence horizontal loads in excess of hydrostatic loads. Velocity also affects the magnitude of debris impact loads (i.e., force of flotation objects carried by floodwaters), and can increase erosion and affect soil stability on slopes. Data on water velocity are listed in Floodway Data Tables, which are often included in FIS reports, and are also available from various floodplain technical studies or can be determined by special hydrological studies. Velocity can also be calculated by assuming floodwaters to be at a uniform flow, estimating some floodplain characteristic, and using Manning's Equation:

$$V = \frac{k}{n}\left(\frac{A}{P}\right)^{2/3} S^{1/2}$$

where: V = Average flow velocity (feet per second)

k = 1.49, unit conversion

A = Cross-sectional flow area (square feet)

P = Wetted perimeter of A (feet)

$\left(\frac{A}{P}\right)$ = Hydraulic radius (ft)

S = Bed slope (feet/feet) (use average ground surface slope within a reach from approximately ½ mile upstream to approximately ½ mile downstream)

n = Manning's channel roughness coefficient, empirical value developed through lab testing of flow through a pipe.

C.6 Frequency

Frequency of flooding is a major consideration in the evaluation of potential installation sites. Frequency of flooding is the probability (in percent) that a random flood event will equal or exceed a specified magnitude in a given time period. Manufactured homes sited at lower elevations near a flooding source will likely have higher frequency of flooding than those located on higher ground away from the flooding source. Flood frequency information is included in FIS reports and other technical floodplain studies. Frequency of flooding can also be statistically determined using historical records of flooding at the location under consideration.

C.7 Rate of Rise

The rate of rise is an expression of how rapidly water depth increases during a flooding event. This factor is important in evaluating buoyancy hazards and investigating the feasibility of an evacuation plan. The rate of rise of floodwaters can be derived from a stream flow hydrograph that relates flooding depth to time for the area under consideration. Information required to determine the rate of rise may also be obtained from existing hydrological studies, on-site investigations, historical records, and nearby gauge records.

C.8 Duration

The duration of flood inundation, which is a function of the rate of rise and fall of water, has several important influences on manufactured home installation. Duration influences the saturation of soils and building materials, the amount of seepage, and the length of time that a manufactured home might be inaccessible. Various floodplain technical studies and historical records are sources of information concerning duration of flooding.

The following tables provide sources of various types of information and assistance.

FLOODPLAIN MANAGEMENT SERVICES

FLOODPLAIN AGENCIES / DATA TYPE	Floodwater Control	Floodproofing Information	Preserve Channel Capacity	Development Regulations	Land Use Controls	Floodwater Control	Public Information	Post-Flood Relief	Flood Warning System
Federal Emergency Management Agency		●		●		●	●	●	
U.S. Army Corps of Engineers	●	●	●	●		●	●	●	●
Natural Resources Conservation Service	●	●	●			●		●	
Department of Housing and Urban Development				●				●	
National Oceanic and Atmospheric Administration						●			●
U.S. Geological Survey						●			
Federal Highway Administration	●		●				●		
State Floodplain Management Coordinating Agency	●	●	●	●	●	●			
Regional Authorities	●	●	●	●		●	●	●	
Local Government Planning Agencies				●	●	●			

SUMMARY OF HYDROLOGIC DATA SOURCES

AGENCIES / DATA TYPE	Coastal Surveys and Reports	Flood Control Measures	Flood Boundary Maps	Flood Insurance Rate Maps	Floodplain Information Reports & Technological Studies	Flood Records & Probabilities	Hydrologic Atlases	National Flood Ins. Program Regulations	State Floodplain Regulations	Technical Assistance	Topographic Maps	Zoning Ordinances & Maps
Local government planning agency or municipal engineer	●	●	●	●	●	●		●	●	●	●	●
State floodplain management coordinating agency	●	●	●	●		●		●	●	●		
Federal Emergency Management Agency	●	●	●	●				●		●		
National Oceanic & Atmospheric Admin. (Dept. of Commerce)	●				●	●						
Soil Conservation Service (U.S. Department of Agriculture)		●			●	●						
U.S. Army Corps of Engineers (Department of Defense)	●	●	●	●	●	●				●	●	●
U.S. Geological Survey (Department of the Interior)					●	●	●				●	
Regional authorities (e.g. TVA)		●			●	●				●	●	

Appendix D:
NFIP Definitions

	DEFINITION IN 44 CFR 59.1	DESCRIPTION
Base Flood	The flood having a 1 percent chance of being equaled or exceeded in any given year.	Also called the 100-year flood.
Base Floodplain / 100-year Floodplain	The land area susceptible to being inundated by water from any source	For the 100-year flood, it is the land area susceptible to flooding from an event with a 1 percent or greater annual chance of occurrence.
Breakaway wall	A wall that is not part of the structural support of the building and is intended through its design and construction to collapse under specific lateral loading forces, without causing damage to the elevated portion of the building or supporting foundation system.	These are used in V1-30, VE, and V-Zones to enclose areas below the lowest floor. Only parking, access, and storage are permitted in these areas.
Coastal high hazard area	An area of special flood hazard extending from offshore to the inland limit of a primary frontal dune along an open coast and any other area subject to high velocity wave action from storms or seismic sources.	This term is often used as a synonym for V-Zones. However, recently, it has also begun to be used to describe Coastal A-Zones, which can also be subject to high velocity flows and wave action during a base flood event.
Existing manufactured home park or subdivision	A manufactured home park or subdivision for which the construction of facilities for servicing the lots on which the manufactured homes are to be affixed (including, at a minimum, the installation of utilities, the construction of streets, and either final site grading or the pouring of concrete pads) is completed before the effective date of the floodplain management regulations adopted by a community.	Here "existing" means it existed prior to the community's adoption of its floodplain management regulations. This is also called pre-FIRM because the date of initial publication of a community's FIRM is the same date as the adoption date of their regulations.
Expansion to an existing manufactured home park or subdivision	The preparation of additional sites by the construction of facilities for servicing the lots on which the manufactured homes are to be affixed (including the installation of utilities, the construction of streets, and either final site grading or the pouring of concrete pads).	------------
Flood Hazard	An official map of a community, issued by	This is a map that is usually created

	DEFINITION IN 44 CFR 59.1	DESCRIPTION
Boundary Map (FHBM)	the Administrator, where the boundaries of the flood, mudslide (i.e., mudflow) related to erosion areas having special hazards have been designated as Zones A, M, and/or E.	for communities when they join the Emergency Program of the NFIP. It shows the boundaries of the SFHA as they are determined by approximate methods. Most communities have their FHBMs replaced by FIRMs following a flood risk assessment conducted in connection with the community's conversion to the NFIP's Regular Program.
Flood Insurance Rate Map (FIRM)	An official map of a community, on which the Administrator (FIA) has delineated both the special hazard areas and the risk premium zones applicable to the community.	The FIRMs show the base floodplain, which is the regulatory floodplain (unless the community has adopted a more restrictive floodplain).
Flood Insurance Study (FIS)	An examination, evaluation, and determination of flood hazards and, if appropriate, corresponding water surface elevations, or an examination, evaluation, and determination of mudslide and/or flood-related erosion hazards.	------------
Floodway	The channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height.	The minimum NFIP requirement for a floodway is the area within the 100-year floodplain necessary to discharge the base flood without cumulatively increasing the water surface elevation more than 1 foot. Some states and communities have a more restrictive regulatory floodway.
Manufactured home	A structure, transportable in one or more sections, that is built on a permanent chassis and is designed for use with or without a permanent foundation when attached to the required utilities. The term "manufactured home" does not include a "recreational vehicle."	------------
Manufactured home park or subdivision	A parcel or (contiguous parcels) of land divided into two or more manufactured home lots for rent or sale.	------------
New manufactured home park or subdivision	A manufactured home park or subdivision for which the construction of facilities for servicing the lots on which the manufactured homes are to be affixed (including, at a minimum, the installation of utilities, the construction of streets, and either final site	------------

	DEFINITION IN 44 CFR 59.1	DESCRIPTION
	grading or the pouring of concrete pads) is completed on or after the effective date of the floodplain management regulations adopted by a community.	
Special Flood Hazard Area (SFHA)	The land in the floodplain within a community subject to a 1 percent or greater chance of flooding in any given year. The area may be designated as Zone A on the FHBM. After detailed ratemaking has been completed in preparation for publication of the FIRM, Zone A is usually refined into Zones A, AO, AH, A1-30, AE, A99, AR, AR/A1-30, AR/AE, AR/AO, AR/AH, AR/A, VO or V1-30, VE, or V.	This is the base floodplain (the 100-year floodplain or the 1-percent annual chance floodplain) as determined by the FIS and shown on the FIRM.
Substantial damage	Damage of any origin sustained by a structure whereby the cost of restoring the structure to its before damaged condition would equal or exceed 50 percent of the market value of the structure before the damage occurred.	The definition of substantial damage provides that the damage can be of any origin. However, some regulations that apply to manufactured housing, only apply floodplain development regulations to those pre-FIRM structures that have been substantially damaged by a flood event.
Substantial improvement	Any reconstruction, rehabilitation, addition, or other improvement of a structure, the cost of which equals or exceeds 50 percent of the market value of the structure before the "start of construction" of the improvement. This term includes structures that have incurred "substantial damage," regardless of the actual repair work performed. The term does not, however, include either: (1) Any project for improvement of a structure to correct existing violations of state or local health, sanitary, or safety code specifications that have been identified by the local code enforcement official and that are the minimum necessary to ensure safe living conditions, or (2) Any alteration of a "historic structure," provided that the alteration will not preclude the structure's continued designation as a "historic structure."	-----------

Other Terms not Defined in 44 CFR 59.1

TERM	DEFINITION / DESCRIPTION
Base Flood Elevation (BFE)	The elevation of the base floodplain as given in the community's FIRM and FIS.
Enclosed areas	The portion of an elevated building below the BFE that is partially or fully surrounded by solid (including breakaway) walls. Floodwaters must be able to automatically enter and exit these areas, and parking, storage and building access are the only permitted used.
Encroachment	Any type of development within the floodplain that results in a loss of floodwater storage space. Encroachments in floodways are particularly important in floodplain development because, under NFIP minimum requirements, any development within the floodway that results in an increase in the base flood elevation is not permitted.
Permanent foundation	A permanent foundation must be constructed of durable materials (i.e. concrete, mortared masonry, or treated wood) and be site-built. It shall have attachment points to anchors and stabilize the manufactured home to transfer all loads, herein defined, to the underlying soil or rock. The permanent foundation shall be structurally developed in accordance with HUD document HUD007487 or be structurally designed by a licensed professional engineer for the items listed in section 100-1C of HUD-007487.
Regulatory floodplain	The floodplain to which a community applies their floodplain development regulations. A community participating in the NFIP is required to adopt the floodplain on their FIRM, or use a more restrictive (larger aerial extent or higher floodplain water surface elevations) floodplain.
Structural fill	Engineered fill, compacted to 90 percent compaction, Modified Proctor Test, ASTM D1557. It should have a minimum bearing capacity as recommended by geotechnical engineer; and be free of organic material such as weeds, or grasses, or other organic matter.

Appendix E:

Acronyms and Abbreviations

ABS	acrylonatrile butadiene styrine
ACI	American Concrete Institute
ACQ	alkaline copper quatemary
ACZA	ammoniacal copper zinc arsenate
AISC	American Institute of Steel Construction
ANSI	American National Standards Institute
ASCE	American Society of Civil Engineers
ASCE 7-02	ASCE Standard,Minimum Design Loads for Buildings and Other Structures, 2002
ASD	allowable stress design
ASFPM	Association of State Flood Plain Managers
ASTM	American Society for Testing Materials
AWPA	American Wood Preservers Association
BFE	base flood elevation
BMP	braced masonry pier
BOCA	Building Officials and Code Administrators
BPAT	Building Performance Assessment Team
C&C	components and cladding
CCA	copper-chromium arsenic
CFR	Code of Federal Regulations
CMU	concrete masonry units

COSAA	Council of State Administrative Agencies
DFE	design flood elevation
DFIRM	Digital Flood Insurance Rate Map
DHS	Department of Homeland Security
DMA 2000	Disaster Mitigation Act of 2000
ERBS	earthquake resistant bracing systems
FBFM	Flood Boundary and Floodway Map
FHA	Federal Highway Administration
FHBM	Flood Hazard Boundary Map
FIA	Federal Insurance Administration
FIMA	Federal Insurance and Mitigation Administration
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
fps	feet per second
ft	foot or feet
FY	fiscal year
g	acceleration due to gravity
G&O	Greenhorne & O'Mara
GPO	Government Printing Office
H&H	hydrologic and hydraulic studies
HSMV	Highway Safety and Motor Vehicles (FL)
HUD	Department of Housing and Urban Development
IBC	International Building Code
ICBO	International Conference of Building Officials
ICC	International Code Council
in	inch or inches

IRC	International Residential Code
lb	pound
LOMR-L	Letter of Map Revision based on the fill
LRFD	load and resistance factor design
MH	manufactured housing
MHCC	Manufactured Housing Consensus Committee
MHCSS	Manufactured Home Construction and Safety Standards
MHI	Manufactured Housing Institute
MHIA 2000	Manufactured Housing Act of 2000
MHRA	Manufactured Housing Research Alliance
mm	millimeter
mph	miles per hour
MWFRS	main wind force resisting system
NAHB	National Association of Home Builders
NAVD	North American Vertical Datum
NCSBCS	National Conference of States on Building Codes and Standards
NDS	National Design Standard
NEHRP	National Earthquake Hazards Reduction Program
NFIP	National Flood Insurance Program
NFPA	National Fire Protection Association
NGVD	National Geodetic Vertical Datum
NIST	National Institute of Standards and Technology
NRCS	National Resources Conservation Service
OC	Oversight Committee
PATH	Partnership for Advancing Technology in Housing

PFGMH	Permanent Foundations Guide for Manufactured Housing
psf	pounds per square foot
psi	pounds per square inch
RM	reinforced masonry
SBCCI	Southern Building Code Congress International
SFHA	Special Flood Hazard Area
S_S	The mapped maximum considered earthquake, 5 percent damped, spectral response acceleration at short periods as defined in Section 9.4.1.2 of ASCE 7-02.
S_1	The mapped maximum considered earthquake, 5 percent damped, spectral response acceleration at a period of 1 second as defined in section 9.4.1.2 of ASCE 7-02.
UBC	Uniform Building Code
USACE	U.S. Army Corps of Engineers
USC	United States Code
USGS	United States Geological Survey
WF	wood framed

Appendix F:

Pre-engineered Foundation Designs

Notes

1. These pre-engineered foundation designs contain guidance for making manufactured homes, placed in Special Flood Hazard Areas, resistant to natural hazards. The designs do not cover all installations. Manufactured homes placed in the following areas are excluded:

   V Zones
   Coastal A Zones
   Floodways
   Areas with Flood Velocities over 5 feet per second
   Areas with Flood Depths over 3 feet
   Areas with Seismic Spectral Acceleration Constants S_s greater than 0.5g or S_1 greater than 0.15g
   Areas with ground snow loads greater than 40 pounds per square foot
   Installations with pier heights over 36 inches
   Manufactured homes weighing less than 25 psf
   Manufactured homes with frames spaced less than 95 inches
   Manufactured homes with endwall heights over 8' 2"

2. The foundation systems have been designed to resist loads specified in ASCE 7-98 Minimum Design Loads for Buildings and Other Structures. Any locally adopted code or ordinance with more stringent requirements shall govern.
3. Any modifications to these drawings must be designed and approved by a licensed professional engineer.
4. The drawings are generic and do not include installation requirements that are specific to a particular manufactured home model. Additional foundation elements, (e.g. marriage wall support), required by the manufacturer shall be provided. Where conflicts exist between the manufacturer's requirements and these drawings, the most stringent shall apply.
5. Pre-engineered foundation design is based on a 60 feet long x 14 feet wide (single unit) and a 60 feet long x 28 feet wide (double unit) manufactured home.

Material Specifications

1. All exposed hardware shall be hot dipped galvanized per ASTM A-153.
2. All concrete shall be normal weight and shall be proportioned to provide a minimum 3,000 psi 28-day compressive strength (fc').
3. Reinforcing steel shall have a minimum 60 ksi yield strength (f_y).
4. All wood below BFE (framing, shims, etc.) shall meet or exceed NFIP flood resistant material requirements. One acceptable method is to provide rot and insect resistance that meets or exceeds protection provided by CCA (chromated copper arsenate) at a retention of 0.40 CCA pounds per cubic foot.
5. All wood shall be grade no. 2 or better and shall provide minimum design value as follows:

   $f_b \geq 975$psi
   $f_t \geq 550$psi
   $f_v \geq 90$psi
   $f_{c\perp} \geq 565$psi
   $f_c \geq 1450$psi

1. Anchor performance shall be based on load testing and probabilistic analysis of anchors tested in both dry and saturated soils. Anchor design values shall be based on a maximum 10% fractile and a minimum 90% confidence interval. Anchor spacing in these designs is based on a minimum stiffness of 1,200 pounds per inch for in-line anchors and 675 pounds per inch for anchors used with 11"x17"steel stabilizer plates. These stiffness values were determined from tests of 5 foot anchors conducted in saturated and unsaturated uniform (poorly graded) medium to fine grained sandy soils in Kissimmee, Florida, July 2002. Torque and penetrometer tests, typically used in ground anchor selection, classify these soils as Class 4a.
2. Preload anchors as required to fully activate the resistance of the stabilizer plates and the anchor helices.
3. Anchor straps shall be galvanized, tested per ASTM D3953, shall have an allowable minimum working load of 3,150 pounds and a minimum tensile strength of 4,725 pounds.
4. Concrete anchors shall provide an allowable working load of 3,150 pounds and a minimum ultimate load of 4,725 pounds.
5. Concrete masonry units shall be Type I or Type II per ASTM C90. Mortar shall be Type M, N, or S per ASTM C270.
6. Grout shall be coarse aggregate and shall be apportioned per ASTM C476.
7. Surface bonded mortar for flows between 1 and 2 ft/sec shall meet ASTM C887-79a (2001) and ASTM C946-91 (2001).
8. Wind speed is a 3-second gust speed in miles per hour at 33 feet above ground in Exposure Category C.
9. Maximum anchor spacing is the spacing designed to limit manufactured home movement during a design event to 3" horizontal or 2" vertical. This criterion has historically been used by the manufactured housing industry. See manual for discussions of anchor spacing that provide improved resistance.
10. End anchors shall be located no more than 2'0" from the ends of the home per 24CFR Part 3280.306 (c)(2).

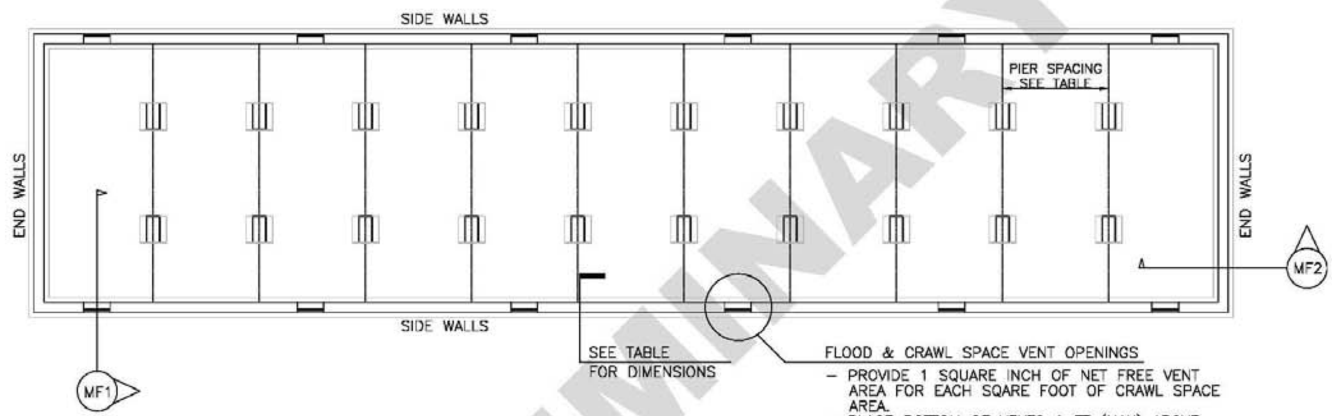
Symbols and Abbreviations

ABS	- Acrylonitrile Butadiene Styrene
fps	- feet per second
f_b	- Bending strength (wood)
$f_{c\perp}$	- compressive strength parallel to grain (wood)
f_c	- compressive strength perpendicular to grain (wood)
f_c'	- compressive strength (concrete)
f_t	- tensile strength parallel to grain (wood)
f_v	- shear strength parallel to grain (wood)
f_y	- yield strength of reinforcing steel
g	- gravitational force
max	- maximum
mph	- miles per hour
o.c	- on center
psf	- pounds per square foot
psi	- pounds per square inch
Ss	- spectral response acceleration at short periods
S_1	- spectral response acceleration at a period of 1 second
Typ.	- typical
$a \geq b$	- a is greater than or equal to b
$a \leq b$	- a is less than or equal to b
$a < b$	- a is less than b

PRELIMINARY

PRE-ENGINEERED FOUNDATION-GENERAL NOTES

February 2004
FEMA 85 GN-1.1



FLOOD & CRAWL SPACE VENT OPENINGS

- PROVIDE 1 SQUARE INCH OF NET FREE VENT AREA FOR EACH SQARE FOOT OF CRAWL SPACE AREA.
- PLACE BOTTOM OF VENTS 1 FT (MAX) ABOVE EXTERIOR GRADE.
- ALL SCREENS AND LOUVERS MUST AUTOMATICALLY OPEN TO ALLOW UNOBSTRUCTED FLOW OF FLOOD WATERS.
- PLACE 1/2 OF REQUIRED VENTS IN EACH LONG WALL. DO NOT PLACE VENTS IN SHORT (SHEAR) WALLS.

Maximum Pier Spacing Table - Single Unit

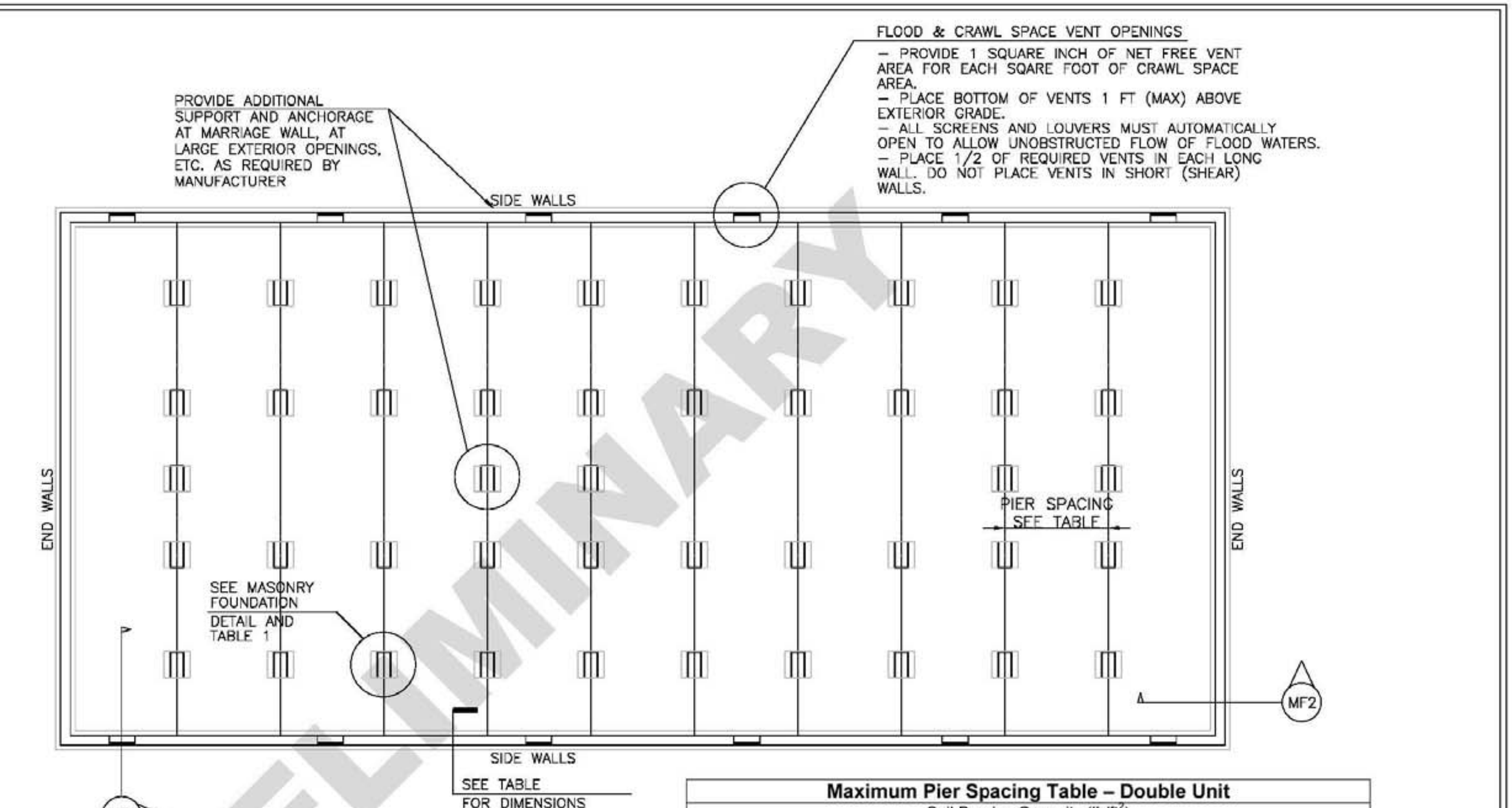
	Soil Bearing Capacity (lb/ft^2)								
	1,000 < 1,500			1,500 < 2,000			2,000 and over		
Wind Speed	Ground Snow Load (lb/ft^2)			Ground Snow Load (lb/ft^2)			Ground Snow Load (lb/ft^2)		
	<20	20<30	30≤40	<20	20<30	30≤40	<20	20<30	30≤40
90	5'3"	4'9"	4'2"	7'10"	7'2"	6'6"	8'0"	8'0"	8'0"
125	5'1"	4'7"	4'2"	7'7"	6'10"	6'4"	8'0"	8'0"	8'0"
140	5'0"	4'7"	4'2"	7'5"	6'9"	6'2"	8'0"	8'0"	8'0"

SINGLE UNIT MASONRY FOUNDATION PLAN

NOT TO SCALE

SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1

February 2004
FEMA 85 M-1



Maximum Pier Spacing Table – Double Unit

	Soil Bearing Capacity (lb/ft^2)								
	1,000 < 1,500			1,500 < 2,000			2,000 and over		
Wind Speed	Ground Snow Load (lb/ft^2)			Ground Snow Load (lb/ft^2)			Ground Snow Load (lb/ft^2)		
	<20	20<30	30≤40	<20	20<30	30≤40	<20	20<30	30≤40
90	5'0"	4'6"	4'0"	7'7"	6'11"	6'3"	8'0"	8'0"	8'0"
125	4'10"	4'4"	4'0"	7'4"	6'7"	6'1"	8'0"	8'0"	8'0"
140	4'9"	4'4"	4'0"	7'2"	6'6"	5'11"	8'0"	8'0"	8'0"

DOUBLE UNIT MASONRY FOUNDATION PLAN

NOT TO SCALE

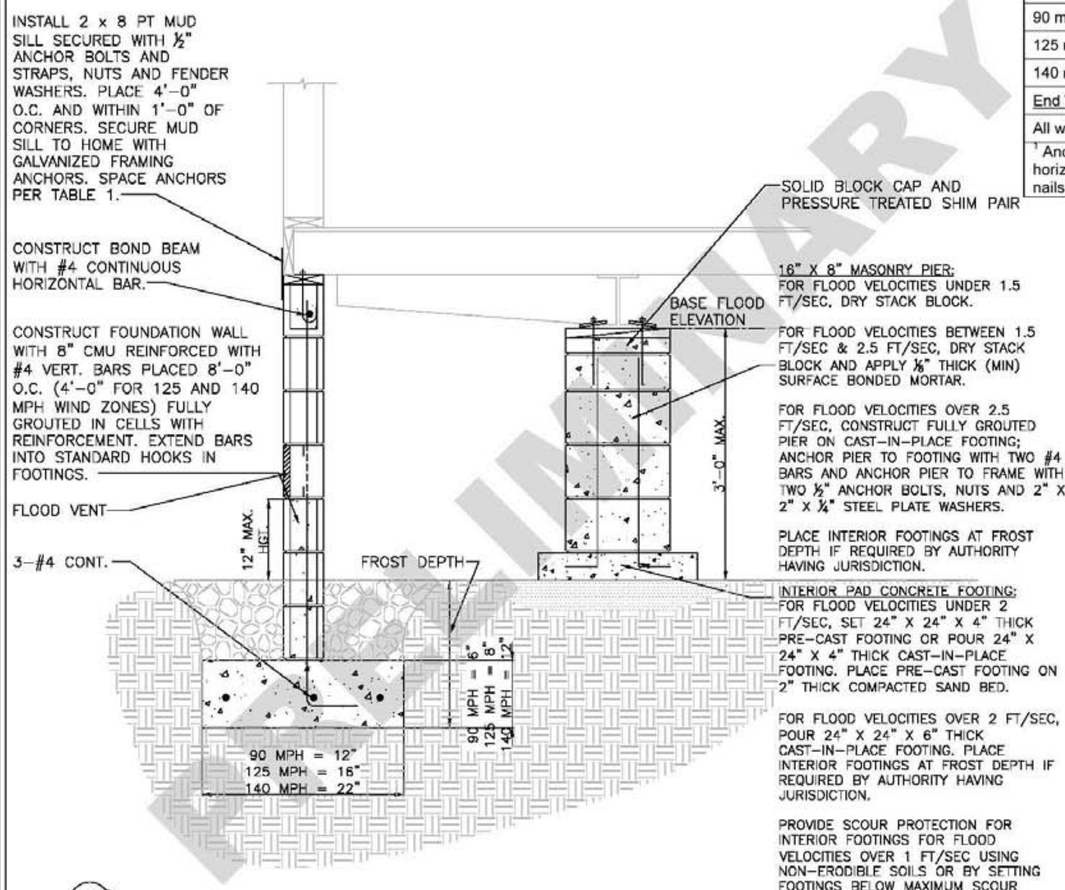
SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1

February 2004
FEMA 85 M-2

Table 1

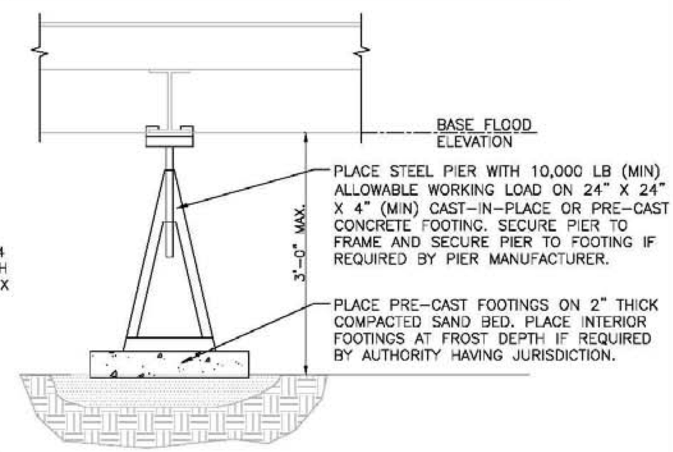
Floor Framing Connection Schedule		
Side Walls	Framing Anchor Spacing[1]	
Wind Speed	Single Unit	Double Unit
90 mph	8' 0"	10' 0"
125 mph	5' 0" (2 anchors)	8' 0" (2 anchors)
140 mph	4' 0" (2 anchors)	6' 0" (2 anchors)
End Walls	Framing Anchor Spacing[1]	
All wind speeds	4' 0" (2 anchors)	4' 0" (2 anchors)

[1] Anchor spacing is based on anchors capability of resisting 515# vertical and horizontal wind loads. (Simpson LTP4 or equivalent anchor secured with 12 – 8d nails)



MF1 **MASONRY WALL FOUNDATION DETAIL**

NOT TO SCALE



STEEL PIER

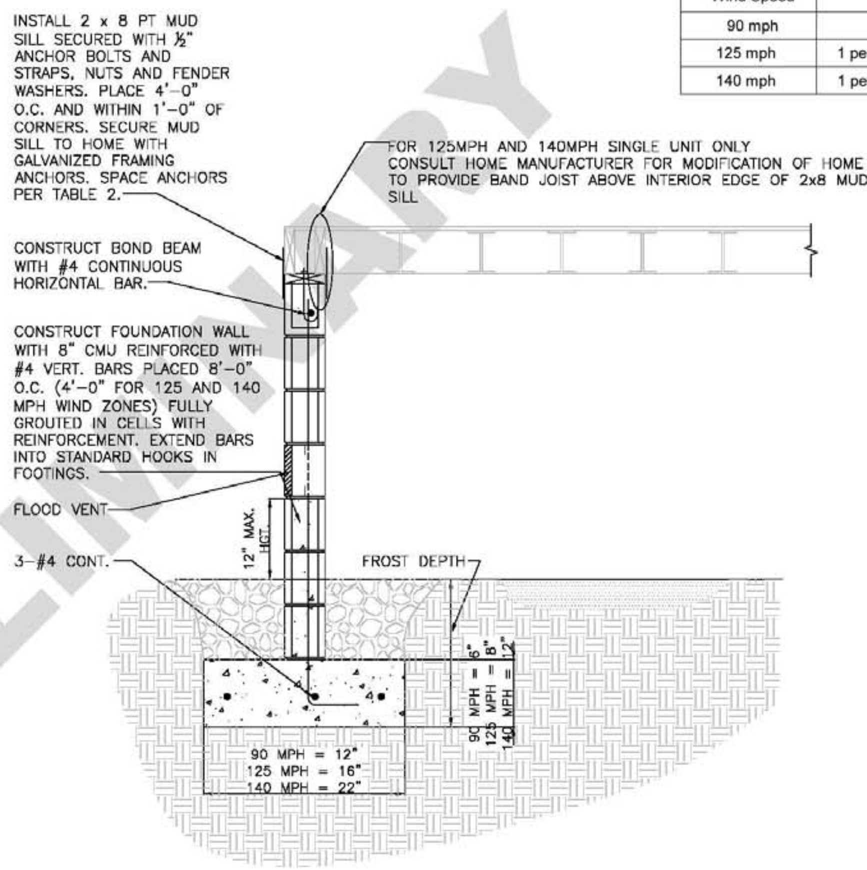
ALTERNATE FOR FLOOD VELOCITIES UNDER 1 FT/SEC

SEE PRE-ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN-1.1

February 2004
FEMA 85 M-3

Table 2

Anchor Spacing for End Wall		
Wind Speed	Single Unit	Double Unit
90 mph	1 per 1'-0"	1 per 2'-3"
125 mph	1 per 1'-3" (two sides)	1 per 1'-3"
140 mph	1 per 1'-0" (two sides)	1 per 1'-0"

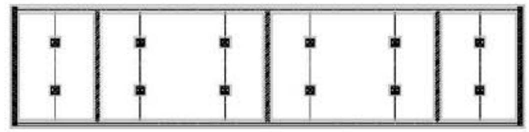


MF2 **END WALL FOUNDATION DETAIL**

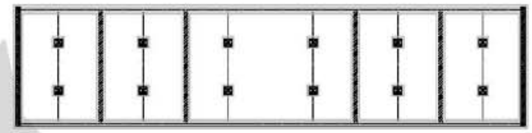
NOT TO SCALE

SEE PRE-ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN-1.1

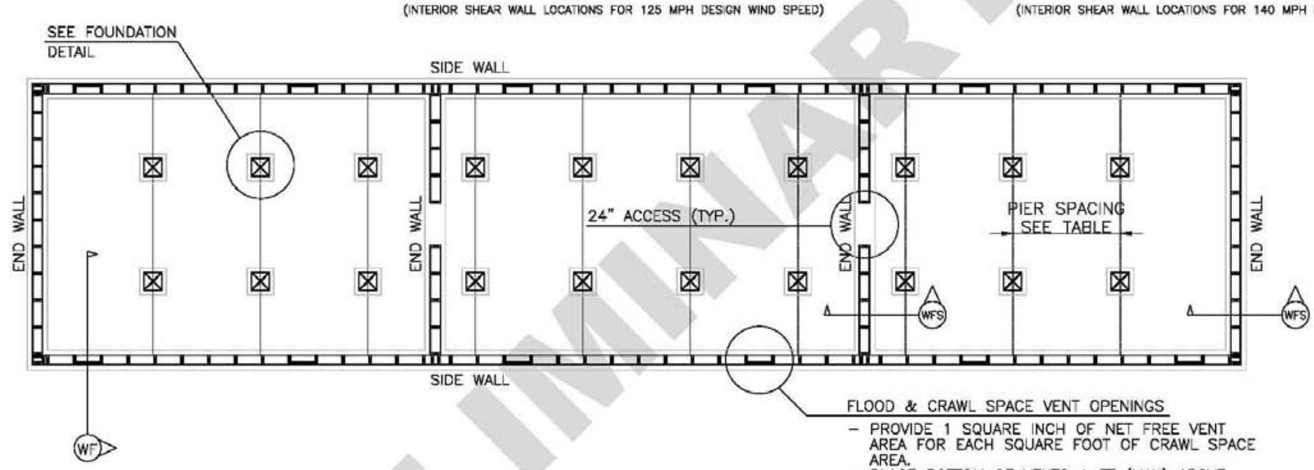
February 2004
FEMA 85 M-4



(INTERIOR SHEAR WALL LOCATIONS FOR 125 MPH DESIGN WIND SPEED)



(INTERIOR SHEAR WALL LOCATIONS FOR 140 MPH DESIGN WIND SPEED)



FLOOD & CRAWL SPACE VENT OPENINGS

- PROVIDE 1 SQUARE INCH OF NET FREE VENT AREA FOR EACH SQUARE FOOT OF CRAWL SPACE AREA.
- PLACE BOTTOM OF VENTS 1 FT (MAX) ABOVE EXTERIOR GRADE.
- ALL SCREENS AND LOUVERS MUST AUTOMATICALLY OPEN TO ALLOW UNOBSTRUCTED FLOW OF FLOOD WATERS.
- PLACE 1/2 OF REQUIRED VENTS IN EACH LONG WALL. DO NOT PLACE VENTS IN SHORT (SHEAR) WALLS.

Maximum Pier Spacing Table

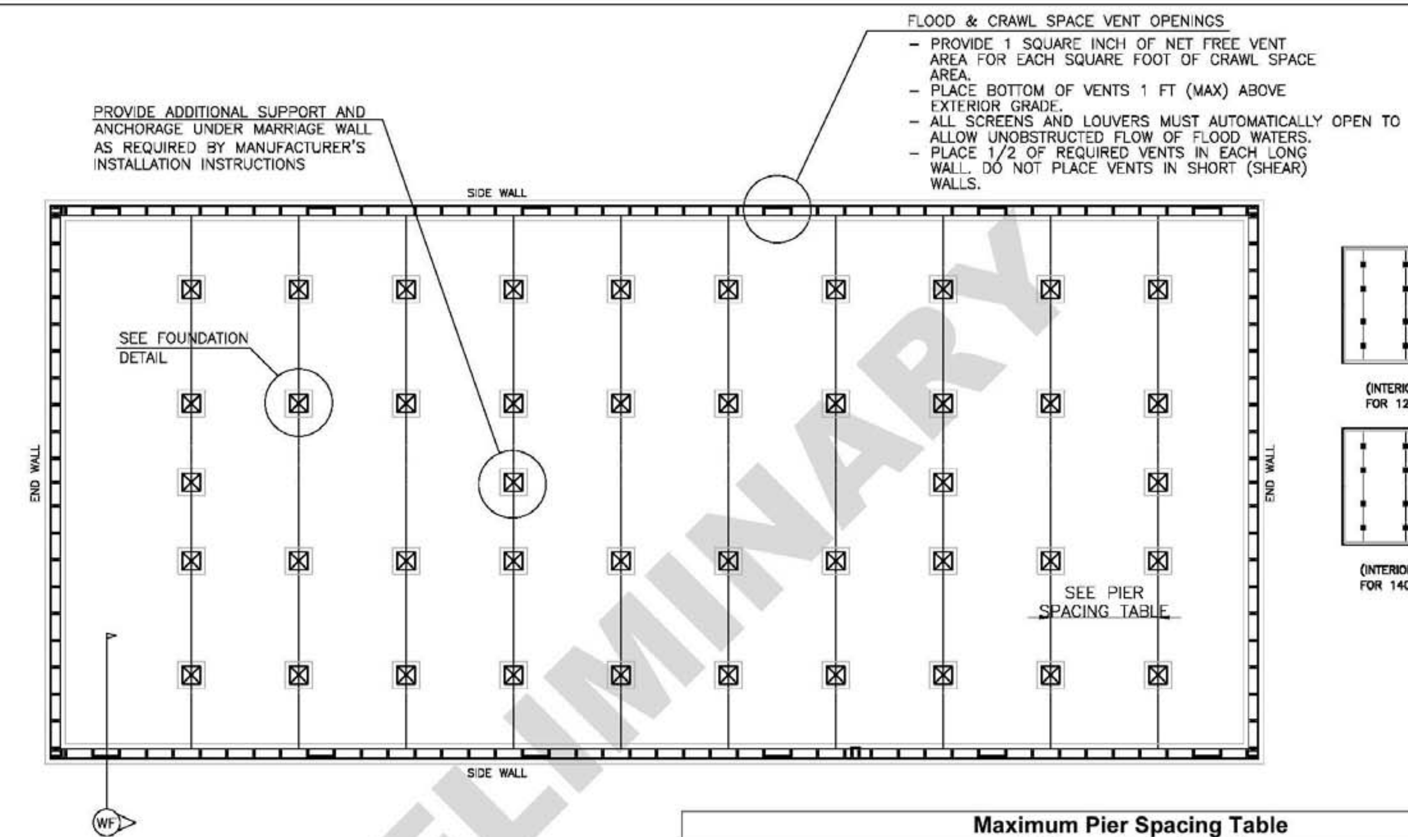
	Soil Bearing Capacity (lb/ft^2)								
	1,000 < 1,500			1,500 < 2,000			2,000 and over		
Footing Style	Ground Snow Load (lb/ft^2)			Ground Snow Load (lb/ft^2)			Ground Snow Load (lb/ft^2)		
	<20	20<30	30≤40	<20	20<30	30≤40	<20	20<30	30≤40
Concrete	5'3"	4'9"	4'2"	7'10"	7'2"	6'6"	8'0"	8'0"	8'0"

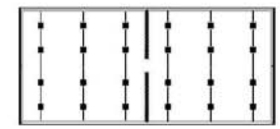
SINGLE UNIT WOOD FRAMED FOUNDATION PLAN

INTERIOR SHEAR WALL LOCATION FOR 90 MPH DESIGN WIND SPEED - NOT TO SCALE

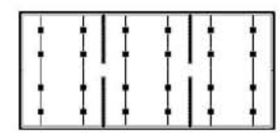
SEE PRE-ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN-1.1

February 2004
FEMA 85 WF-1





(INTERIOR SHEAR WALL LOCATIONS FOR 125 MPH DESIGN WIND SPEED)



(INTERIOR SHEAR WALL LOCATIONS FOR 140 MPH DESIGN WIND SPEED)

Maximum Pier Spacing Table

Soil Bearing Capacity (lb/ft^2)	1,000 < 1,500			1,500 < 2,000			2,000 and over		
Footing Style	Ground Snow Load (lb/ft^2)			Ground Snow Load (lb/ft^2)			Ground Snow Load (lb/ft^2)		
	<20	20<30	30≤40	<20	20<30	30≤40	<20	20<30	30≤40
Concrete	5'0"	4'6"	4'0"	7'7"	6'11"	6'3"	8'0"	8'0"	8'0"

DOUBLE UNIT WOOD FRAMED FOUNDATION PLAN

NOT TO SCALE

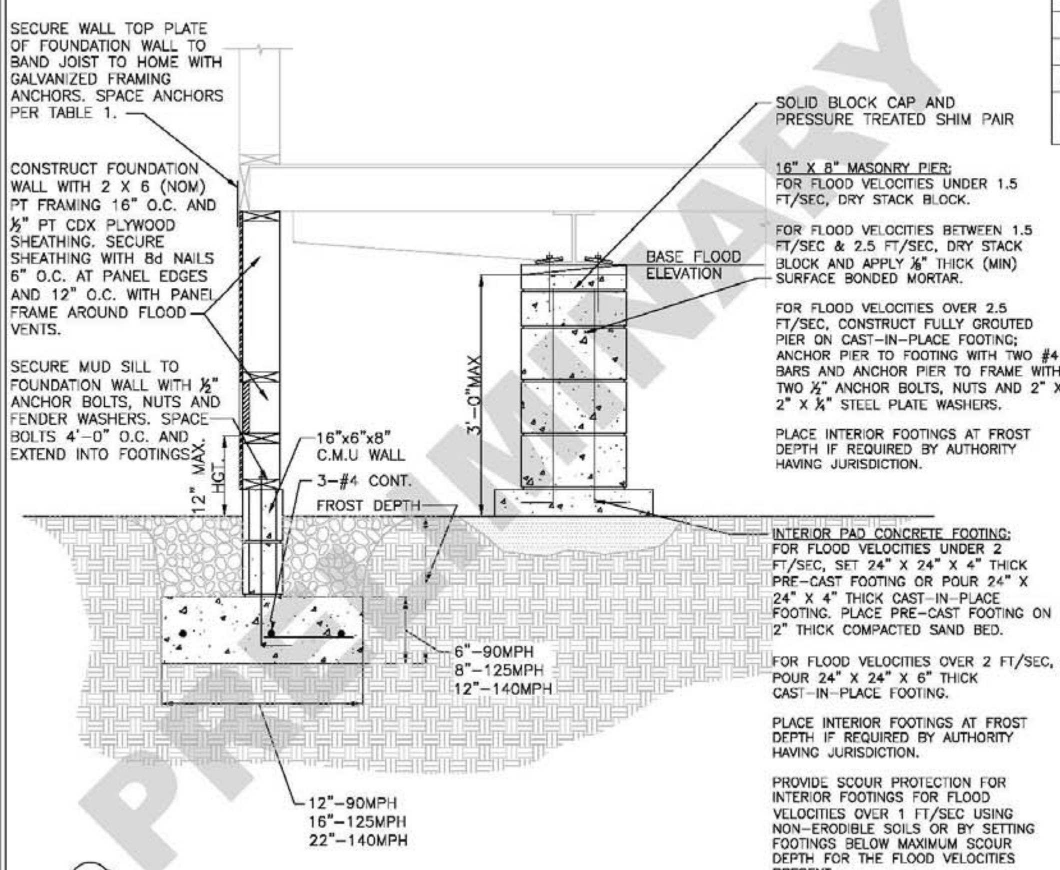
SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1

February 2004
FEMA 85 WF-2

Table 1

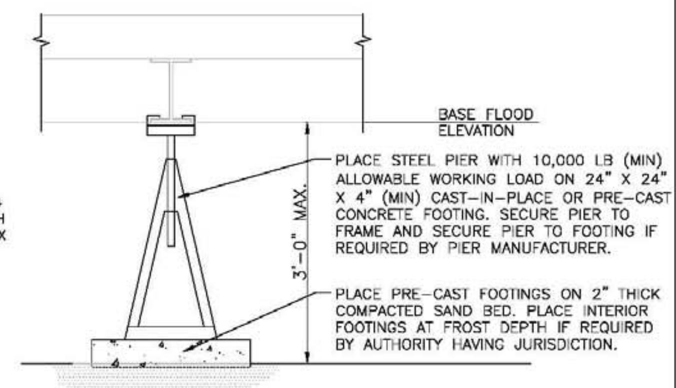
Floor Framing Connection Schedule		
Side Walls	Framing Anchor Spacing[1]	
Wind Speed	Single Unit	Double Unit
90 mph	8' 0"	10' 0"
125 mph	5' 0" (2 anchors)	8' 0" (2 anchors)
140 mph	4' 0" (2 anchors)	6' 0" (2 anchors)
End Walls	Framing Anchor Spacing[1]	
All wind speeds	4' 0" (2 anchors)	4' 0" (2 anchors)

[1] Anchor spacing is based on anchors capability of resisting 515# vertical and horizontal wind loads. (Simpson LTP4 or equivalent anchor secured with 12 – 8d nails)



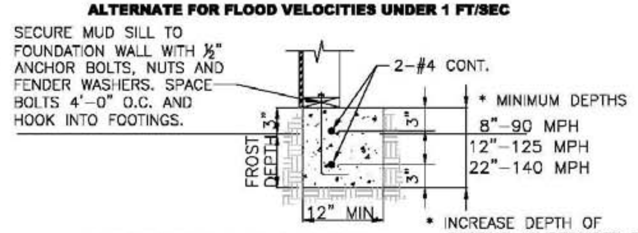
WF1 **WOOD FRAMED FOUNDATION DETAIL**

NOT TO SCALE



STEEL PIER

ALTERNATE FOR FLOOD VELOCITIES UNDER 1 FT/SEC



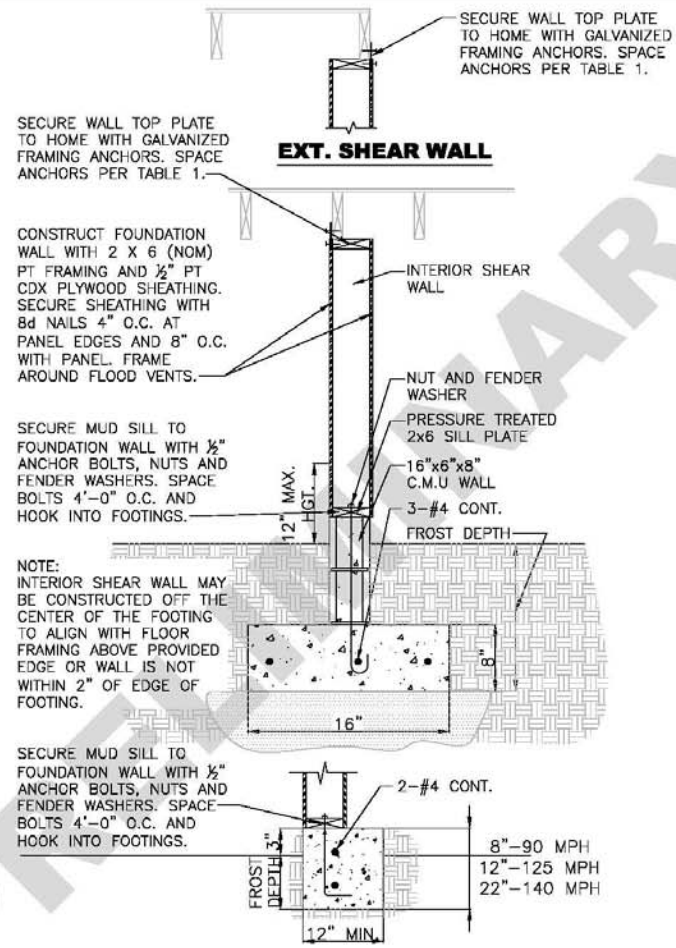
MONOLITHIC POUR

ALTERNATE FOOTING

* INCREASE DEPTH OF FOOTING AS REQUIRED TO PLACE BOTTOM OF FOOTING BELOW DESIGN FROST DEPTH

SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1

February 2004
FEMA 85 WF-3



MONOLITHIC POUR

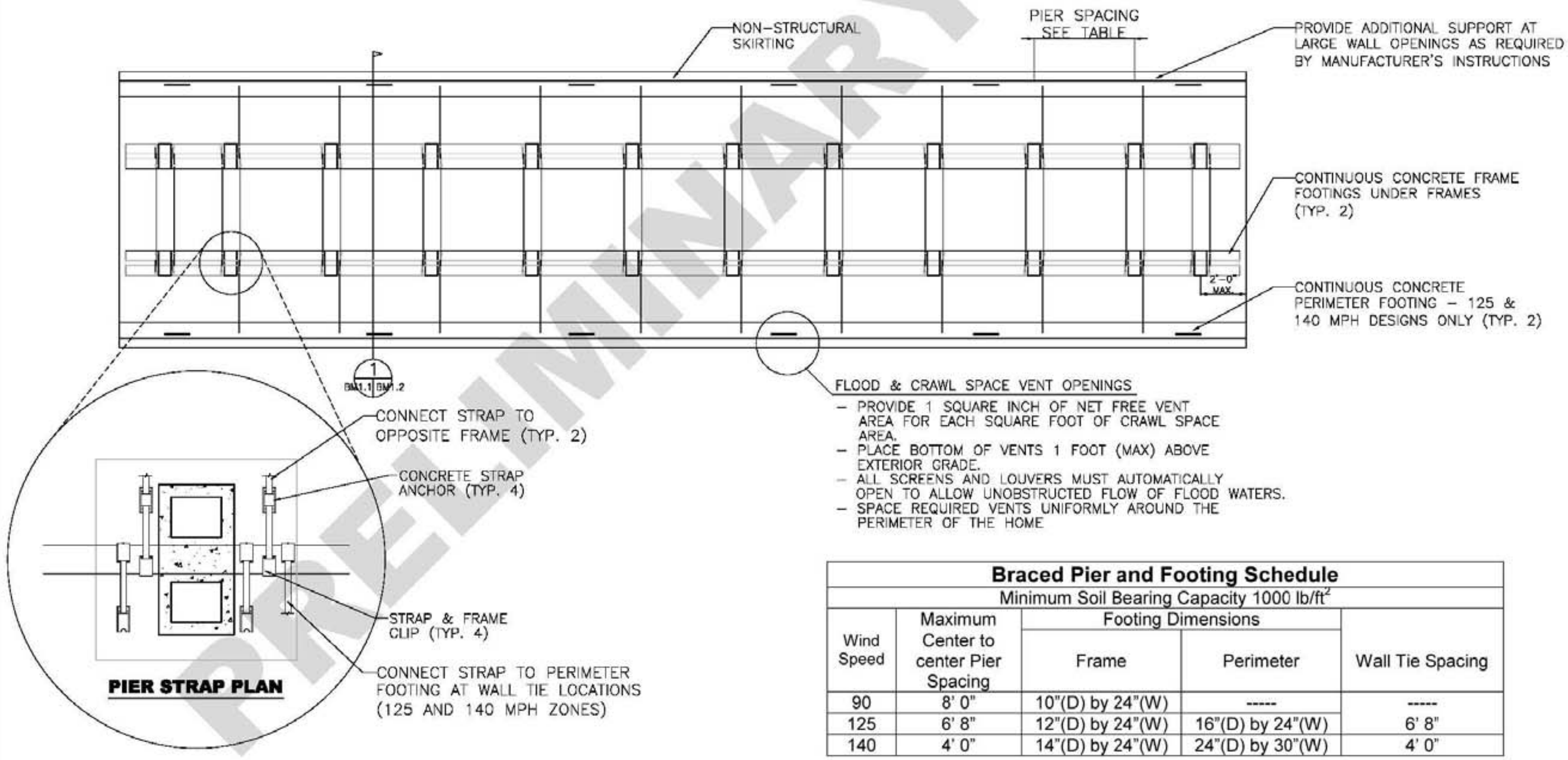
ALTERNATE FOOTING

WF2 WOOD FRAMED SHEAR WALL DETAIL

NOT TO SCALE

SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1

February 2004
FEMA 85 WF-4



FLOOD & CRAWL SPACE VENT OPENINGS

- PROVIDE 1 SQUARE INCH OF NET FREE VENT AREA FOR EACH SQUARE FOOT OF CRAWL SPACE AREA.
- PLACE BOTTOM OF VENTS 1 FOOT (MAX) ABOVE EXTERIOR GRADE.
- ALL SCREENS AND LOUVERS MUST AUTOMATICALLY OPEN TO ALLOW UNOBSTRUCTED FLOW OF FLOOD WATERS.
- SPACE REQUIRED VENTS UNIFORMLY AROUND THE PERIMETER OF THE HOME

Braced Pier and Footing Schedule

Minimum Soil Bearing Capacity 1000 lb/ft^2

Wind Speed	Maximum Center to center Pier Spacing	Footing Dimensions		Wall Tie Spacing
		Frame	Perimeter	
90	8' 0"	10"(D) by 24"(W)	-----	-----
125	6' 8"	12"(D) by 24"(W)	16"(D) by 24"(W)	6' 8"
140	4' 0"	14"(D) by 24"(W)	24"(D) by 30"(W)	4' 0"

SINGLE UNIT BRACED MASONRY PIER FOUNDATION PLAN

CONTINUOUS STRAP FOOTING - NOT TO SCALE

SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1

February 2004
FEMA 85 BM-1.1

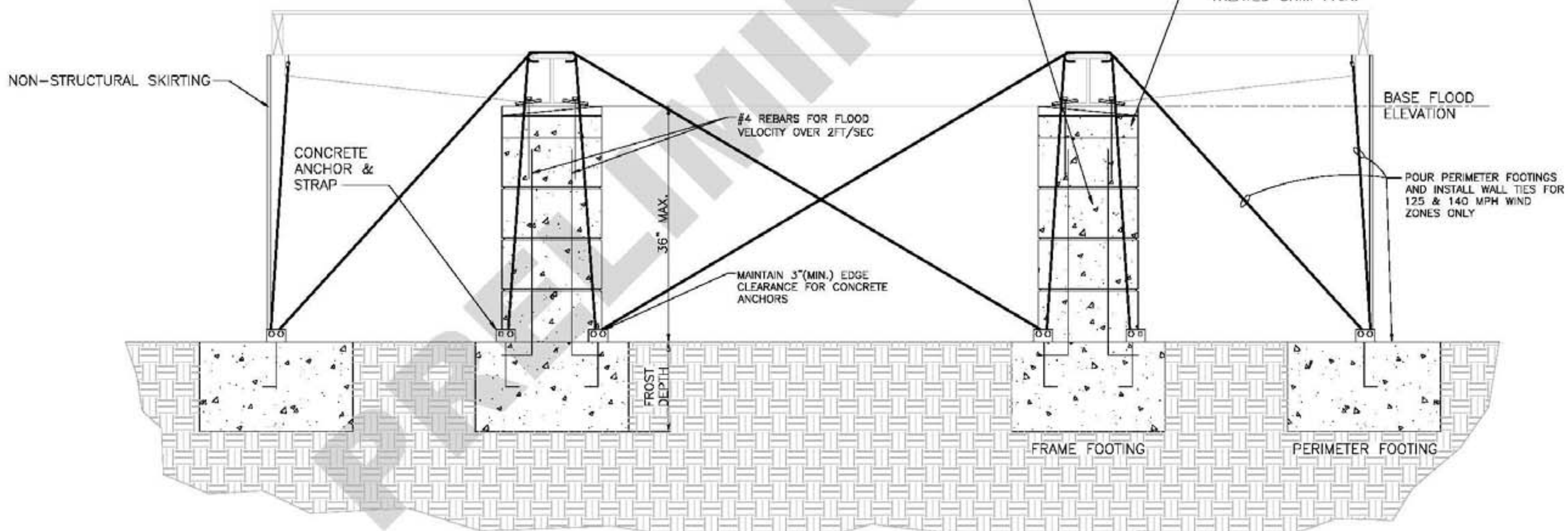
16" x 8" MASONRY PIER & CAST-IN-PLACE FOOTING:
SECURE PIER, FOOTING AND FRAME WITH STRAPS, FRAME CLIPS AND CONCRETE ANCHORS. PROVIDE FRAME CLIP FOR EACH STRAP.

FOR FLOOD VELOCITIES UNDER 1.5 FT/SEC CONSTRUCT PIER WITH DRY STACK BLOCK. USE SOLID BLOCK FOR TOP CAP.

FOR FLOOD VELOCITIES BETWEEN 1.5 FT/SEC & 2.5 FT/SEC, CONSTRUCT PIER WITH DRY STACK BLOCK DESCRIBED ABOVE AND APPLY ⅛" THICK (MIN) SURFACE BONDED MORTAR.

FOR FLOOD VELOCITIES OVER 2.5 FT/SEC, CONSTRUCT FULLY GROUTED PIER; ANCHOR PIER TO FOOTING WITH TWO FULL-HEIGHT #4 BARS AND 2-½" ANCHOR BOLTS, NUTS AND 2" X 2" X ¼" STEEL PLATE WASHER.

FOOTINGS SHALL BE CONTINUOUS CAST-IN-PLACE CONCRETE. PROVIDE FOOTINGS UNDER HOUSE FRAMES FOR ALL WIND ZONES AND FOOTINGS UNDER PERIMETER WALLS FOR 125 AND 140 MPH WIND ZONES. CONTINUE ALL FOOTINGS TO APPROXIMATELY 6" FROM THE ENDS OF THE HOME. SEE BRACED PIER AND FOOTING SCHEDULE FOR PIER SPACING AND FOOTING DIMENSIONS. PLACE FOOTINGS AT FROST DEPTH IF REQUIRED BY AUTHORITY HAVING JURISDICTION. PROVIDE SCOUR PROTECTION AROUND PIERS IN AREAS WHERE FLOOD VELOCITIES EXCEED 1 FT/SEC USING NON-ERODIBLE SOILS OR BY PLACING FOOTINGS BELOW THE MAXIMUM SCOUR DEPTH FOR THE FLOOD VELOCITIES PRESENT.

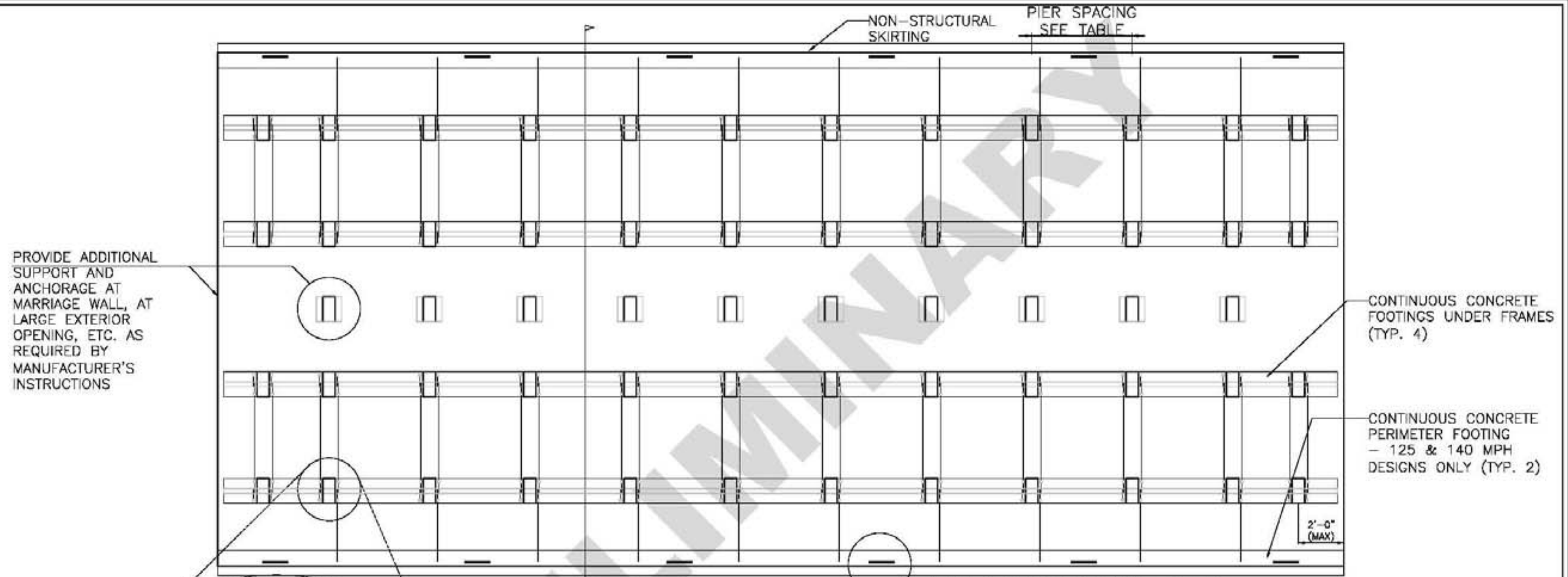


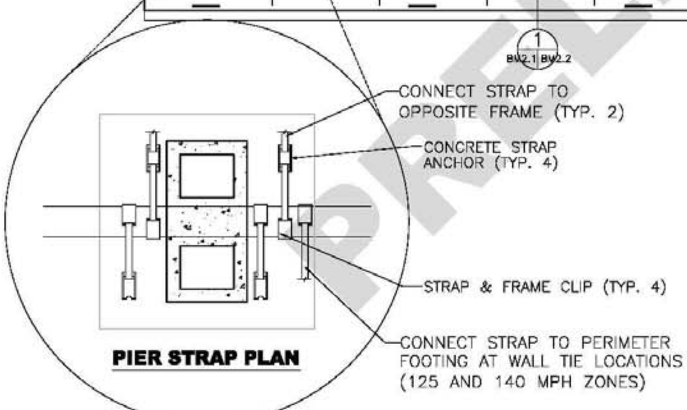
1 BM1.1 BM1.2 **BRACED MASONRY PIER DETAIL**

NOT TO SCALE

SEE PRE-ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN-1.1

February 2004
FEMA 85 BM-1.2





FLOOD & CRAWL SPACE VENT OPENINGS

- PROVIDE 1 SQUARE INCH OF NET FREE VENT AREA FOR EACH SQUARE FOOT OF CRAWL SPACE AREA.
- PLACE BOTTOM OF VENTS 1 FOOT (MAX) ABOVE EXTERIOR GRADE.
- ALL SCREENS AND LOUVERS MUST AUTOMATICALLY OPEN TO ALLOW UNOBSTRUCTED FLOW OF FLOOD WATERS.
- SPACE REQUIRED VENTS UNIFORMLY AROUND THE PERIMETER OF THE HOME

Braced Pier and Footing Schedule

Minimum Soil Bearing Capacity 1000 lb/ft^2

Wind Speed	Maximum Center to Center Pier Spacing	Footing Dimensions		Wall Tie Spacing
		Frame	Perimeter	
90	8' 0"	10"(D) by 24"(W)	-----	-----
125	6' 8"	12"(D) by 24"(W)	16"(D) by 24"(W)	6' 8"
140	4' 0"	14"(D) by 24"(W)	24"(D) by 30"(W)	4' 0"

DOUBLE UNIT BRACED MASONRY PIER FOUNDATION PLAN

CONTINUOUS SPREAD FOOTING - NOT TO SCALE

SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1

February 2004
FEMA 85 BM-2.1

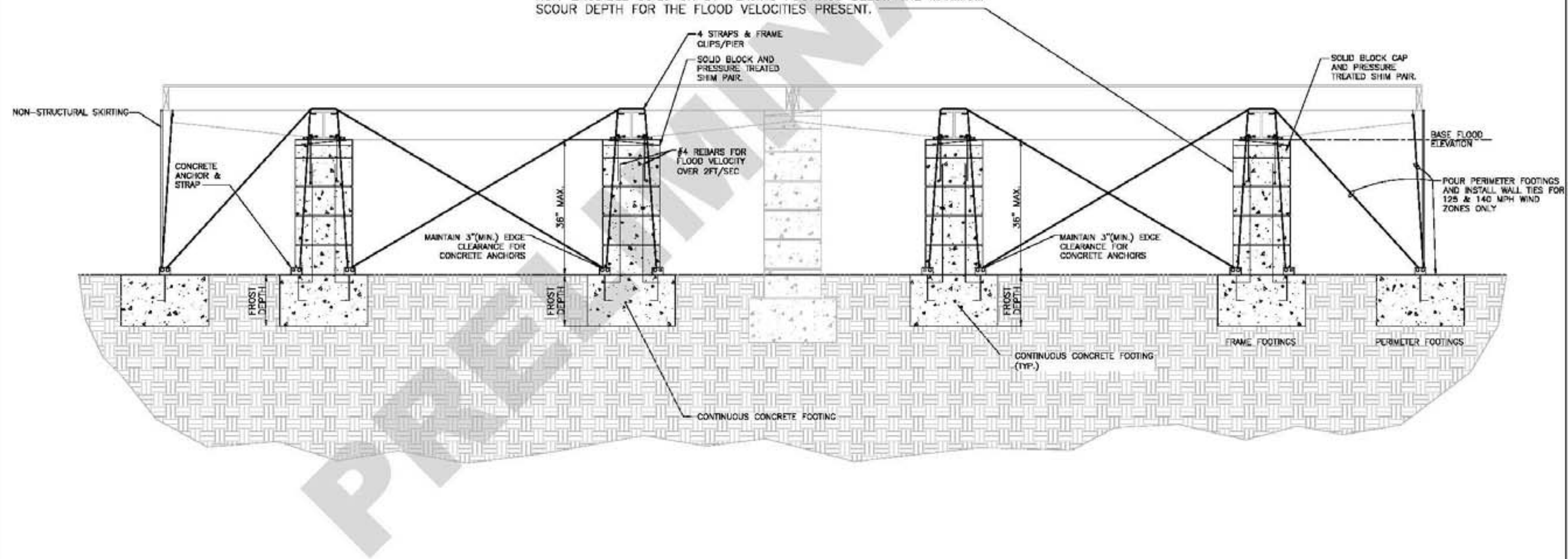
16" x 8" MASONRY PIER & CAST-IN-PLACE FOOTING:
SECURE PIER, FOOTING AND FRAME WITH STRAPS, FRAME CLIPS AND CONCRETE ANCHORS. PROVIDE FRAME CLIP FOR EACH STRAP.

FOR FLOOD VELOCITIES UNDER 1.5 FT/SEC CONSTRUCT PIER WITH DRY STACK BLOCK. USE SOLID BLOCK FOR TOP CAP.

FOR FLOOD VELOCITIES BETWEEN 1.5 FT/SEC & 2.5 FT/SEC, CONSTRUCT PIER WITH DRY STACK BLOCK DESCRIBED ABOVE AND APPLY ⅛" THICK (MIN) SURFACE BONDED MORTAR.

FOR FLOOD VELOCITIES OVER 2.5 FT/SEC, CONSTRUCT FULLY GROUTED PIER; ANCHOR PIER TO FOOTING WITH TWO FULL-HEIGHT #4 BARS AND 2-½" ANCHOR BOLTS, NUTS AND 2" X 2" X ¼" STEEL PLATE WASHER.

FOOTINGS SHALL BE CONTINUOUS CAST-IN-PLACE CONCRETE. PROVIDE FOOTINGS UNDER HOUSE FRAMES FOR ALL WIND ZONES AND FOOTINGS UNDER PERIMETER WALLS FOR 125 AND 140 MPH WIND ZONES. CONTINUE ALL FOOTINGS TO APPROXIMATELY 6" FROM THE ENDS OF THE HOME. SEE BRACED PIER AND FOOTING SCHEDULE FOR PIER SPACING AND FOOTING DIMENSIONS. PLACE FOOTINGS AT FROST DEPTH IF REQUIRED BY AUTHORITY HAVING JURISDICTION. PROVIDE SCOUR PROTECTION AROUND PIERS IN AREAS WHERE FLOOD VELOCITIES EXCEED 1 FT/SEC USING NON-ERODIBLE SOILS OR BY PLACING FOOTINGS BELOW THE MAXIMUM SCOUR DEPTH FOR THE FLOOD VELOCITIES PRESENT.



1 BM2.1 BM2.2 **BRACED MASONRY PIER DETAIL**

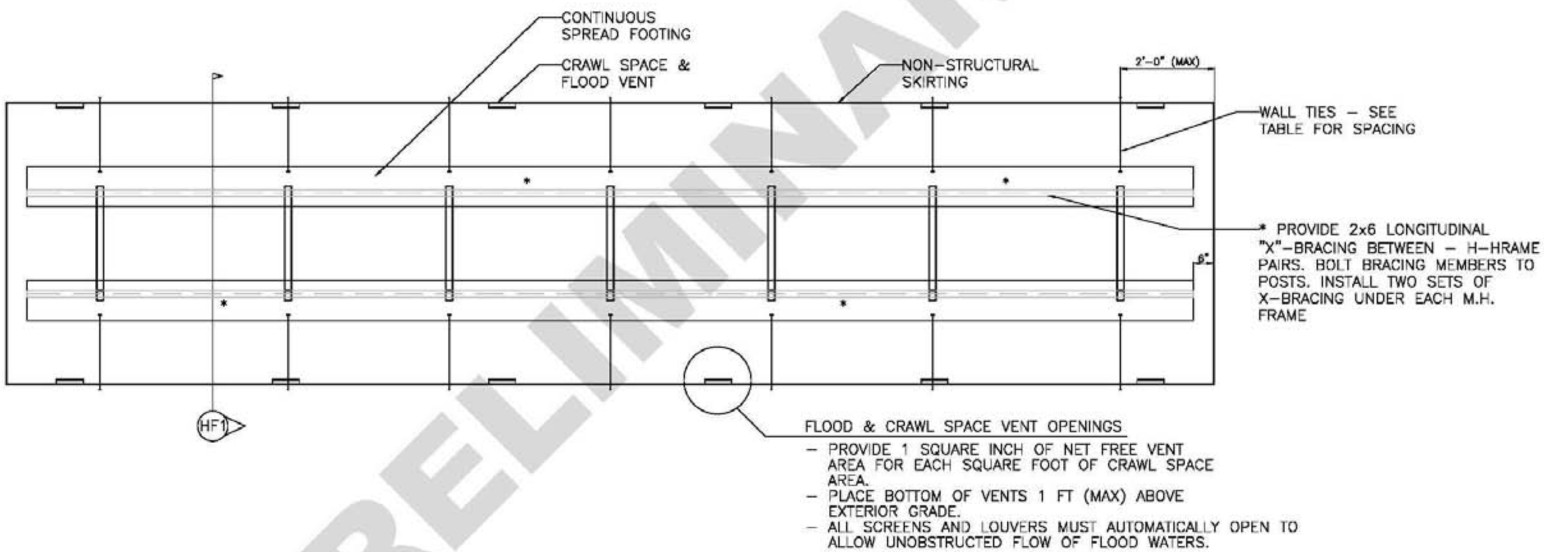
NOT TO SCALE

SEE PRE-ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN-1.1

February 2004
FEMA 85 BM-2.2

H-FRAME SPACING TABLE

WIND SPEED	H-FRAME SPACING	WALL TIE SPACING
90 MPH	8'-0"	–
125 MPH	6'-8"	5'-4"
140 MPH	6'-4"	4'-0"

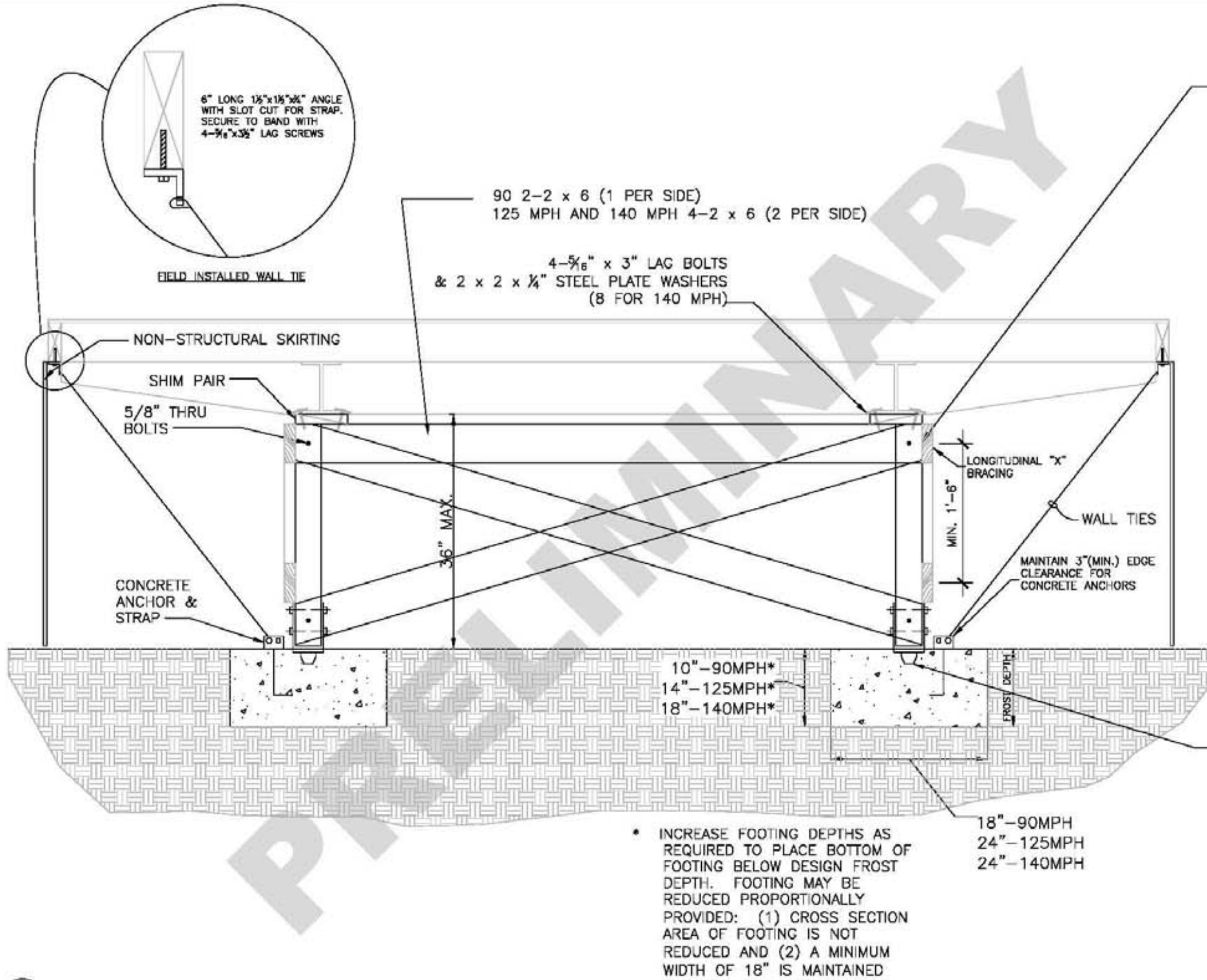


SINGLE UNIT BRACED WOOD H-FRAME FOUNDATION PLAN

CONTINUOUS SPREAD FOOTING - NOT TO SCALE

SEE PRE-ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN-1.1

February 2004
FEMA 85 HF-1.1



"H" FRAME:
CONSTRUCT H-FRAME IN 90 ZONES WITH 4"x4" (NOM) PT WOOD POSTS, TWO 2"x6" CROSS BEAMS AND TWO 2"x6" DIAGONAL BRACES. THROUGH BOLT ALL FRAME COMPONENTS AS DETAILED.

CONSTRUCT FRAMES IN 125 MPH AND 140 MPH WIND ZONES WITH 6"x6" POSTS AND FOUR 2"x6" CROSS BEAMS. FASTEN EACH CHASIS TO FRAME WITH FOUR 5/16" BY 3" LAG BOLTS EACH WITH A 2" x 2" x ¼" PLATE WASHER. FASTEN EACH CHASIS IN 140 MPH WIND ZONES WITH EIGHT – 5/16" x 3" LAG BOLTS AND WASHERS.

PLACE FRAMES ON CONTINUOUS CAST-IN-PLACE CONCRETE FOOTINGS. SECURE FRAME POSTS WITH CAST-IN-PLACE POST BASE ANCHORS.

IN 125 MPH AND 140 MPH WIND ZONES, INSTALL WALL TIES FASTENED TO CONCRETE STRAP ANCHORS PLACED IN THE CONTINUOUS FOOTINGS.

PLACE FOOTINGS AT FROST DEPTH IF REQUIRED BY AUTHORITY HAVING JURISDICTION.

PROVIDE SCOUR PROTECTION FOR FOOTINGS FOR FLOOD VELOCITIES OVER 1 FT/SEC USING NON-ERODIBLE SOILS OR BY SETTING FOOTINGS BELOW MAXIMUM SCOUR DEPTH FOR THE FLOOD VELOCITIES PRESENT.

CAST-IN-PLACE POST BASE SIMPSON PBS44A OR EQUIVALENT WITH 14-16D NAILS FOR 90 MPH WIND ZONE (ALLOWABLE UPLIFT LOAD 2400#) & SIMPSON PBS66 OR EQUIVALENT FOR 125 MPH AND 140 MPH WIND ZONE

* INCREASE FOOTING DEPTHS AS REQUIRED TO PLACE BOTTOM OF FOOTING BELOW DESIGN FROST DEPTH. FOOTING MAY BE REDUCED PROPORTIONALLY PROVIDED: (1) CROSS SECTION AREA OF FOOTING IS NOT REDUCED AND (2) A MINIMUM WIDTH OF 18" IS MAINTAINED

HF1 SINGLE UNIT WOOD H-FRAME DETAIL

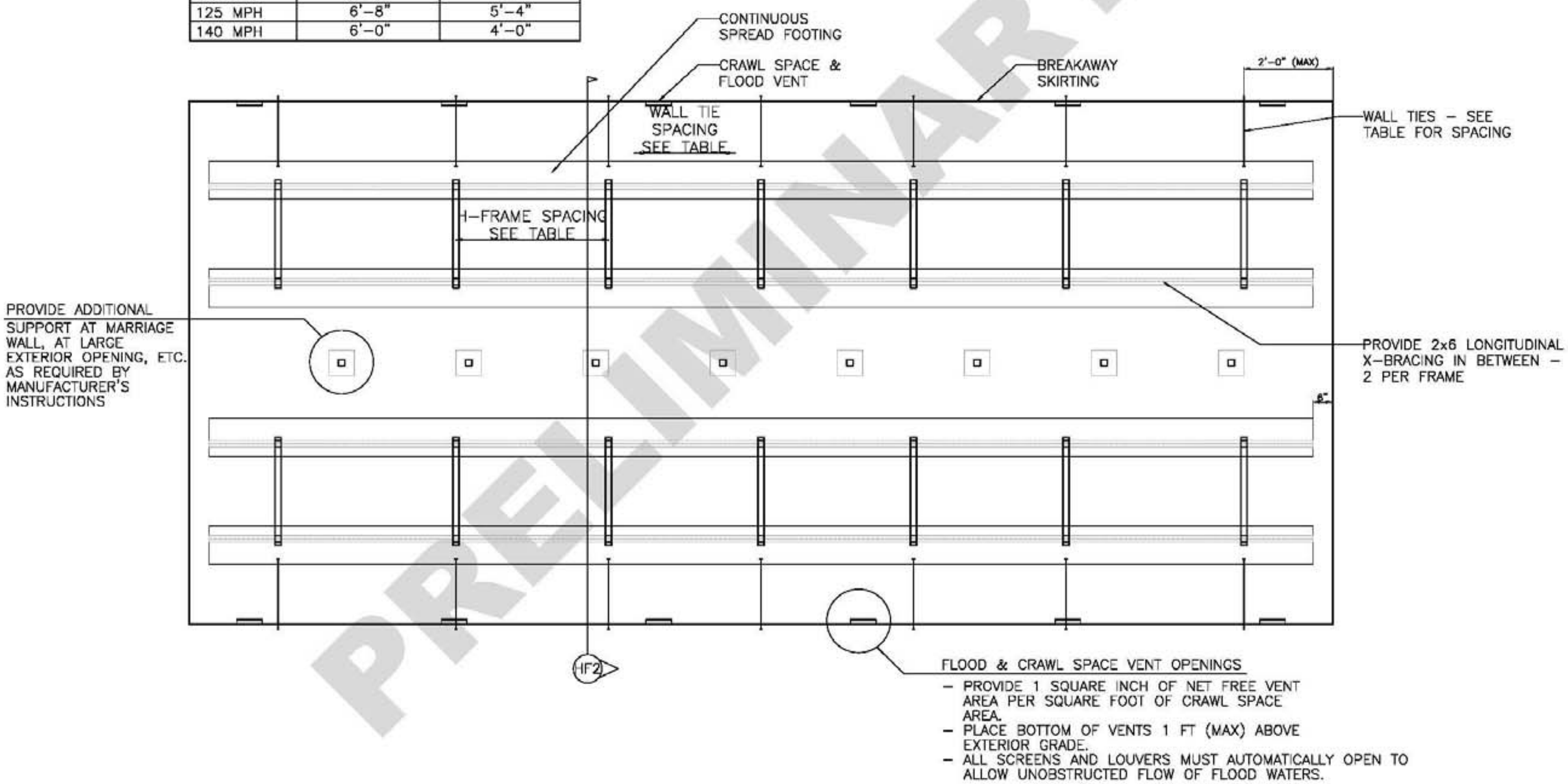
NOT TO SCLAE

SEE PRE-ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN-1.1

February 2004
FEMA 85 HF-1.2

H-FRAME SPACING TABLE

WIND SPEED	H-FRAME SPACING	WALL TIE SPACING
90 MPH	8'-0"	-
125 MPH	6'-8"	5'-4"
140 MPH	6'-0"	4'-0"



FLOOD & CRAWL SPACE VENT OPENINGS

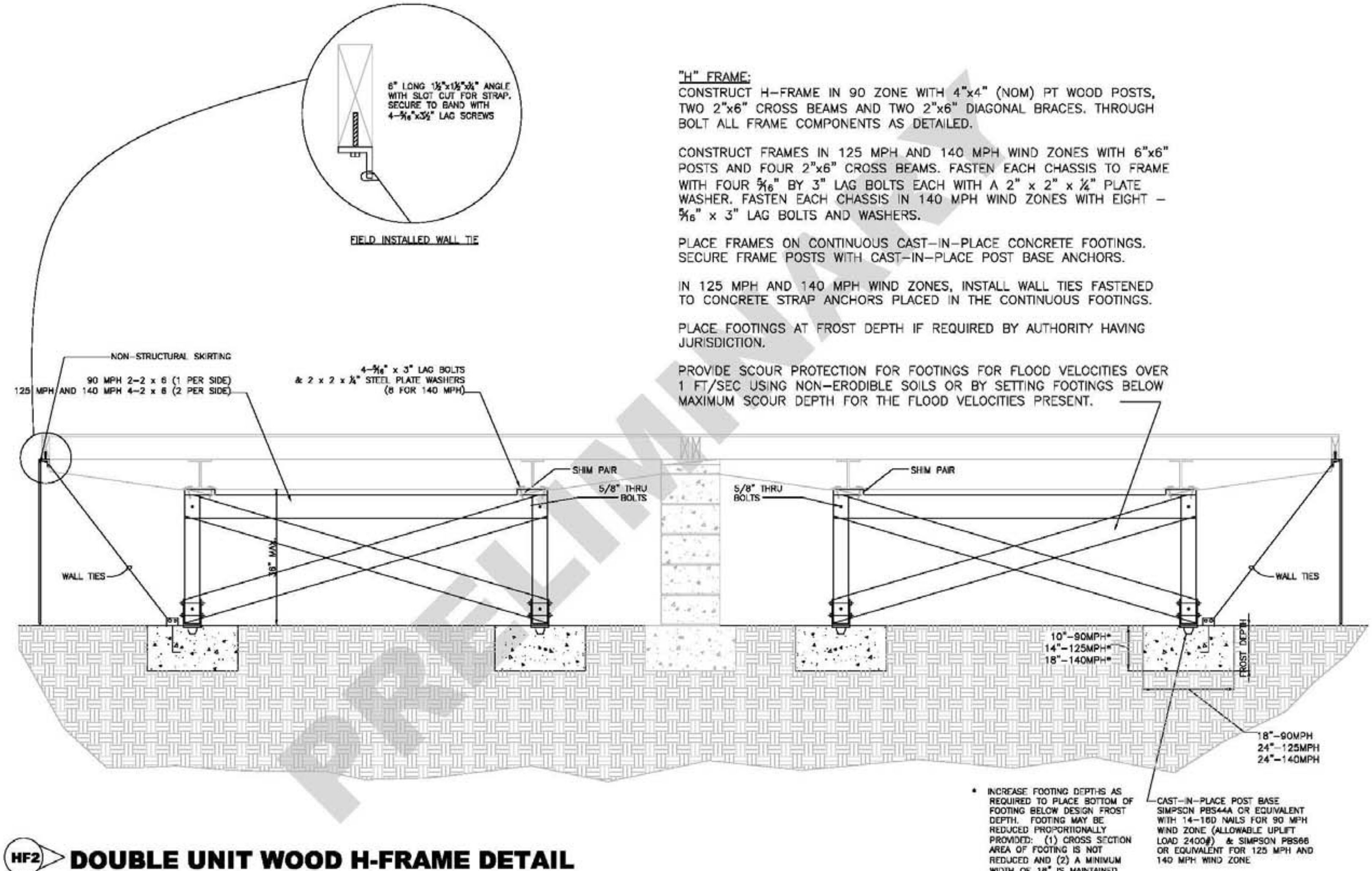
- PROVIDE 1 SQUARE INCH OF NET FREE VENT AREA PER SQUARE FOOT OF CRAWL SPACE AREA.
- PLACE BOTTOM OF VENTS 1 FT (MAX) ABOVE EXTERIOR GRADE.
- ALL SCREENS AND LOUVERS MUST AUTOMATICALLY OPEN TO ALLOW UNOBSTRUCTED FLOW OF FLOOD WATERS.

DOUBLE UNIT BRACED WOOD H-FRAME FOUNDATION PLAN

CONTINUOUS SPREAD FOOTING - NOT TO SCALE

SEE PRE-ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN-1.1

February 2004
FEMA 85 HF-2.1



"H" FRAME:

CONSTRUCT H-FRAME IN 90 ZONE WITH 4"x4" (NOM) PT WOOD POSTS, TWO 2"x6" CROSS BEAMS AND TWO 2"x6" DIAGONAL BRACES. THROUGH BOLT ALL FRAME COMPONENTS AS DETAILED.

CONSTRUCT FRAMES IN 125 MPH AND 140 MPH WIND ZONES WITH 6"x6" POSTS AND FOUR 2"x6" CROSS BEAMS. FASTEN EACH CHASSIS TO FRAME WITH FOUR 5/16" BY 3" LAG BOLTS EACH WITH A 2" x 2" x ¼" PLATE WASHER. FASTEN EACH CHASSIS IN 140 MPH WIND ZONES WITH EIGHT – 5/16" x 3" LAG BOLTS AND WASHERS.

PLACE FRAMES ON CONTINUOUS CAST-IN-PLACE CONCRETE FOOTINGS. SECURE FRAME POSTS WITH CAST-IN-PLACE POST BASE ANCHORS.

IN 125 MPH AND 140 MPH WIND ZONES, INSTALL WALL TIES FASTENED TO CONCRETE STRAP ANCHORS PLACED IN THE CONTINUOUS FOOTINGS.

PLACE FOOTINGS AT FROST DEPTH IF REQUIRED BY AUTHORITY HAVING JURISDICTION.

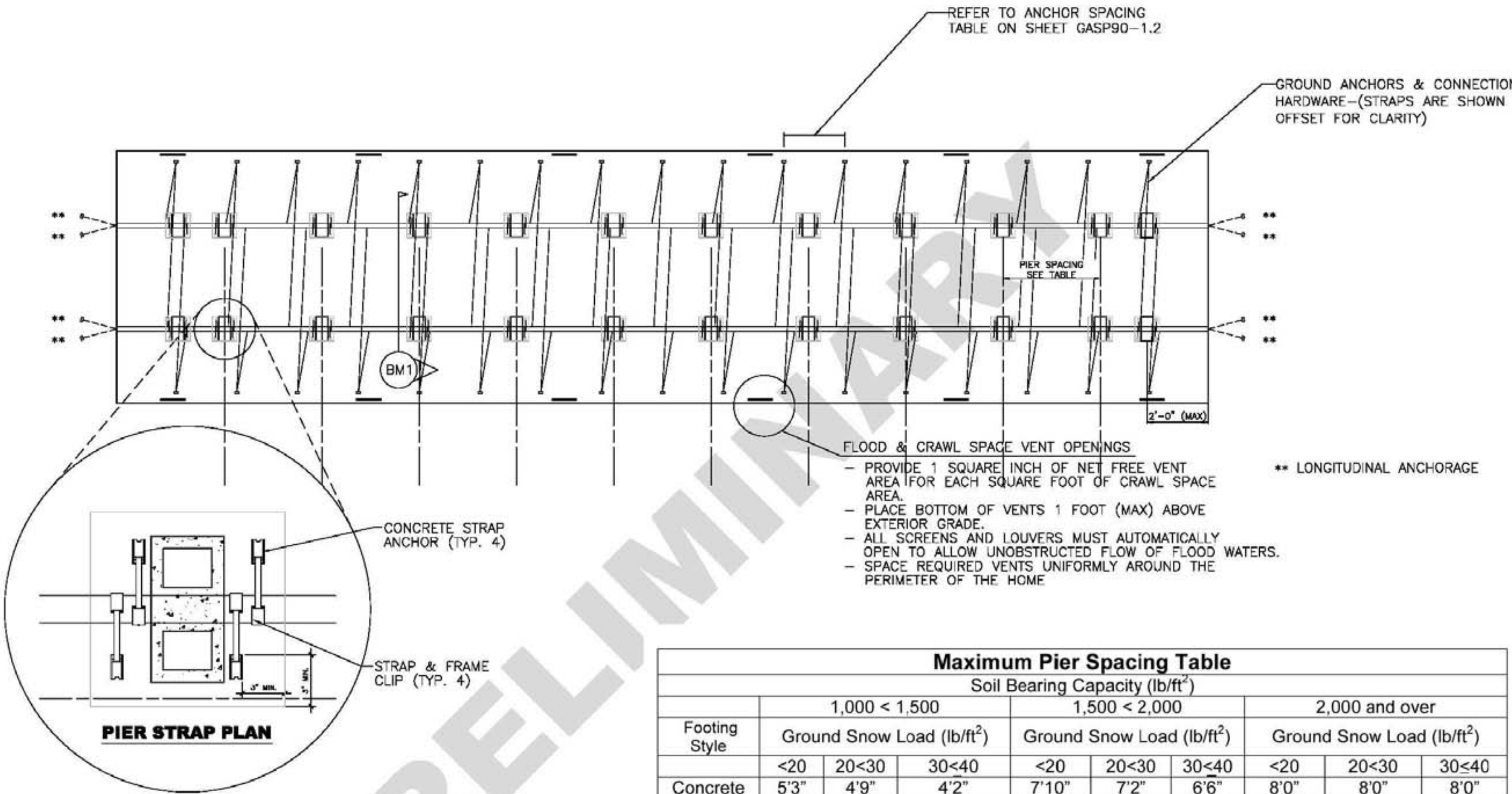
PROVIDE SCOUR PROTECTION FOR FOOTINGS FOR FLOOD VELOCITIES OVER 1 FT/SEC USING NON-ERODIBLE SOILS OR BY SETTING FOOTINGS BELOW MAXIMUM SCOUR DEPTH FOR THE FLOOD VELOCITIES PRESENT.

HF2 DOUBLE UNIT WOOD H-FRAME DETAIL

NOT TO SCALE

SEE PRE-ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN-1.1

February 2004
FEMA 85 HF-2.2



Maximum Pier Spacing Table

Soil Bearing Capacity (lb/ft^2)	1,000 < 1,500			1,500 < 2,000			2,000 and over		
Footing Style	Ground Snow Load (lb/ft^2)			Ground Snow Load (lb/ft^2)			Ground Snow Load (lb/ft^2)		
	<20	20<30	30<40	<20	20<30	30<40	<20	20<30	30≤40
Concrete	5'3"	4'9"	4'2"	7'10"	7'2"	6'6"	8'0"	8'0"	8'0"
ABS*	4'7"	4'3"	4'0"	7'0"	6'4"	5'10"	8'0"	8'0"	7'10"

*LOW FLOW APPLICATIONS ONLY

SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1

SINGLE UNIT GROUND ANCHOR FOUNDATION PLAN

CONTINUOUS SPREAD FOOTING - NOT TO SCALE

February 2004
FEMA 85 GASP90-1.1

Anchor Spacing Table for Single Unit Homes		
		Anchors With Stabilizer Plates
Wind Speed	Flood Rate	Maximum Spacing
90	1 fps	6'-8"
	5 fps	5'-4"
	ABS*	4'-0"

*Low flow using Alternate Pier System

16" x 8" MASONRY PIER & CAST-IN-PLACE FOOTING:
SECURE PIER, FOOTING AND FRAME WITH STRAPS, FRAME CLIPS AND CONCRETE ANCHORS. PROVIDE FRAME CLIP FOR EACH STRAP.

FOR FLOOD VELOCITIES UNDER 1.5 FT/SEC CONSTRUCT PIER WITH DRY STACK BLOCK.

FOR FLOOD VELOCITIES BETWEEN 1.5 FT/SEC & 2.5 FT/SEC, CONSTRUCT PIER WITH DRY STACK BLOCK AND APPLY ⅜" THICK (MIN) SURFACE BONDED MORTAR.

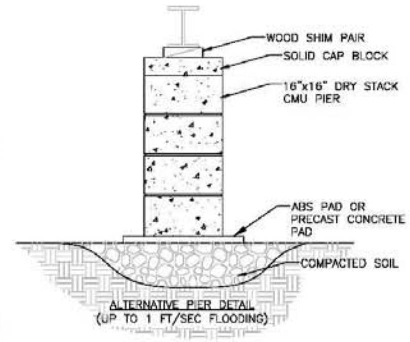
FOR FLOOD VELOCITIES OVER 2.5 FT/SEC, CONSTRUCT FULLY GROUTED PIER; ANCHOR PIER TO FOOTING WITH TWO FULL-HEIGHT #4 BARS.

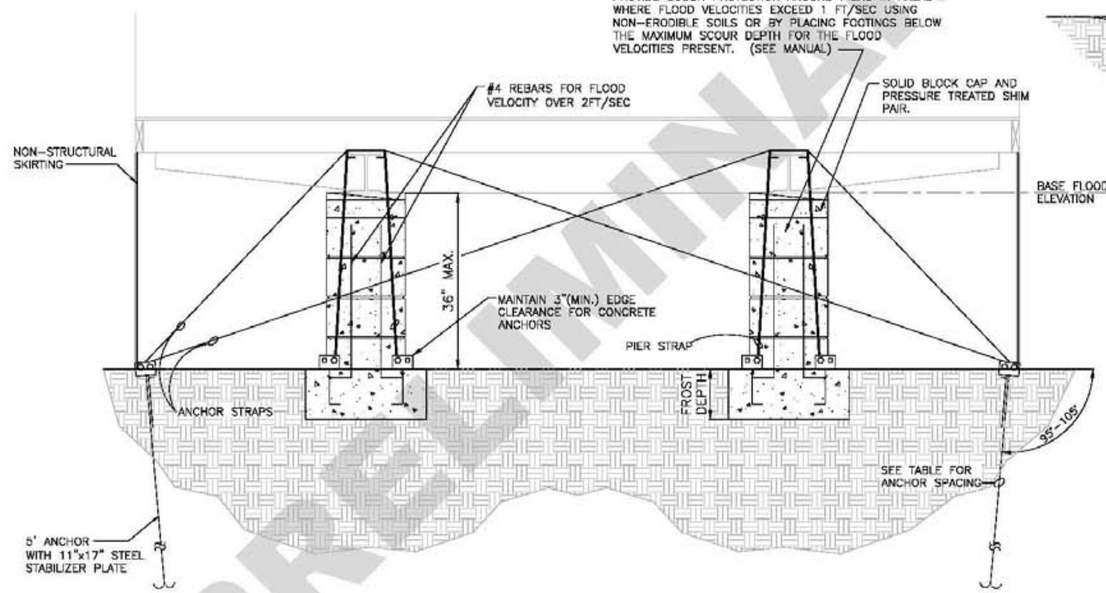
FOOTINGS SHALL BE 24" x 24" CAST-IN-PLACE CONCRETE 8" THICK.

PLACE FOOTINGS AT FROST DEPTH IF REQUIRED BY AUTHORITY HAVING JURISDICTION.

PROVIDE SCOUR PROTECTION AROUND PIERS IN AREAS WHERE FLOOD VELOCITIES EXCEED 1 FT/SEC USING NON-ERODIBLE SOILS OR BY PLACING FOOTINGS BELOW THE MAXIMUM SCOUR DEPTH FOR THE FLOOD VELOCITIES PRESENT. (SEE MANUAL)

ALTERNATIVE PIER FOR FLOOD VELOCITIES UP TO 1 FT/SEC:
CONSTRUCT 16"x16" DRY STACK PIER WITH ⅜" THICK(MIN) SURFACE BONDED MORTAR PLACED ON 4 SQ FT ABS PAD. INSTALL GROUND ANCHORS 4'-0" CENTERS.



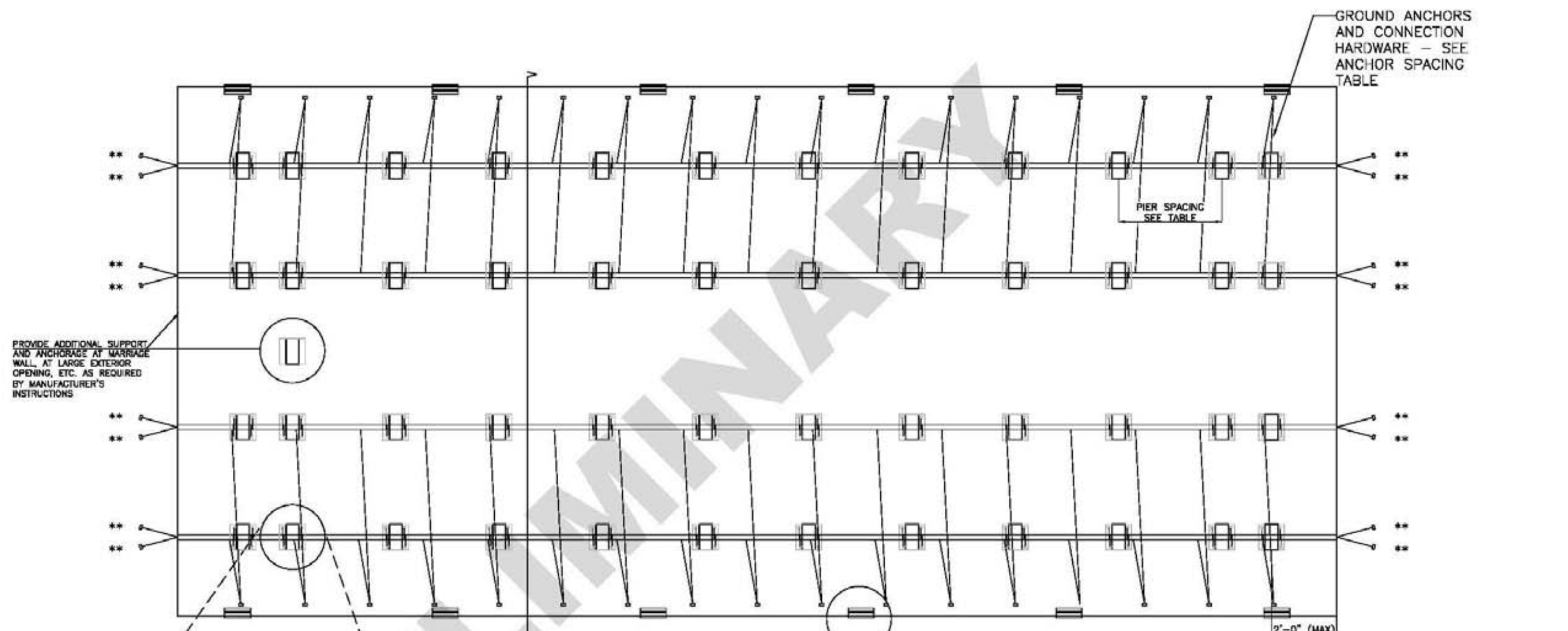


BM1 GROUND ANCHOR AND PIER DETAIL (SINGLE UNIT)

NOT TO SCALE

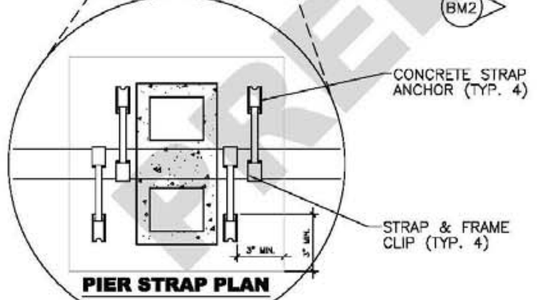
SEE PRE-ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN-1.1

February 2004
FEMA 85 GASP90-1.2



FLOOD & CRAWL SPACE VENT OPENINGS

- PROVIDE 1 SQUARE INCH OF NET FREE VENT AREA FOR EACH SQUARE FOOT OF CRAWL SPACE AREA.
- PLACE BOTTOM OF VENTS 1 FOOT (MAX) ABOVE EXTERIOR GRADE.
- ALL SCREENS AND LOUVERS MUST AUTOMATICALLY OPEN TO ALLOW UNOBSTRUCTED FLOW OF FLOOD WATERS.
- SPACE REQUIRED VENTS UNIFORMLY AROUND THE PERIMETER OF THE HOME



PIER STRAP PLAN

Maximum Pier Spacing Table

Footing Style	Soil Bearing Capacity (lb/ft²) 1,000 < 1,500 – Ground Snow Load (lb/ft²)			1,500 < 2,000 – Ground Snow Load (lb/ft²)			2,000 and over – Ground Snow Load (lb/ft²)		
	<20	20<30	30≤40	<20	20<30	30≤40	<20	20<30	30≤40
Concrete	5'3"	4'9"	4'2"	7'10"	7'2"	6'6"	8'0"	8'0"	8'0"
ABS*	4'7"	4'3"	4'0"	7'0"	6'4"	5'10"	8'0"	8'0"	7'10"

*LOW FLOW APPLICATIONS ONLY

SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1

DOUBLE UNIT GROUND ANCHOR FOUNDATION PLAN

CONTINUOUS SPREAD FOOTING - NOT TO SCALE

February 2004

FEMA 85 GASP90-2.1

PRELIMINARY

Anchor Spacing Table for Double Unit Homes		
		Anchors With Stabilizer Plates
Wind Speed	Flood Rate	Maximum Spacing
90	1 fps	6'-8"
	5 fps	5'-4"
	ABS*	4'-0"

*Low flow using Alternate Pier System

16" x 8" MASONRY PIER & CAST-IN-PLACE FOOTING:
SECURE PIER, FOOTING AND FRAME WITH STRAPS, FRAME CLIPS AND CONCRETE ANCHORS. PROVIDE FRAME CLIP FOR EACH STRAP.

FOR FLOOD VELOCITIES UNDER 1.5 FT/SEC CONSTRUCT PIER WITH DRY STACK BLOCK.

FOR FLOOD VELOCITIES BETWEEN 1.5 FT/SEC & 2.5 FT/SEC, CONSTRUCT PIER WITH DRY STACK BLOCK AND APPLY ⅜" THICK (MIN) SURFACE BONDED MORTAR.

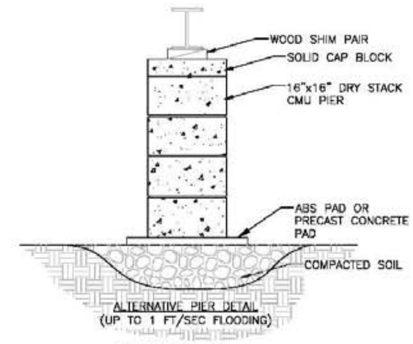
FOR FLOOD VELOCITIES OVER 2.5 FT/SEC, CONSTRUCT FULLY GROUTED PIER; ANCHOR PIER TO FOOTING WITH TWO FULL-HEIGHT #4 BARS.

FOOTINGS SHALL BE 24" x 24" CAST-IN-PLACE CONCRETE 8" THICK.

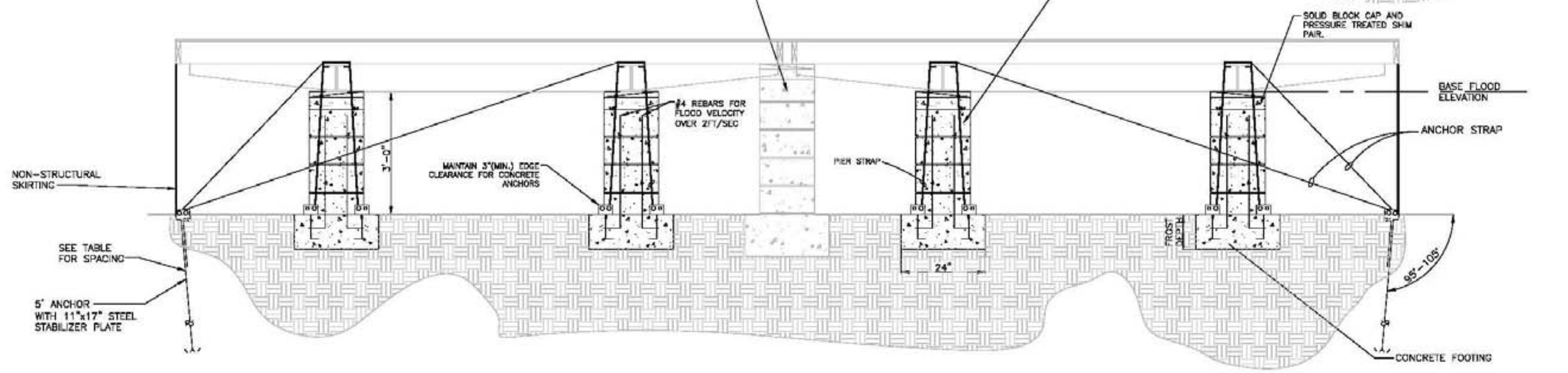
PLACE FOOTINGS AT FROST DEPTH IF REQUIRED BY AUTHORITY HAVING JURISDICTION.

PROVIDE SCOUR PROTECTION AROUND PIERS IN AREAS WHERE FLOOD VELOCITIES EXCEED 1 FT/SEC USING NON-ERODIBLE SOILS OR BY PLACING FOOTINGS BELOW THE MAXIMUM SCOUR DEPTH FOR THE FLOOD VELOCITIES PRESENT. (SEE MANUAL)

ALTERNATIVE PIER FOR FLOOD VELOCITIES UP TO 1 FT/SEC:
CONSTRUCT 16"x16" DRY STACK PIER WITH ⅜" THICK(MIN) SURFACE BONDED MORTAR PLACED ON 4 SQ FT ABS PAD. INSTALL GROUND ANCHORS 4'-0" O.C.



CONSTRUCT PIERS SUPPORTING THE MARRIAGE WALL AND SUPPORTING EXTERIOR WALL POINT LOADS USING THE SAME CONSTRUCTION METHOD USED FOR PIERS SUPPORTING THE MANUFACTURED HOME FRAMES.

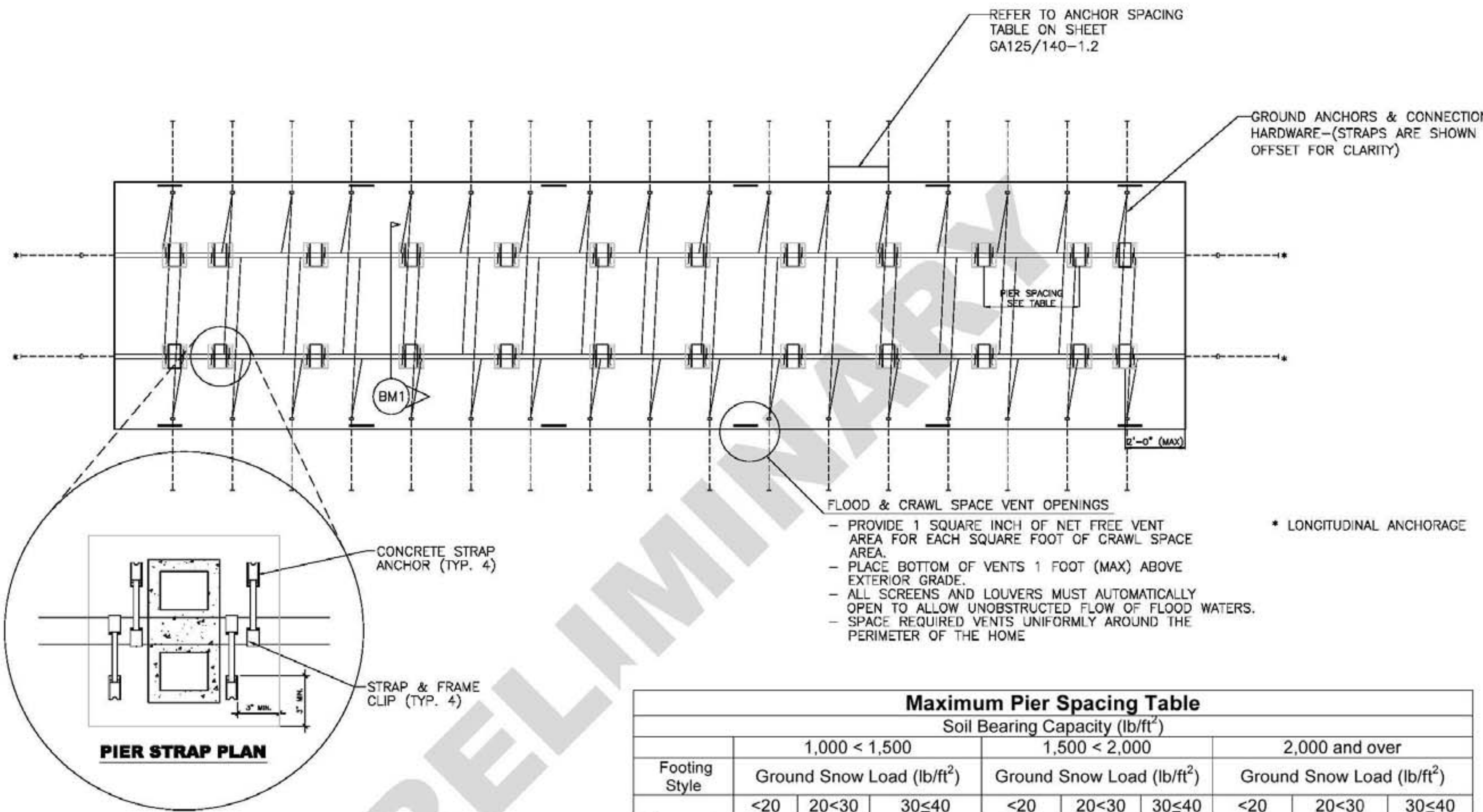


GROUND ANCHOR & PIER DETAIL (DOUBLE UNIT)

NOT TO SCALE

SEE PRE-ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN-1.1

February 2004
FEMA 85 GASP90-2.2



FLOOD & CRAWL SPACE VENT OPENINGS

- PROVIDE 1 SQUARE INCH OF NET FREE VENT AREA FOR EACH SQUARE FOOT OF CRAWL SPACE AREA.
- PLACE BOTTOM OF VENTS 1 FOOT (MAX) ABOVE EXTERIOR GRADE.
- ALL SCREENS AND LOUVERS MUST AUTOMATICALLY OPEN TO ALLOW UNOBSTRUCTED FLOW OF FLOOD WATERS.
- SPACE REQUIRED VENTS UNIFORMLY AROUND THE PERIMETER OF THE HOME

* LONGITUDINAL ANCHORAGE

Maximum Pier Spacing Table

Soil Bearing Capacity (lb/ft^2)	1,000 < 1,500			1,500 < 2,000			2,000 and over		
Footing Style	Ground Snow Load (lb/ft^2)			Ground Snow Load (lb/ft^2)			Ground Snow Load (lb/ft^2)		
	<20	20<30	30≤40	<20	20<30	30≤40	<20	20<30	30≤40
Concrete	5'1"	4'7"	4'2"	7'7"	6'10"	6'4"	8'0"	8'0"	8'0"
ABS*	4'7"	4'3"	4'0"	7'0"	6'4"	5'10"	8'0"	8'0"	7'10"

*LOW FLOW APPLICATIONS ONLY

SINGLE UNIT GROUND ANCHOR FOUNDATION PLAN

NOT TO SCALE

SEE PRE-ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN-1.1

February 2004

FEMA 85 GA125/140-1.1

Anchor Spacing Table for Single Unit Homes

Wind Speed	Flood Rate	Anchors with Stabilizer Plates: Maximum Spacing
125/ 140	1 fps	4'-0"
	5 fps	
125/ 140	ABS*	2'-8"

*Low flow using Alternate Pier System

16" x 8" MASONRY PIER & CAST-IN-PLACE FOOTING:
SECURE PIER, FOOTING AND FRAME WITH STRAPS, FRAME CLIPS AND CONCRETE ANCHORS. PROVIDE FRAME CLIP FOR EACH STRAP.

FOR FLOOD VELOCITIES UNDER 1.5 FT/SEC CONSTRUCT PIER WITH DRY STACK BLOCK.

FOR FLOOD VELOCITIES BETWEEN 1.5 FT/SEC & 2.5 FT/SEC, CONSTRUCT PIER WITH DRY STACK BLOCK AND APPLY ⅛" THICK (MIN) SURFACE BONDED MORTAR.

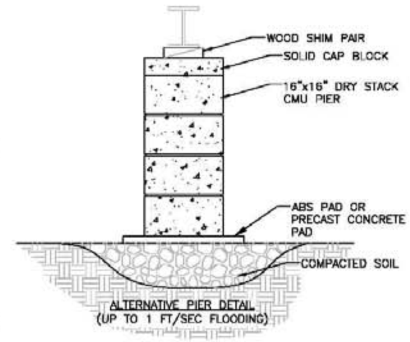
FOR FLOOD VELOCITIES OVER 2.5 FT/SEC, CONSTRUCT FULLY GROUTED PIER; ANCHOR PIER TO FOOTING WITH TWO FULL-HEIGHT #4 BARS.

FOOTINGS SHALL BE 24" x 24" CAST-IN-PLACE CONCRETE 8" THICK FOR 125 MPH WIND ZONES AND 12" THICK FOR 140 MPH WIND ZONES.

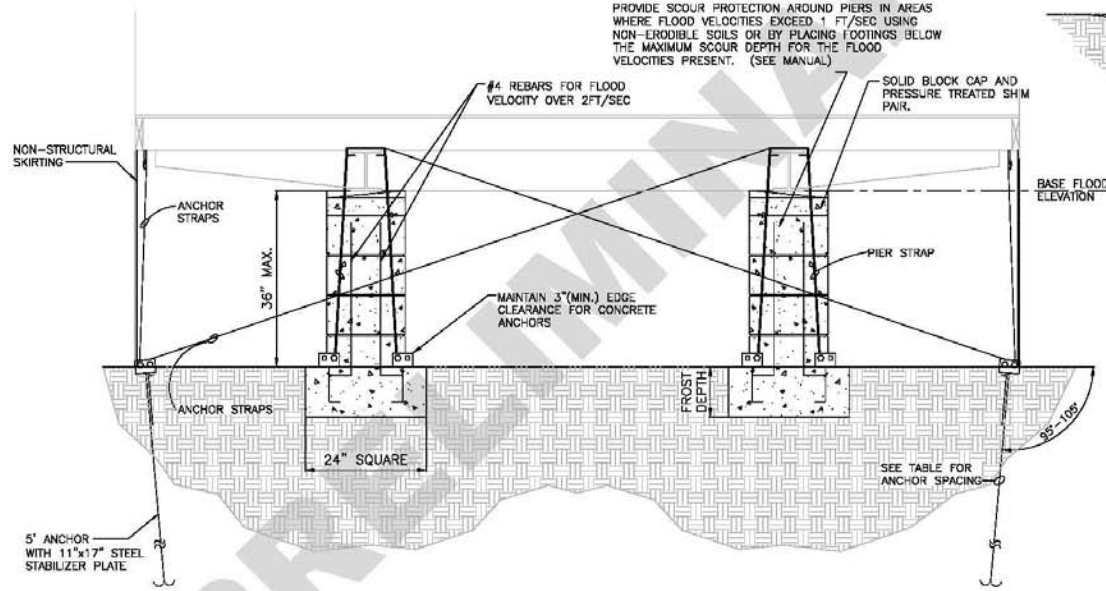
PLACE FOOTINGS AT FROST DEPTH IF REQUIRED BY AUTHORITY HAVING JURISDICTION.

PROVIDE SCOUR PROTECTION AROUND PIERS IN AREAS WHERE FLOOD VELOCITIES EXCEED 1 FT/SEC USING NON-ERODIBLE SOILS OR BY PLACING FOOTINGS BELOW THE MAXIMUM SCOUR DEPTH FOR THE FLOOD VELOCITIES PRESENT. (SEE MANUAL)

ALTERNATIVE PIER FOR FLOOD VELOCITIES UP TO 1 FT/SEC:
CONSTRUCT 16"x16" DRY STACK PIER WITH ⅛" THICK(MIN) SURFACE BONDED MORTAR PLACED ON 4 SQ FT ABS PAD. INSTALL GROUND ANCHORS 2'-8" CENTERS.



ALTERNATIVE PIER DETAIL (UP TO 1 FT/SEC FLOODING)

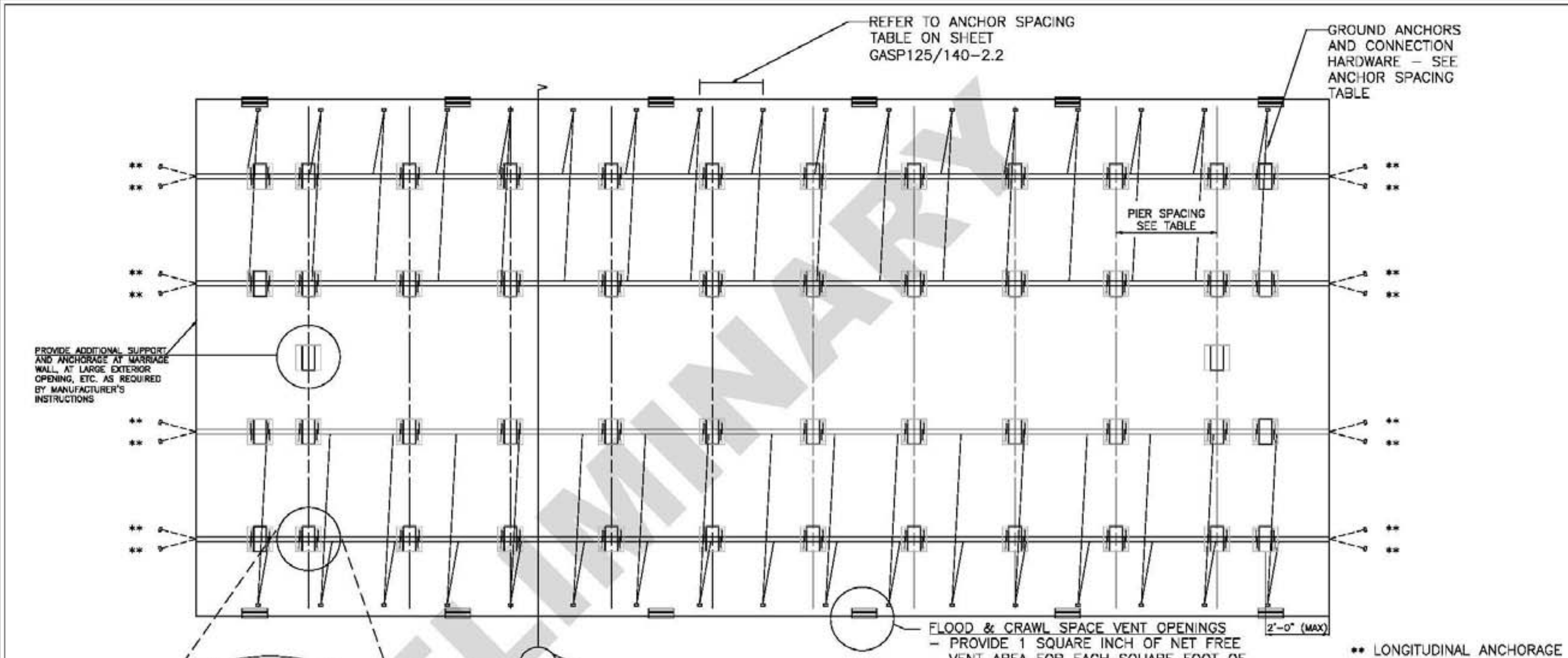


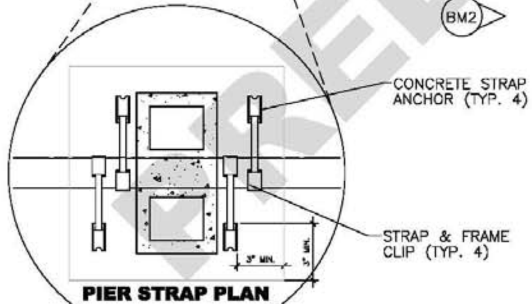
BM1 **GROUND ANCHOR AND PIER DETAIL (SINGLE UNIT)**

NOT TO SCALE

SEE PRE-ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN-1.1

February 2004
FEMA 85 GASP125/140-1.2





FLOOD & CRAWL SPACE VENT OPENINGS
- PROVIDE 1 SQUARE INCH OF NET FREE VENT AREA FOR EACH SQUARE FOOT OF CRAWL SPACE AREA.
- PLACE BOTTOM OF VENTS 1 FOOT (MAX) ABOVE EXTERIOR GRADE.
- ALL SCREENS AND LOUVERS MUST AUTOMATICALLY OPEN TO ALLOW UNOBSTRUCTED FLOW OF FLOOD WATERS.
- SPACE REQUIRED VENTS UNIFORMLY AROUND THE PERIMETER OF THE HOME

** LONGITUDINAL ANCHORAGE

Maximum Pier Spacing Table

	Soil Bearing Capacity (lb/ft^2)								
	1,000 < 1,500			1,500 < 2,000			2,000 and over		
Footing Style	Ground Snow Load (lb/ft^2)			Ground Snow Load (lb/ft^2)			Ground Snow Load (lb/ft^2)		
	<20	20<30	30≤40	<20	20<30	30≤40	<20	20<30	30≤40
Concrete	5'1"	4'7"	4'2"	7'7"	6'10"	6'4"	8'0"	8'0"	8'0"
ABS*	4'4"	4'0"	3'6"	6'6"	6'0"	5'6"	8'0"	7'6"	7'0"

*LOW FLOW APPLICATIONS ONLY

SEE PRE-ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN-1.1

DOUBLE UNIT GROUND ANCHOR FOUNDATION PLAN

CONTINUOUS SPREAD FOOTING - NOT TO SCALE

February 2004

FEMA 85 GASP125/140-2.1

Anchor Spacing Table for Double Unit Homes

Wind Speed	Flood Rate	Anchors with Stabilizer Plates: Maximum Spacing
125/140	1 fps	4'-0"
	5 fps	
125/140	ABS*	2'-8"

*Low flow using Alternate Pier System

16" x 8" MASONRY PIER & CAST-IN-PLACE FOOTING: SECURE PIER, FOOTING AND FRAME WITH STRAPS, FRAME CLIPS AND CONCRETE ANCHORS. PROVIDE FRAME CLIP FOR EACH STRAP.

FOR FLOOD VELOCITIES UNDER 1.5 FT/SEC CONSTRUCT PIER WITH DRY STACK BLOCK.

FOR FLOOD VELOCITIES BETWEEN 1.5 FT/SEC & 2.5 FT/SEC, CONSTRUCT PIER WITH DRY STACK BLOCK AND APPLY ⅛" THICK (MIN) SURFACE BONDED MORTAR.

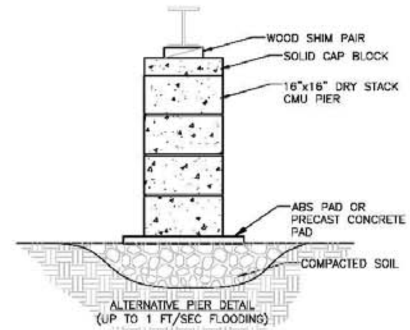
FOR FLOOD VELOCITIES OVER 2.5 FT/SEC, CONSTRUCT FULLY GROUTED PIER; ANCHOR PIER TO FOOTING WITH TWO FULL-HEIGHT #4 BARS.

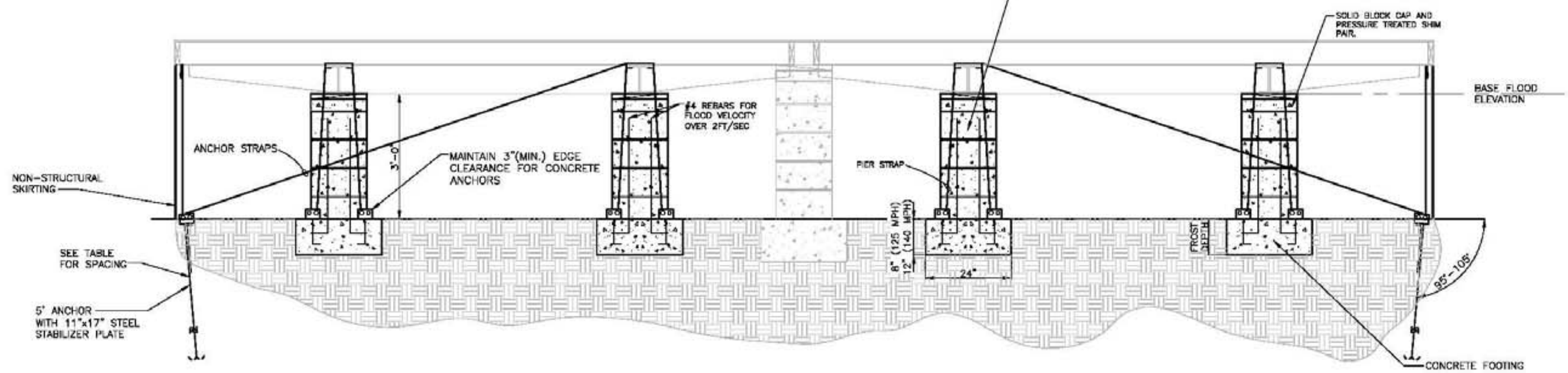
FOOTINGS SHALL BE 24" x 24" CAST-IN-PLACE CONCRETE 8" THICK FOR 125 MPH WIND ZONES AND 12" THICK FOR 140 MPH WIND ZONES.

PLACE FOOTINGS AT FROST DEPTH IF REQUIRED BY AUTHORITY HAVING JURISDICTION.

PROVIDE SCOUR PROTECTION AROUND PIERS IN AREAS WHERE FLOOD VELOCITIES EXCEED 1 FT/SEC USING NON-ERODIBLE SOILS OR BY PLACING FOOTINGS BELOW THE MAXIMUM SCOUR DEPTH FOR THE FLOOD VELOCITIES PRESENT. (SEE MANUAL)

ALTERNATIVE PIER FOR FLOOD VELOCITIES UP TO 1 FT/SEC
CONSTRUCT 16"x16" DRY STACK PIER WITH ⅛" THICK(MIN) SURFACE BONDED MORTAR PLACED ON 4 SQ FT ABS PAD. INSTALL GROUND ANCHORS 2'-8" CENTERS.



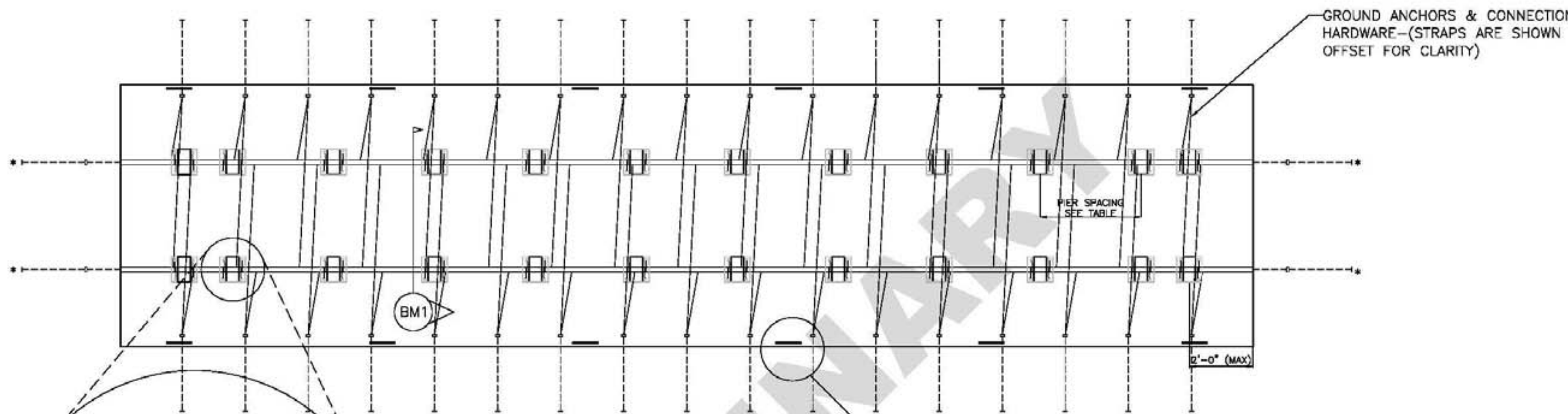


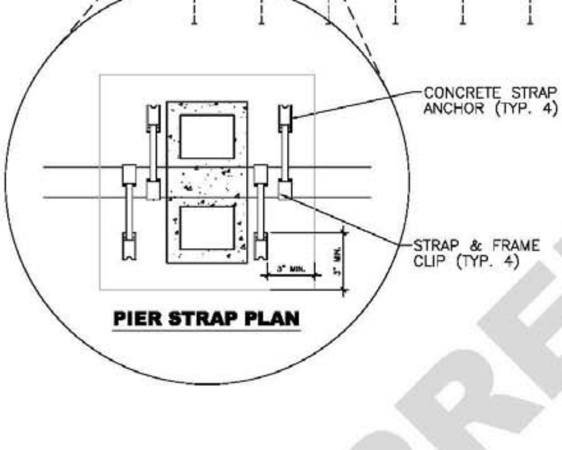
BM2 **GROUND ANCHOR & PIER DETAIL (DOUBLE UNIT)**

NOT TO SCALE

SEE PRE-ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN-1.1

February 2004
FEMA 85 GASP125/140-2.2





PIER STRAP PLAN

FLOOD & CRAWL SPACE VENT OPENINGS

- PROVIDE 1 SQUARE INCH OF NET FREE VENT AREA FOR EACH SQUARE FOOT OF CRAWL SPACE AREA.
- PLACE BOTTOM OF VENTS 1 FOOT (MAX) ABOVE EXTERIOR GRADE.
- ALL SCREENS AND LOUVERS MUST AUTOMATICALLY OPEN TO ALLOW UNOBSTRUCTED FLOW OF FLOOD WATERS.
- SPACE REQUIRED VENTS UNIFORMLY AROUND THE PERIMETER OF THE HOME

Maximum Pier Spacing Table

Soil Bearing Capacity (lb/ft^2)									
	1,000 < 1,500			1,500 < 2,000			2,000 and over		
Footing Style	Ground Snow Load (lb/ft^2)			Ground Snow Load (lb/ft^2)			Ground Snow Load (lb/ft^2)		
	<20	20<30	30≤40	<20	20<30	30≤40	<20	20<30	30≤40
Concrete	5'3"	4'9"	4'2"	7'10"	7'2"	6'6"	8'0"	8'0"	8'0"
ABS*	4'7"	4'3"	4'0'	7'0"	6'4"	5'10"	8'0"	8'0"	7'10"

*LOW FLOW APPLICATIONS ONLY

SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1

SINGLE UNIT GROUND ANCHOR FOUNDATION PLAN

NOT TO SCALE

February 2004
FEMA 85 GA90-1.1

Anchor Spacing Table for Single Unit Homes		
		Anchors With Stabilizer Plates
Wind Speed	Flood Rate	Spacing
90	1 fps	8'-0"
	5 fps	8'-0"
	ABS*	6'-8"

*Low flow using Alternate Pier System

16" x 8" MASONRY PIER & CAST-IN-PLACE FOOTING:
SECURE PIER, FOOTING AND FRAME WITH STRAPS, FRAME CLIPS AND CONCRETE ANCHORS. PROVIDE FRAME CLIP FOR EACH STRAP.

FOR FLOOD VELOCITIES UNDER 1.5 FT/SEC CONSTRUCT PIER WITH DRY STACK BLOCK.

FOR FLOOD VELOCITIES BETWEEN 1.5 FT/SEC & 2.5 FT/SEC, CONSTRUCT PIER WITH DRY STACK BLOCK AND APPLY ⅛" THICK (MIN) SURFACE BONDED MORTAR.

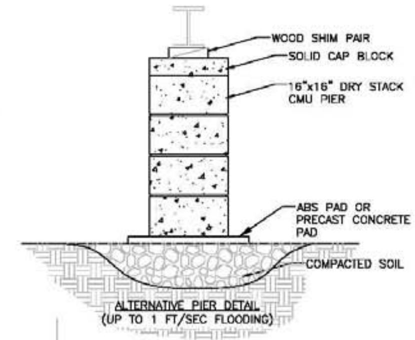
FOR FLOOD VELOCITIES OVER 2.5 FT/SEC, CONSTRUCT FULLY GROUTED PIER; ANCHOR PIER TO FOOTING WITH TWO FULL-HEIGHT #4 BARS.

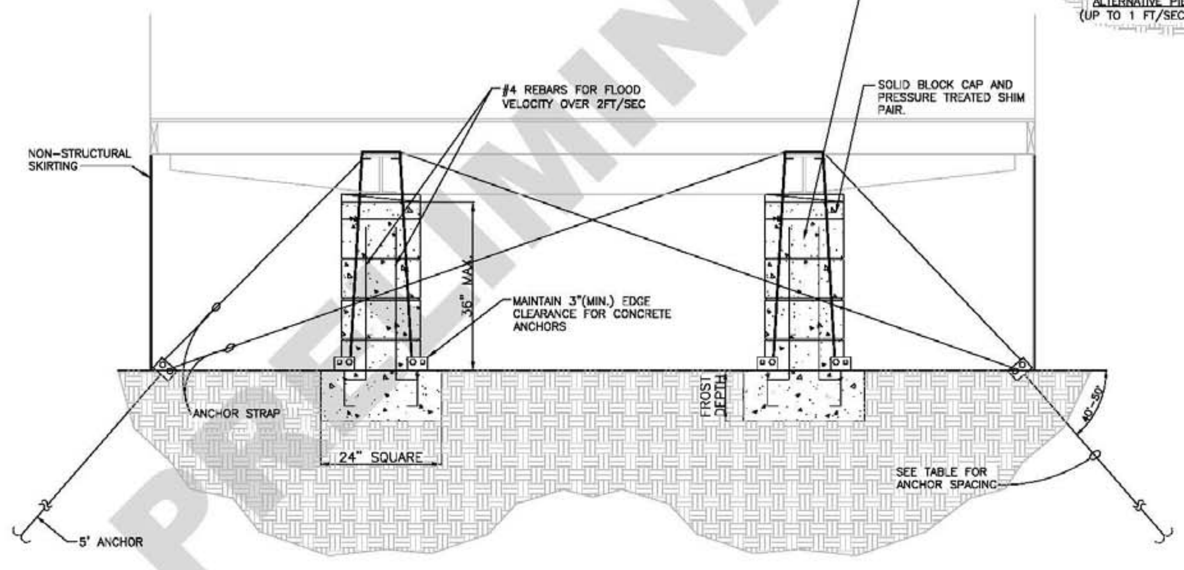
FOOTINGS SHALL BE 24" x 24" CAST-IN-PLACE CONCRETE 8" THICK.

PLACE FOOTINGS AT FROST DEPTH IF REQUIRED BY AUTHORITY HAVING JURISDICTION.

PROVIDE SCOUR PROTECTION AROUND PIERS IN AREAS WHERE FLOOD VELOCITIES EXCEED 1 FT/SEC USING NON-ERODIBLE SOILS OR BY PLACING FOOTINGS BELOW THE MAXIMUM SCOUR DEPTH FOR THE FLOOD VELOCITIES PRESENT. (SEE MANUAL)

ALTERNATIVE PIER FOR FLOOD VELOCITIES UP TO 1 FT/SEC
CONSTRUCT 16"x16" DRY STACK PIER WITH ⅛" THICK(MIN) SURFACE BONDED MORTAR PLACED ON 4 SQ FT ABS PAD. INSTALL GROUND ANCHORS 6'-8" CENTERS.



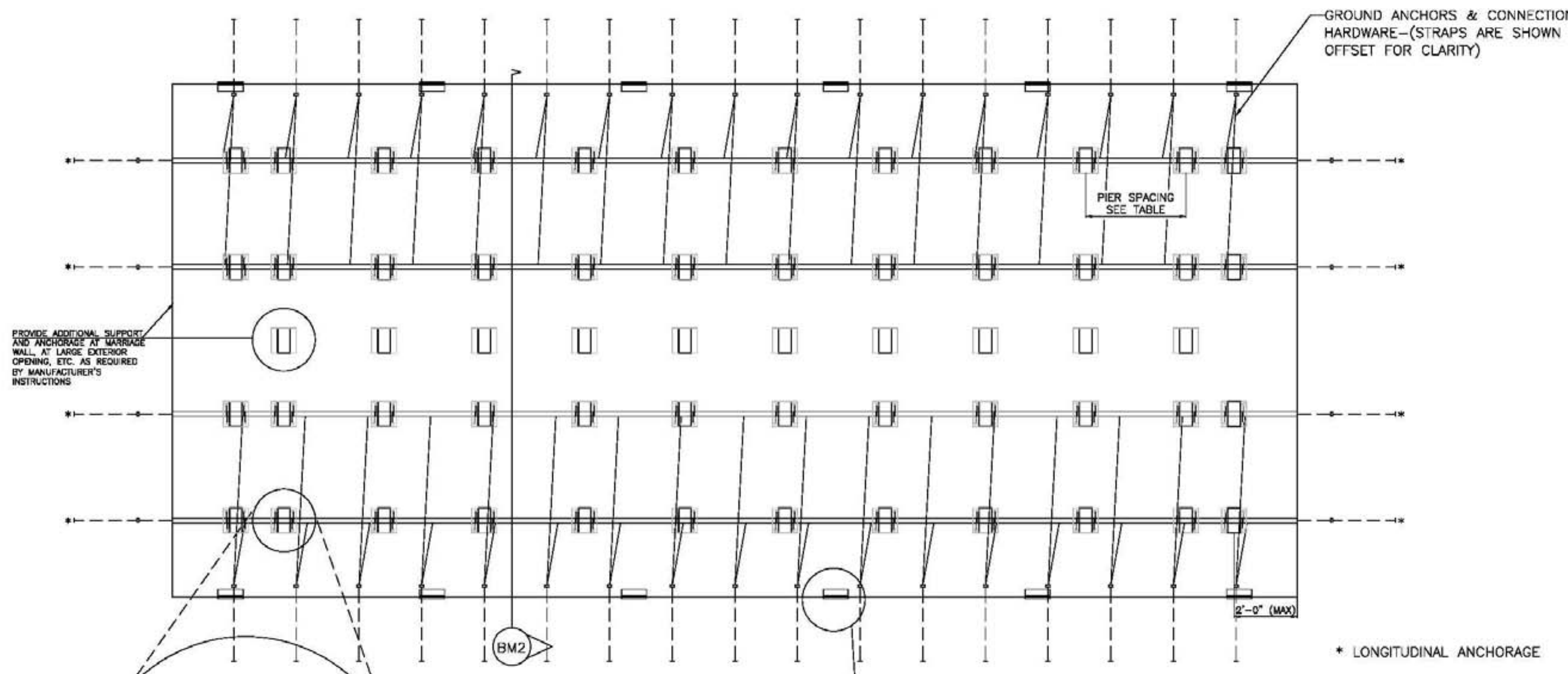


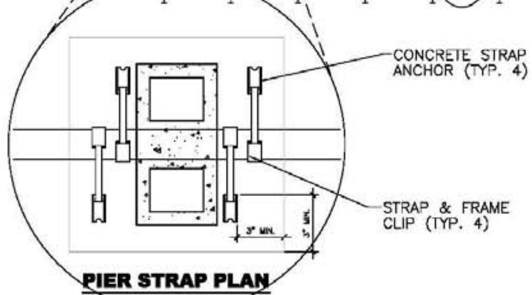
BM1 GROUND ANCHOR AND PIER DETAIL (SINGLE UNIT)

NOT TO SCALE

SEE PRE-ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN-1.1

February 2004
FEMA 85 GA90-1.2





PIER STRAP PLAN

FLOOD & CRAWL SPACE VENT OPENINGS
- PROVIDE 1 SQUARE INCH OF NET FREE VENT AREA FOR EACH SQUARE FOOT OF CRAWL SPACE AREA.
- PLACE BOTTOM OF VENTS 1 FOOT (MAX) ABOVE EXTERIOR GRADE.
- ALL SCREENS AND LOUVERS MUST AUTOMATICALLY OPEN TO ALLOW UNOBSTRUCTED FLOW OF FLOOD WATERS.
- SPACE REQUIRED VENTS UNIFORMLY AROUND THE PERIMETER OF THE HOME

Maximum Pier Spacing Table

Footing Style	Soil Bearing Capacity (lb/ft^2) 1,000 < 1,500 Ground Snow Load (lb/ft^2)			1,500 < 2,000 Ground Snow Load (lb/ft^2)			2,000 and over Ground Snow Load (lb/ft^2)		
	<20	20<30	30≤40	<20	20<30	30≤40	<20	20<30	30≤40
Concrete	5'3"	4'9"	4'2"	7'10"	7'2"	6'6"	8'0"	8'0"	8'0"
ABS*	4'7"	4'3"	4'0"	7'0"	6'4"	5'10"	8'0"	8'0"	7'10"

*LOW FLOW APPLICATIONS ONLY

SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1

DOUBLE UNIT GROUND ANCHOR FOUNDATION PLAN

NOT TO SCALE

February 2004

FEMA 85 GA90-2.1

Anchor Spacing Table for Double Unit Homes		
		Anchors With Stabilizer Plates
Wind Speed	Flood Rate	Maximum Spacing
90	1 fps	8'-0"
	5 fps	8'-0"
	ABS*	6'-8"

*Low flow using Alternate Pier System

16" x 8" MASONRY PIER & CAST-IN-PLACE FOOTING:
SECURE PIER, FOOTING AND FRAME WITH STRAPS, FRAME CLIPS AND CONCRETE ANCHORS. PROVIDE FRAME CLIP FOR EACH STRAP.

FOR FLOOD VELOCITIES UNDER 1.5 FT/SEC CONSTRUCT PIER WITH DRY STACK BLOCK.

FOR FLOOD VELOCITIES BETWEEN 1.5 FT/SEC & 2.5 FT/SEC, CONSTRUCT PIER WITH DRY STACK BLOCK AND APPLY ⅜" THICK (MIN) SURFACE BONDED MORTAR.

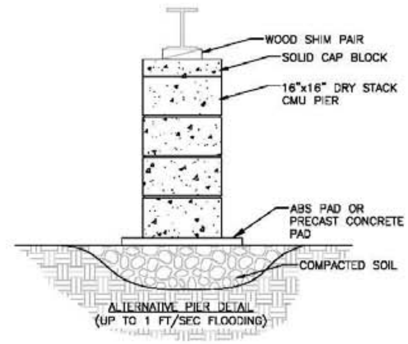
FOR FLOOD VELOCITIES OVER 2.5 FT/SEC, CONSTRUCT FULLY GROUTED PIER; ANCHOR PIER TO FOOTING WITH TWO FULL-HEIGHT #4 BARS.

FOOTINGS SHALL BE 24" x 24" CAST-IN-PLACE CONCRETE 8" THICK.

PLACE FOOTINGS AT FROST DEPTH IF REQUIRED BY AUTHORITY HAVING JURISDICTION.

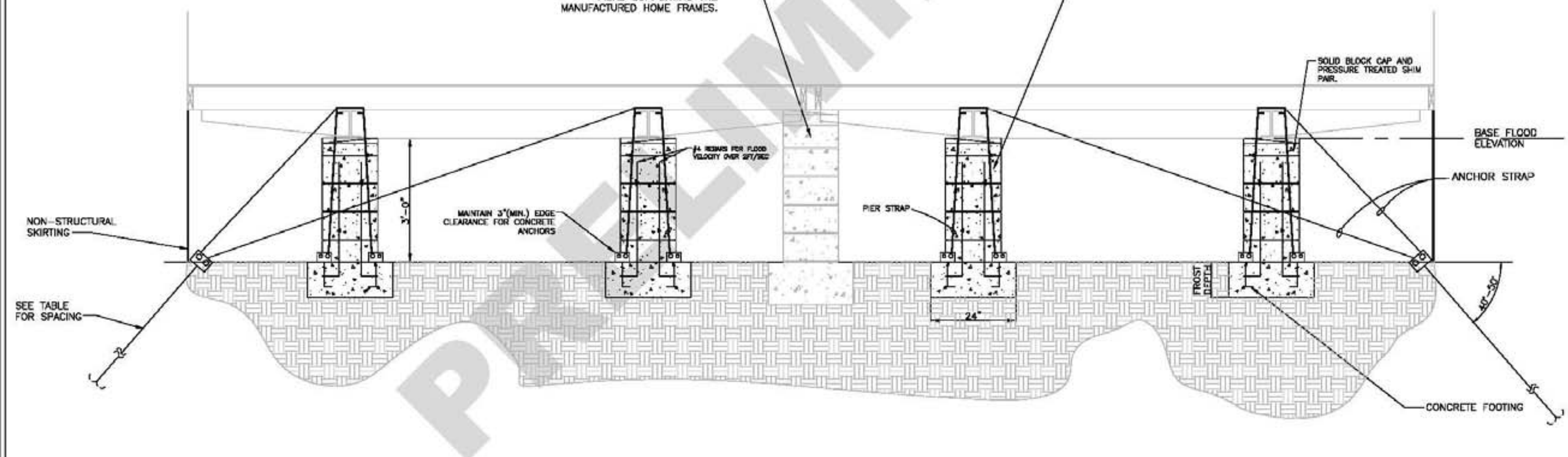
PROVIDE SCOUR PROTECTION AROUND PIERS IN AREAS WHERE FLOOD VELOCITIES EXCEED 1 FT/SEC USING NON-ERODIBLE SOILS OR BY PLACING FOOTINGS BELOW THE MAXIMUM SCOUR DEPTH FOR THE FLOOD VELOCITIES PRESENT. (SEE MANUAL)

ALTERNATIVE PIER FOR FLOOD VELOCITIES UP TO 1 FT/SEC
CONSTRUCT 16"x16" DRY STACK PIER WITH ⅜" THICK(MIN) SURFACE BONDED MORTAR PLACED ON 4 SQ FT ABS PAD. INSTALL GROUND ANCHORS 6'-8" O.C.



ALTERNATIVE PIER DETAIL
(UP TO 1 FT/SEC FLOODING)

CONSTRUCT PIERS SUPPORTING THE MARRIAGE WALL AND SUPPORTING EXTERIOR WALL POINT LOADS USING THE SAME CONSTRUCTION METHOD USED FOR PIERS SUPPORTING THE MANUFACTURED HOME FRAMES.

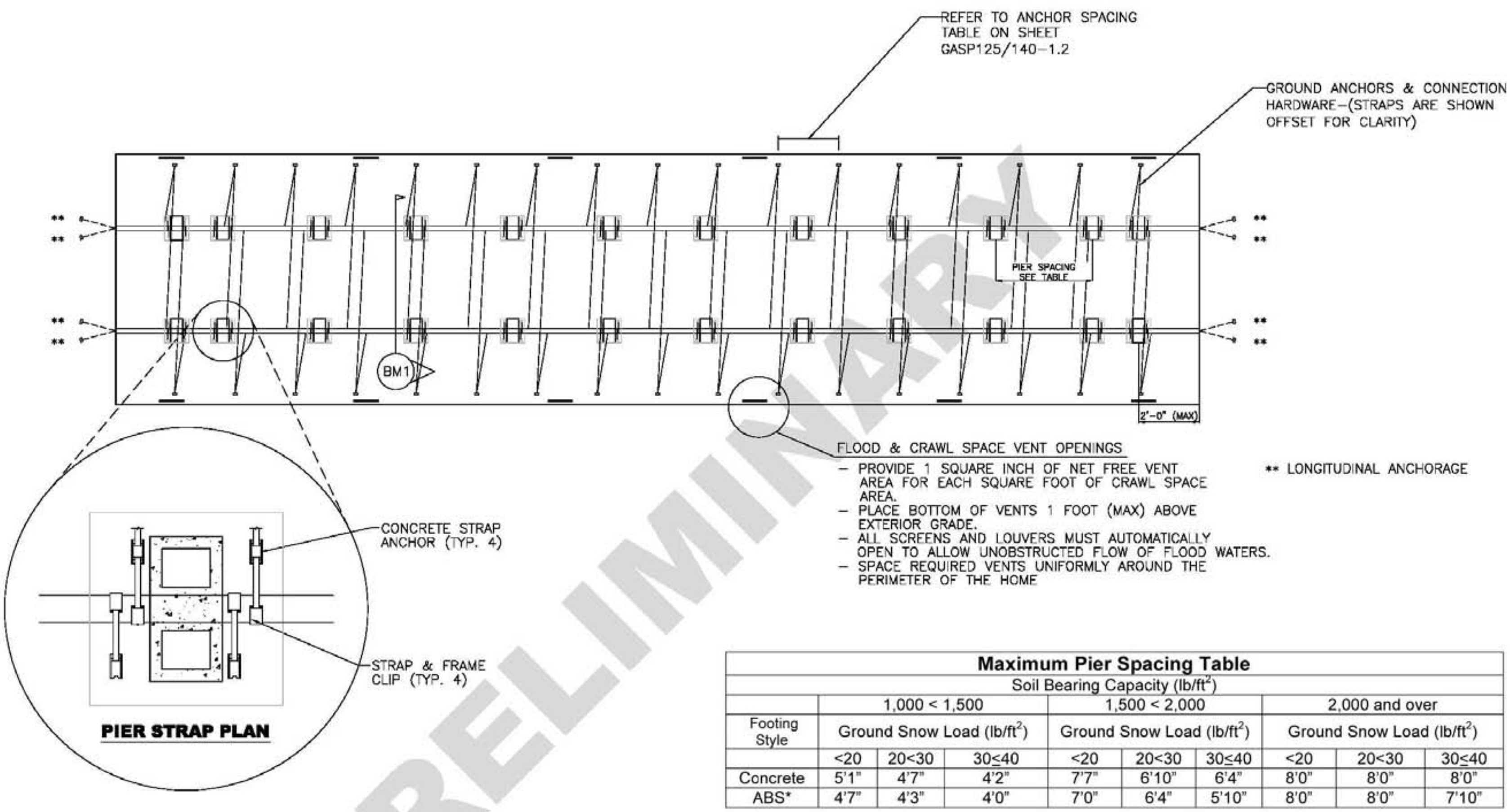


BM2 GROUND ANCHOR & PIER DETAIL (DOUBLE UNIT)

NOT TO SCALE

SEE PRE-ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN-1.1

February 2004
FEMA 85 GA90-2.2



FLOOD & CRAWL SPACE VENT OPENINGS

- PROVIDE 1 SQUARE INCH OF NET FREE VENT AREA FOR EACH SQUARE FOOT OF CRAWL SPACE AREA.
- PLACE BOTTOM OF VENTS 1 FOOT (MAX) ABOVE EXTERIOR GRADE.
- ALL SCREENS AND LOUVERS MUST AUTOMATICALLY OPEN TO ALLOW UNOBSTRUCTED FLOW OF FLOOD WATERS.
- SPACE REQUIRED VENTS UNIFORMLY AROUND THE PERIMETER OF THE HOME

** LONGITUDINAL ANCHORAGE

Maximum Pier Spacing Table

Soil Bearing Capacity (lb/ft^2)									
	1,000 < 1,500			1,500 < 2,000			2,000 and over		
Footing Style	Ground Snow Load (lb/ft^2)			Ground Snow Load (lb/ft^2)			Ground Snow Load (lb/ft^2)		
	<20	20<30	30≤40	<20	20<30	30≤40	<20	20<30	30≤40
Concrete	5'1"	4'7"	4'2"	7'7"	6'10"	6'4"	8'0"	8'0"	8'0"
ABS*	4'7"	4'3"	4'0"	7'0"	6'4"	5'10"	8'0"	8'0"	7'10"

*LOW FLOW APPLICATIONS ONLY

SINGLE UNIT GROUND ANCHOR FOUNDATION PLAN

CONTINUOUS SPREAD FOOTING - NOT TO SCALE

SEE PRE-ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN-1.1

February 2004

FEMA 85 GASP125/140-1.1

Anchor Spacing Table for Single Unit Homes

Wind Speed	Flood Rate	In-Line Anchors Maximum Spacing
125	1 fps	8'0"
	5 fps	6'8"
140	1 fps	6'8"
	5 fps	5'4"
125/140	ABS*	4'-0"

*Low flow using Alternate Pier System

16" x 8" MASONRY PIER & CAST-IN-PLACE FOOTING:
SECURE PIER, FOOTING AND FRAME WITH STRAPS, FRAME CLIPS AND CONCRETE ANCHORS. PROVIDE FRAME CLIP FOR EACH STRAP.

FOR FLOOD VELOCITIES UNDER 1.5 FT/SEC CONSTRUCT PIER WITH DRY STACK BLOCK.

FOR FLOOD VELOCITIES BETWEEN 1.5 FT/SEC & 2.5 FT/SEC, CONSTRUCT PIER WITH DRY STACK BLOCK AND APPLY ⅛" THICK (MIN) SURFACE BONDED MORTAR.

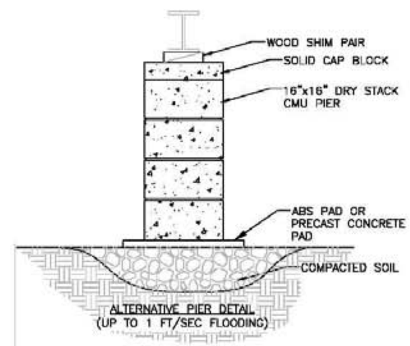
FOR FLOOD VELOCITIES OVER 2.5 FT/SEC, CONSTRUCT FULLY GROUTED PIER; ANCHOR PIER TO FOOTING WITH TWO FULL-HEIGHT #4 BARS.

FOOTINGS SHALL BE 24" x 24" CAST-IN-PLACE CONCRETE 8" THICK FOR 125 MPH WIND ZONES AND 12" THICK FOR 140 MPH WIND ZONES.

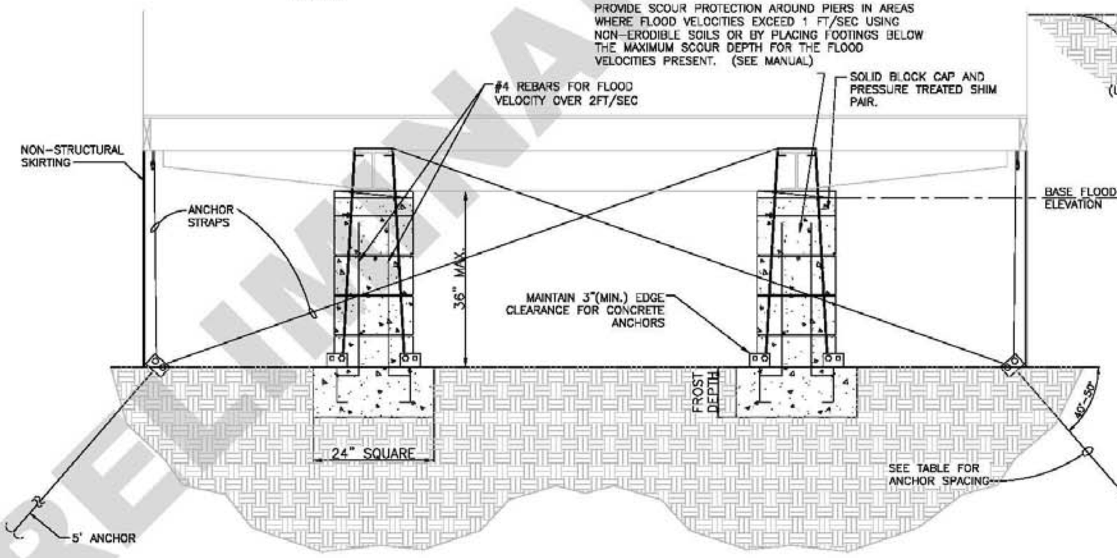
PLACE FOOTINGS AT FROST DEPTH IF REQUIRED BY AUTHORITY HAVING JURISDICTION.

PROVIDE SCOUR PROTECTION AROUND PIERS IN AREAS WHERE FLOOD VELOCITIES EXCEED 1 FT/SEC USING NON-ERODIBLE SOILS OR BY PLACING FOOTINGS BELOW THE MAXIMUM SCOUR DEPTH FOR THE FLOOD VELOCITIES PRESENT. (SEE MANUAL)

ALTERNATIVE PIER FOR FLOOD VELOCITIES UP TO 1 FT/SEC
CONSTRUCT 16"x16" DRY STACK PIER WITH ⅛" THICK(MIN) SURFACE BONDED MORTAR PLACED ON 4 SQ FT ABS PAD. INSTALL GROUND ANCHORS 4'-0" CENTERS.



ALTERNATIVE PIER DETAIL
(UP TO 1 FT/SEC FLOODING)

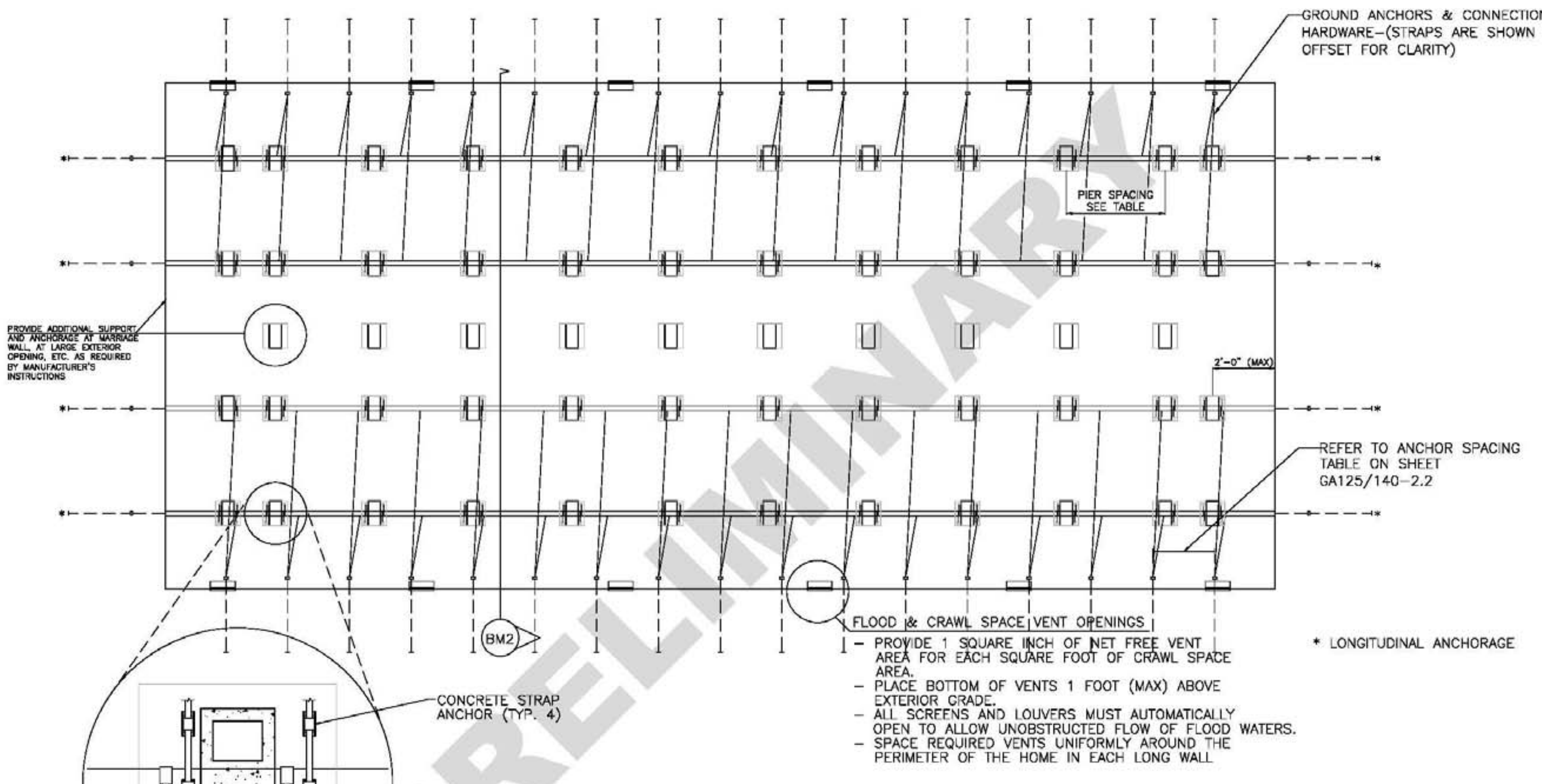


GROUND ANCHOR AND PIER DETAIL (SINGLE UNIT)

NOT TO SCALE

SEE PRE-ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN-1.1

February 2004
FEMA 85 GA125/140-1.2



Maximum Pier Spacing Table

Footing Style	Soil Bearing Capacity (lb/ft²): 1,000 < 1,500 — Ground Snow Load (lb/ft²)			1,500 < 2,000 — Ground Snow Load (lb/ft²)			2,000 and over — Ground Snow Load (lb/ft²)		
	<20	20<30	30≤40	<20	20<30	30≤40	<20	20<30	30≤40
Concrete	5'1"	4'7"	4'2"	7'7"	6'10"	6'4"	8'0"	8'0"	8'0"
ABS*	4'4"	4'0"	3'6"	6'6"	6'0"	5'6"	8'0"	7'6"	7'0"

*LOW FLOW APPLICATIONS ONLY

SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1

DOUBLE UNIT GROUND ANCHOR FOUNDATION PLAN

NOT TO SCALE

February 2004

FEMA 85 GA125/140-2.1

Anchor Spacing Table for Double Unit Homes		
		Anchors With Stabilizer Plates
Wind Speed	Flood Rate	Spacing
125	1 fps	6'8"
	5 fps	5'4"
140	1 fps	5'4"
	5 fps	4'0"
125/140	ABS*	4'0"

*Low flow using Alternate pier system

16" x 8" MASONRY PIER & CAST-IN-PLACE FOOTING:
SECURE PIER, FOOTING AND FRAME WITH STRAPS, FRAME CLIPS AND CONCRETE ANCHORS. PROVIDE FRAME CLIP FOR EACH STRAP.

FOR FLOOD VELOCITIES UNDER 1.5 FT/SEC CONSTRUCT PIER WITH DRY STACK BLOCK.

FOR FLOOD VELOCITIES BETWEEN 1.5 FT/SEC & 2.5 FT/SEC, CONSTRUCT PIER WITH DRY STACK BLOCK AND APPLY ⅜" THICK (MIN) SURFACE BONDED MORTAR.

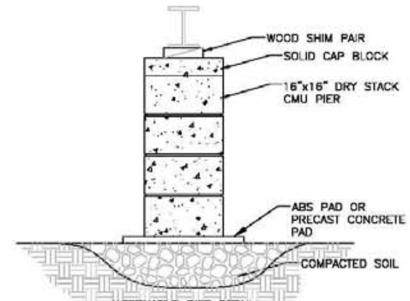
FOR FLOOD VELOCITIES OVER 2.5 FT/SEC, CONSTRUCT FULLY GROUTED PIER; ANCHOR PIER TO FOOTING WITH TWO FULL-HEIGHT #4 BARS.

FOOTINGS SHALL BE 24" x 24" CAST-IN-PLACE CONCRETE 8" THICK FOR 125 MPH WIND ZONES AND 12" THICK FOR 140 MPH WIND ZONES.

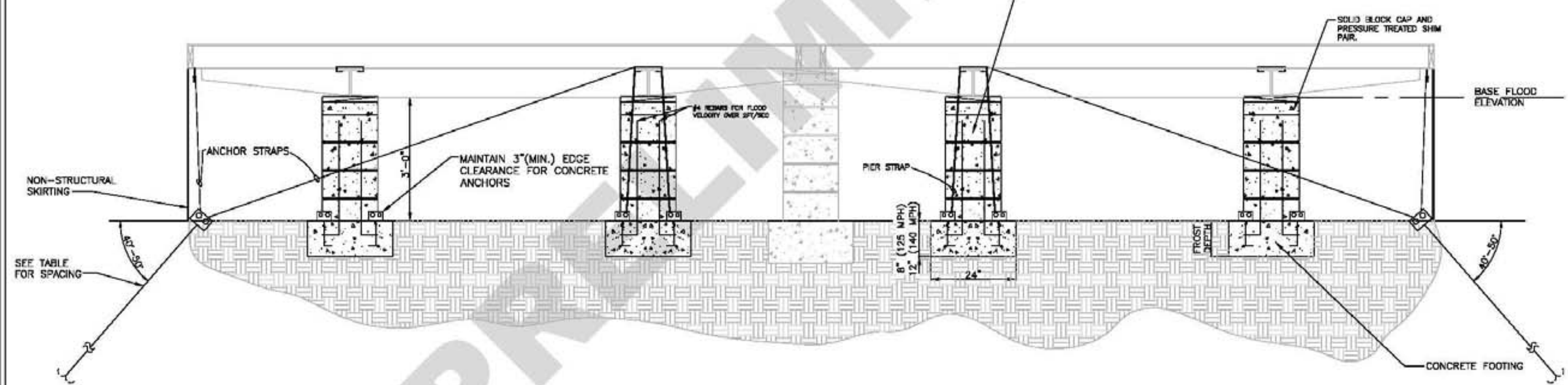
PLACE FOOTINGS AT FROST DEPTH IF REQUIRED BY AUTHORITY HAVING JURISDICTION.

PROVIDE SCOUR PROTECTION AROUND PIERS IN AREAS WHERE FLOOD VELOCITIES EXCEED 1 FT/SEC USING NON-ERODIBLE SOILS OR BY PLACING FOOTINGS BELOW THE MAXIMUM SCOUR DEPTH FOR THE FLOOD VELOCITIES PRESENT. (SEE MANUAL)

ALTERNATIVE PIER FOR FLOOD VELOCITIES UP TO 1 FT/SEC
CONSTRUCT 16"x16" DRY STACK PIER WITH ⅜" THICK(MIN) SURFACE BONDED MORTAR PLACED ON 4 SQ FT ABS PAD. INSTALL GROUND ANCHORS 4'-0" CENTERS.



ALTERNATIVE PIER DETAIL
(UP TO 1 FT/SEC FLOODING)



GROUND ANCHOR & PIER DETAIL (DOUBLE UNIT)

NOT TO SCALE

SEE PRE-ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN-1.1

February 2004
FEMA 85 GA125/140-2.2

Appendix G:

Example Calculations

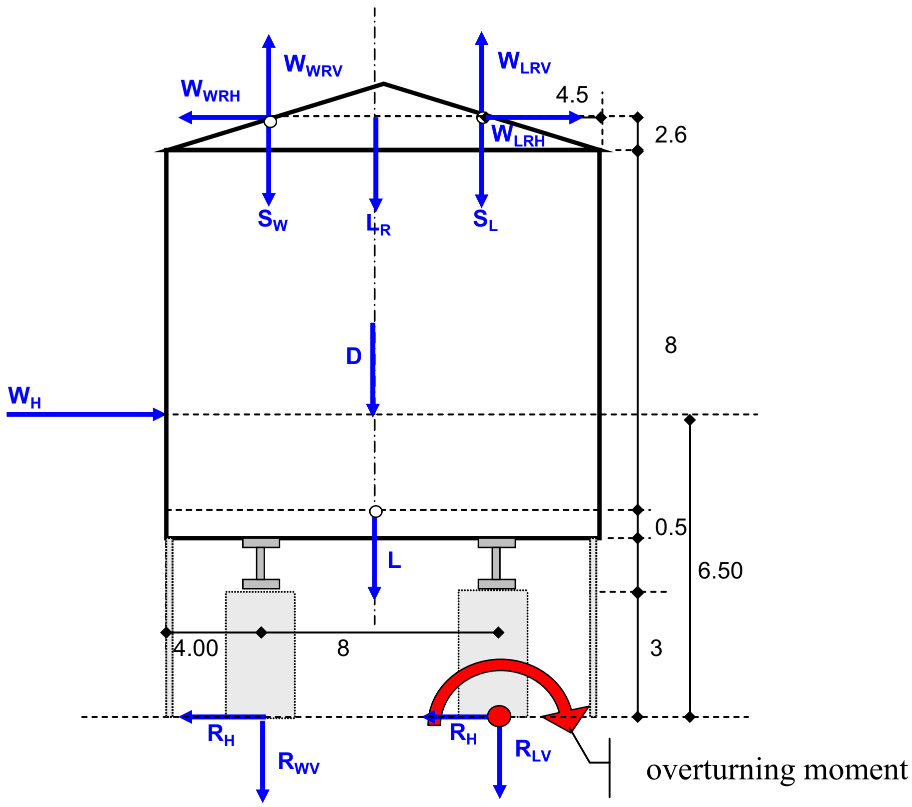


Figure G-1. Loading on a Manufactured Home

Table G-1. Load Nomenclature

Load Nomenclature	
D	dead load
L	live load
L_R	roof live load
R_H	horizontal reaction
R_{LV}	leeward vertical reaction
R_{WV}	windward vertical reaction
S_L	leeward snow load
S_W	windward snow load
W_H	horizontal wall wind pressure
W_{LRH}	leeward roof horizontal wind pressure
W_{LRV}	leeward roof vertical wind pressure
W_{WRH}	windward roof horizontal wind pressure
W_{WRV}	windward roof vertical wind pressure

Uplift Failure Mode

Uplift Failure is a vertical force phenomena. The loads that act vertically are wind, snow, dead, and live loads Table G-2 summarizes the loads that influence uplift failure mode.

Maximum uplift and downward loading produced by wind loads occurs when the wind is parallel to the roof ridge. Maximum uplift loading occurs with positive internal pressures and maximum downward loading occurs with negative internal pressures. Uplift failure load combinations are assessed in Table G-3.

Table G-2. Vertical Load Values

Load Type	Total load acting on the structure and therefore must be supported by the foundation
D	D = [dead load per square foot][width of the manufactured home) D = [20 psf][(16 ft)] D = 320 lbs per linear ft of manufactured home length
L	L = [live load per square foot][width of the manufactured home) L = [40 psf][(16 ft)] L = 640 lbs
L_r	L_r = [roof live load per square foot][width of the manufactured home) L_r = [17 psf][(18 ft)] L_r = 306 lbs per linear ft of manufactured home length
W	Maximum wind uplift loads occur for winds parallel to the roof ridge with positive internal pressures. W = W_{WRV}+W_{LRV} = ([vertical component roof wind pressures][area roof])/manufactured home length W = [(-30.3 psf)(cos30)][(10.4 ft)(15 ft)(2)] $_{0\text{ ft to }15\text{ ft}}$ + [(-22.5 psf)(cos30)][(10.4 ft)(15 ft)(2)] $_{15\text{ ft to }30\text{ ft}}$ +

	[(-18.6 psf)(cos30)][(10.4 ft)(30 ft)(2)] $_{30\text{ ft to }60\text{ ft}}$ W = (-24318 lbs)/60ft = -406 lbs per linear ft of manufactured home length Maximum wind compression loads occur for wind parallel to the roof ridge with negative internal pressures. W = [(9.1psf)(cos30)][(10.4 ft)(2)] $_{0\text{ ft to }60\text{ ft}}$ = 82 lbs -
S	$S = S_W + S_L$ = [snow pressure][horizontal projected roof area] S = [14 psf][(9 ft)]$_{SW}$ + [21 psf][(9 ft)]$_{SL}$ S = 189 lbs per linear ft of manufactured home length

Table G-3. Uplift Failure Mode LRFD Load Combinations

Load Combinations	
1	1.4D 1.4(320 lbs) = 448 lbs per linear ft of manufactured home length
2	1.2D + 1.6L + 0.5S – snow load is greater than the roof live load, therefore snow governs 1.2(320 lbs) + 1.6(640 lbs) + 0.5(189 lbs) = 1503 lbs
3	1.2D + 1.6S + (0.5L or 0.8W) live load 1.2D + 1.6S + 0.5L 1.2(320 lbs) + 1.6(189 lbs) + 0.5(640 lbs) = 1007 lbs wind load 1.2D + 1.6S + 0.8W *wind || to the roof ridge* ***(+ internal pressures)*** 1.2(320 lbs) + 1.6(189 lbs) + 0.8(-406 lbs) = 362 lbs ***(- internal pressures)*** 1.2(320 lbs) + 1.6(189 lbs) + 0.8(82 lbs) = 752 lbs
4	1.2D + 0.8W + 0.5L + 0.5S *wind || to the roof ridge* ***(+ internal pressures)*** 1.2(320 lbs) + 0.8(-406 lbs) + 0.5(640 lbs) + 0.5(189 lbs) = 474 lbs ***(- internal pressures)*** 1.2(320 lbs) + 0.8(82 lbs) + 0.5(640 lbs) + 0.5(189 lbs) = 865 lbs
5	1.2D + 1.0E + 0.5L + 0.2S wind forces are larger than earthquake forces at this location
6	0.9D + 0.8W *wind || to the roof ridge* ***(+ internal pressures)*** 0.9(320 lbs) + 0.8(-406 lbs) = -37 lbs – uplift ***(- internal pressures)*** 0.9(320 lbs) + 0.8(82 lbs) = 354 lbs - compression
7	0.9D + 1.0E wind forces are larger than earthquake forces at this location

Sliding or Shearing Failure Mode

Sliding failure is a lateral force phenomena. The loads that act laterally are wind and flood loads. Table G-4 summarizes the lateral loads and their values. Note that lateral wind loads act on the overall structural (i.e., foundation), where flood loads act on the individual piers.

Table G-5 gives the load combinations for sliding failure. Once the number of piers is defined, then the hydrodynamic forces on these piers will have to be added to load combination 4 and the foundation design will have to be checked to make sure it can resist the added hydrodynamic loads.

Maximum lateral wind loads occur when the wind is perpendicular to the roof ridge with negative internal pressures.

Table G-4. Lateral Load Values

Load Type	Total load acting on the structure and therefore must be supported by the foundation
W	Maximum lateral wind loads occur for winds γ to the roof ridge with (-) internal pressures. $W = W_{HRH} + W_{LRH} + W_H$ = [lateral roof pressures][roof height] + [wall pressures][wall height] $W = [28.4\ psf - 8.7\ psf][(13\ ft)]_{WHRH + WLRH} + [31.6\ psf(10.4\ ft)]_{WH}$ W = 289 lbs per linear ft of manufactured home length
Fa	Hydrodynamic load per pier Fa = [hydrodynamic force][pier length] Fa = [307lb/ft][1.3ft] = 410 lbs per pier

Table G-5. Sliding Load Combinations

Load Combinations	
1	No lateral loads
2	No lateral loads
3	0.8W wind γ to the roof ridge ***(- internal pressures)*** 0.8(289 lbs) = 232 lbs
4	$0.8W + 1.0F_a$ 0.8(289 lbs) + 1.0(to be determined) = to be determined
5	1.0E Wind loading at this location is greater than earthquake loading.
6	0.8W same as load combination 3
7	1.0E same as load combination 5

Overturning Failure Mode

Overturning failure results from loads that act about the bottom of the leeward pier. Dead, live, wind, and snow loads all influence the overturning moment. Table G-6 summarizes the moments and their values. Table G-7 assesses the moment load combinations.

Table G-6. Moment Load Values

Moment Type	Total moment at the bottom of the leeward foundation support. (positive moment is counter clockwise)
D	D = [dead load per square foot][home width][moment arm] D = [20 psf][(16 ft)(4 ft)] D = 1280 ft-lbs per linear ft of manufactured home length
L	L = [live load per square foot][home width][moment arm] L = [40 psf][(16 ft)(4 ft)] L = 2560 ft-lbs per linear ft of manufactured home length
L_r	L_r = [roof live load per square foot][roof width][moment arm] L_r = [17 psf][(18 ft)(4 ft)] L_r = 1224 ft-lbs per linear ft of manufactured home length
W	**Wind parallel to the roof ridge** ***(+ internal pressures)*** $+W_{LRV}$ = [vertical component roof wind pressures][roof width][moment arm] $+W_{LRV}$ = [(-30.3 psf)(cos30)][(18 ft)(4 ft)]$_{0\text{ ft to }15\text{ ft}}$ + [(-22.5 psf)(cos30)][(18 ft)(4 ft)]$_{15\text{ ft to }30\text{ ft}}$ + [(-18.6 psf)(cos30)][(18 ft)(4 ft)]$_{30\text{ ft to }60\text{ ft}}$ $W_{WRV}+W_{LRV}$ = -4,452 ft-lbs per linear ft of manufactured home length Since W_{WRH}=W_{LRH} moments cancel each other out W_{W+L} = [windward wall pressure + leeward wall pressure][homes height from ground to roof eave][moment arm] W_{W+L} = -[3 psf + 22.5 psf][13 ft][6.5 ft] W_{W+L} = -2,154.8 ft-lbs per linear ft of manufactured home length ***(- internal pressures)*** $W_{WRV}+W_{LRV}$ = [vertical component roof wind pressures][roof width][moment arm] $W_{WRV}+W_{LRV}$ = [(9.1psf)(cos30)][(18 ft)(4 ft)]$_{0\text{ ft to }60\text{ ft}}$ $W_{WRV}+W_{LRV}$ = 567.5 ft-lbs per linear ft of manufactured home length Since W_{WRH} = W_{LRH} moments cancel each other out W_{W+L} = [windward wall pressure + leeward wall pressure][homes height from ground to roof eave][moment arm] W_{W+L} = -[28.4 psf - 2.9 psf][13 ft][6.5 ft] = W_{W+L} = -2,154.8 ft-lbs per linear ft of manufactured home length **Wind perpendicular to the roof ridge** ***(+ internal pressures)*** W_{WRV} = [vertical component roof wind pressures][roof width][moment arm] W_{WRV} = -[18.6 psf(cos30)][9 ft][8.5 ft] W_{WRV} = -1232.3 ft-lbs per linear ft of manufactured home length W_{LRV} = [vertical component roof wind pressures][roof width][moment arm] W_{LRV} = [24.5 psf(cos30)][9 ft][0.5 ft]

	W_{LRV} = 95.5 ft-lbs per linear ft of manufactured home length W_{WRH} = [horizontal component roof wind pressures][roof height][moment arm] W_{WRH} = [18.6 psf(sin30)][5.2 ft][15.6 ft] W_{WRH} = 754.5 ft-lbs per linear ft of manufactured home length W_{LRH} = [vertical component roof wind pressures][roof width][moment arm] W_{LRH} = -[24.5 psf(sin30)][5.2 ft][15.6 ft] W_{LRH} = -993.8 ft-lbs per linear ft of manufactured home length W_{W+L} = [windward wall pressure + leeward wall pressure][homes height from ground to roof eave][moment arm] W_{W+L} = -[3.0 psf + 10.7 psf][13 ft][6.5 ft] = W_{W+L} = -1157.7 ft-lbs per linear ft of manufactured home length ***(- internal pressures)*** W_{WRV} = [vertical component roof wind pressures][roof width][moment arm] W_{WRV} = -[16.7 psf(cos30)][9 ft][8.5 ft] W_{WRV} = -1106.4 ft-lbs per linear ft of manufactured home length W_{LRV} = [vertical component roof wind pressures][roof width][moment arm] W_{LRV} = [0.9 psf(cos30)][9 ft][0.5 ft] W_{LRV} = 3.6 ft-lbs per linear ft of manufactured home length W_{WRH} = [horizontal component roof wind pressures][roof height][moment arm] W_{WRH} = [16.7 psf(sin30)][5.2 ft][15.6 ft] W_{WRH} = 677.4 ft-lbs per linear ft of manufactured home length W_{LRH} = [vertical component roof wind pressures][roof width][moment arm] W_{LRH} = -[0.9 psf(sin30)][5.2 ft][15.6 ft] W_{LRH} = -36.6 ft-lbs per linear ft of manufactured home length W_{W+L} = [windward wall pressure + leeward wall pressure][homes height from ground to roof eave][moment arm] W_{W+L} = -[28.4 psf – 8.6 psf][13 ft][6.5 ft] = W_{W+L} = -1673.1 ft-lbs per linear ft of manufactured home length
S	S_W = [windward snow pressure][horizontal projected roof area][moment arm] S_W = [14 psf][9 ft][8.5 ft] S_W = 1071.0 ft-lbs per linear ft of manufactured home length S_L = [leeward snow pressure][horizontal projected roof area][moment arm] S_L = -[21 psf][9 ft][0.5 ft] S_L = -94.5 ft-lbs per linear ft of manufactured home length

Table G-7. Overturning Load Combinations

Moment Load Combinations (positive moment is counter clockwise)	
1	1.4D 1.4(1,280 ft-lbs) = 1,792 ft-lbs
2	1.2D + 1.6L + 0.5(S or L_r) **roof live load** 1.2D + 1.6L + 0.5(L_r) 1.2(1,280 ft-lbs) + 1.6(2,560 ft-lbs) + 0.5(1,224 ft-lbs) = 6,244.0 ft-lbs per linear ft home length **snow load** 1.2D + 1.6L + 0.5(S) 1.2(1,280 ft-lbs) + 1.6(2,560 ft-lbs) + 0.5(1071.0 ft-lbs)$_{Sw}$ - 0.5(94.5 ft-lbs)$_{SL}$ = 6,120.3 ft-lbs per linear ft of home length
3	1.2D + 1.6S + (0.5L or 0.8W) **live load** 1.2D + 1.6S + 0.5L 1.2(1,280 ft-lbs) + 1.6(1071.0 ft-lbs)$_{Sw}$ + 1.6(-94.5 ft-lbs)$_{SL}$ + 0.5(2,560 ft-lbs) = 4878.4 ft-lbs per linear ft of home length **wind load** 1.2D + 1.6S + 0.8W ***wind parallel to the roof ridge*** *(+ internal pressures)* 1.2(1,280 ft-lbs) + 1.6(1071.0 ft-lbs)$_{Sw}$ + 1.6(-94.5 ft-lbs)$_{SL}$ + 0.8(-4,452 ft-lbs)$_{W_{WRV}+W_{LRV}}$ + 0.8(-2,154.8 ft-lbs)$_{W_{W+L}}$= -2187.4 ft-lbs *(- internal pressures)* 1.2(1,280 ft-lbs) + 1.6(1071.0 ft-lbs)$_{Sw}$ + 1.6(-94.5 ft-lbs)$_{SL}$ + 0.8(567.5 ft-lbs)$_{W_{WRV}+W_{LRV}}$ + 0.8(-2,154.8 ft-lbs)$_{W_{W+L}}$= 1828.6 ft-lbs ***wind perpendicular to the roof ridge*** *(+ internal pressures)* 1.2(1,280 ft-lbs) + 1.6(1071.0 ft-lbs)$_{Sw}$ + 1.6(-94.5 ft-lbs)$_{SL}$ + 0.8(-1232.3 ft-lbs)$_{W_{WRV}}$ + 0.8(95.5 ft-lbs)$_{W_{LRV}}$ + 0.8(754.5 ft-lbs)$_{W_{WRH}}$ + 0.8(-993.8 ft-lbs)$_{W_{LRH}}$ + 0.8(-1157.7 ft-lbs)$_{W_{W+L}}$ = 1071.4 ft-lbs per linear ft length of home *(- internal pressures)* 1.2(1,280 ft-lbs) + 1.6(1071.0 ft-lbs)$_{Sw}$ + 1.6(-94.5 ft-lbs)$_{SL}$ + 0.8(-1106.4 ft-lbs)$_{W_{WRV}}$ + 0.8(3.6 ft-lbs)$_{W_{LRV}}$ + 0.8(677.4 ft-lbs)$_{W_{WRH}}$ + 0.8(-36.6 ft-lbs)$_{W_{LRH}}$ + 0.8(-1673.1 ft-lbs)$_{W_{W+L}}$ = 1390.4 ft-lbs per linear ft length of home

Load combination 2 produces the maximum positive moment.

Load combination 3 produces the maximum overturning moment.

4	**1.2D + 0.8W + 0.5L + 0.5S** *wind parallel to the roof ridge* ***(+ internal pressures)*** **1.2(1,280 ft-lbs) + 0.8(-4,452 ft-lbs)$_{W_{WRV}+W_{LRV}}$ + 0.8(-2,154.8 ft-lbs)$_{W_{W+L}}$ + 0.5(2,560 ft-lbs) + 0.5(1071.0 ft-lbs)$_{S_W}$ + 0.5(-94.5 ft-lbs) $_{S_L}$= -1981.7 ft-lbs** ***(- internal pressures)*** **1.2(1,280 ft-lbs) + 0.8(567.5 ft-lbs)$_{W_{WRV}+W_{LRV}}$ + 0.8(-2,154.8 ft-lbs)$_{W_{W+L}}$ + 0.5(2,560 ft-lbs) + 0.5(1071.0 ft-lbs)$_{S_W}$ + 0.5(-94.5 ft-lbs) $_{S_L}$ = 2034.5 ft-lbs** *wind perpendicular to the roof ridge* ***(+ internal pressures)*** **1.2(1,280 ft-lbs) + 0.8(-1232.3 ft-lbs)$_{W_{WRV}}$ + 0.8(95.5 ft-lbs) $_{W_{LRV}}$ + 0.8(754.5 ft-lbs)$_{W_{WRH}}$ + 0.8(-993.8 ft-lbs)$_{W_{LRH}}$ + 0.8(-1157.7 ft-lbs)$_{W_{W+L}}$ + 0.5(2,560 ft-lbs) + 0.5(1071.0 ft-lbs)$_{S_W}$ + 0.5(-94.5 ft-lbs) $_{S_L}$ = 1277.3 ft-lbs per linear ft length** ***(- internal pressures)*** **1.2(1,280 ft-lbs) + 0.8(3.6 ft-lbs) $_{W_{LRV}}$ + 0.8(677.4 ft-lbs)$_{W_{WRH}}$ + 0.8(-36.6 ft-lbs)$_{W_{LRH}}$ + 0.8(-1673.1 ft-lbs)$_{W_{W+L}}$ + 0.5(2,560 ft-lbs) + 0.5(1071.0 ft-lbs)$_{S_W}$ + 0.5(-94.5 ft-lbs) $_{S_L}$ = 5,493.7 ft-lbs per linear ft length**
5	1.2D + 1.0E + 0.5L + 0.2S wind forces are larger than earthquake forces at this location

6	**0.9D + 0.8W** *wind perpendicular to the roof ridge* ***(+ internal pressures)*** **-0.9(20 psf)(16 ft)(4 ft) + 0.8[(18.6 psf)cos30(10.4 ft)(7.5 ft)]*windward* + 0.8[(24.5 psf)cos30(10.4 ft)(0.5 ft)]*leeward*** **-0.9(1,280 ft-lbs) + 0.8(1,256.5 ft-lbs)*windward* + 0.8(110.4 ft-lbs)*leeward* = -58.5 ft-lbs per linear ft length** ***(- internal pressures)*** **-0.9(20 psf)(16 ft)(4 ft) - 0.8[(16.7 psf)cos30(10.4 ft)(7.5 ft)]*windward* - 0.8[(0.9 psf)cos30(10.4 ft)(0.5 ft)]*leeward*** **-0.9(1,280 ft-lbs) - 0.8(1,128.5 ft-lbs)*windward* - 0.8(4.1 ft-lbs)*leeward* = -2058.1 ft-lbs per linear ft length** *wind parallel to the roof ridge* ***(+ internal pressures)*** **-0.9(20 psf)(16 ft)(4 ft) + 0.8[((30.3 psf)cos30(10.4 ft)2(15 ft)(4 ft))/60 ft]*0 to 15 ft* + 0.8[((22.5 psf)cos30(10.4 ft)2(15 ft)(4.0 ft))/60 ft]*15 ft to 30 ft*+ 0.8[((18.6 psf)cos30(10.4 ft)2(30 ft)(4.0 ft))/60 ft]*30 ft to 60 ft*** **-0.9(1,280 ft-lbs) + 0.8(545.8ft-lbs)*0 to 15 ft* + 0.8(405.3 ft-lbs)*15 ft to 30 ft*+ 0.8(670.1 ft lbs)*30 ft to 60 ft* = 144.96 ft-lbs** ***(- internal pressures)*** **-0.9(20 psf)(16 ft)(4 ft) - 0.8[((9.1 psf)cos30(10.4 ft)2(4 ft))]*0 to 60 ft*** **-0.9(1,280 ft-lbs) - 0.8(655.7ft-lbs)*0 to 60 ft* = -1676.6 ft-lbs**
7	0.9D + 1.0E wind forces are larger than earthquake forces at this location