8 Foundation Systems

8.1 Introduction

Properly designed and constructed manufactured home foundations can significantly reduce the potential for damages from flooding, high winds, and seismic events. 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 piles; and systems consisting of piers and ground anchors are some of the options available to a manufactured homeowner and installer.

To be effective, manufactured home foundations must perform the following:

- Support the weight of the home, its contents, and its occupants
- Resist design loads from wind, snow, seismic events, and moving floodwaters
- Elevate the home sufficiently to prevent losses from a design flood event

Elevated foundations are classified as enclosed or open. As the name implies, enclosed foundations enclose the space below the elevated home. Perimeter masonry, concrete, or sheathed wood walls are enclosed styles. Open foundations consist of a system of individual members that support the home only at discrete locations. Pier, post, and pile foundation systems are open systems. Many open foundations have a non-structural skirting to enclose the space below the home. The skirting is primarily for aesthetics and does not add to the strength of the foundation. Skirting can help to protect piping installed below the home from freezing and reduce both heat loss from the home and the potential for animal or insect entry into the home.

Selecting an appropriate foundation system depends on a number of variables, including the building site conditions (elevation, slope, access restrictions, drainage); the flood zone; the design loads (wind, flood, snow, and, if appropriate, seismic) at the site; the availability of materials; on-site soil characteristics; local construction practices; and cost. Whatever foundation system is chosen, both the HUD Code and NFIP require a foundation to resist flotation, collapse, or lateral movement during a design event to prevent damages to the home and surrounding structures. Tables 8-1 through 8-3 at the conclusion of this chapter provide guidance to the selection of appropriate manufactured home foundation systems as a function of flood depth and flow velocity.

Proprietary systems are also an option for the manufactured homeowner. Proprietary systems are discussed in Section 2.2.2 and the system must meet the design and performance criteria described in Chapter 9.

More information on proprietary foundations is contained in the SBRA's *Guide to Foundation and Support Systems for Manufactured Homes* available at http://www.research-alliance.org/pages/foundations_guide.htm.

8.2 Enclosed Foundations

Enclosed foundations consist of perimeter foundation walls placed on continuous footings. The walls enclose the area below the living space of the home (Figure 8-1). Perimeter walls are commonly constructed of concrete, masonry, or wood. Enclosed foundations are occasionally used to raise manufactured homes, often creating the appearance of a site-built home (Figure 8-1).

Figure 8-1. A manufactured home elevated on a perimeter foundation wall. Although it appears the openings are too high, the bottoms of the openings are less than 1 foot above the top of the interior slab.

NFIP regulations permit enclosed foundations for manufactured homes in SFHA A zones with a requirement that the foundation walls include flood vents. 44 CFR 60.3(c)(5) requires that:

> "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 an area 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 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."

This elevation technique should not be used in high-velocity or highly erosive flood conditions, and is not permitted in V zones. Additional information on wall vents for floodwater flow is provided in FEMA Technical Bulletin 1, *Openings in Foundation Walls and Walls of Enclosures* (2008).

Perimeter walls of enclosed foundations should include adequate reinforcement to resist unbalanced hydrostatic and/or hydrodynamic loads that may occur in fast rising flood events. Such floods may result in water levels higher on the exterior side of the wall than the inside until flow through the flood vents can equalize them.

8.3 Open Foundations and Breakaway Walls

NFIP regulations require manufactured homes in SFHAs designated V1-30, VE, or V on the community's FIRM have the space below the lowest floor either free of obstruction or constructed with non-supporting breakaway walls (44 CFR 60.3(e)(5)). Elevating a manufactured home on an open foundation involves raising it onto piers, posts, or piles. If the home is located in an area of coastal flooding, an open foundation is the only way to safely elevate the home. If the home is subjected to high-velocity riverine floodwaters, significant water depth, or potential erosions, the home should also be elevated on an open foundation. Open foundations are intrinsically more resistant to moving floodwaters and breaking waves than enclosed foundations since the home has a smaller surface area exposed to flood forces. Selection of the proper open foundation for various flooding and site characteristics is critical to the success of the foundation.

Breakaway walls, including non-structural skirting around a manufactured home, are walls that are not part of the structural support of the home. They are designed and constructed to fail under the loads imposed by floodwaters without jeopardizing the elevated portion of the home or the structural support of the home. Because such enclosures are designed to fail at a lateral load of no greater than 20 pounds per square foot, they will transfer minimal additional loads to the foundation. Insect screening and latticework both allow floodwaters to pass through. Detailed discussions on design and construction for breakaway walls can be found in FEMA Technical Bulletin 9, *Design and Construction Guidance for Breakaway Walls* (2008).

8.3.1 Pier Systems

Most manufactured homes are placed on pier foundations. Although there are many variations, pier foundations fall into two general styles. One style contains pier foundations combined with other components (such as anchors and frame straps) for lateral stability; the second style relies on the piers and their footings to resist all imposed loads. The foundation styles that use supplemental lateral-supporting devices often do not require reinforced piers. The determination of the need for and the amount of reinforcing required is part of the design analyses. The final design requirements for pier reinforcing is a function of the combination of flood, wind, and seismic loads acting on the manufactured home, and the resulting pier capacity required to resist flotation, collapse, or lateral movement.

When flood velocities are less than 1 fps, piers can be constructed using unbonded (dry-stacked) concrete blocks or steel piers. When pier foundation systems are used without separate components to resist lateral loads, the piers and footings must be much stronger. They not only have to transfer all imposed loads to the bearing soils, but also must do so in a manner that does not damage the piers and footings or overload the supporting soils.

Piers designed to resist lateral and/or uplift loads without the use of ground anchors or straps typically consist of reinforced brick masonry, reinforced concrete masonry units, or reinforced cast-in-place concrete with steel reinforcing bars for both the piers and the below-grade footings. Because the ground around pier footings in SFHAs can be susceptible to erosion and scour, the footings must be embedded below the anticipated scour depth.

In areas exposed to moving floodwaters, special consideration must also be given to controlling scour around the pier foundation elements. Moving floodwaters can remove soil around and beneath foundations, potentially reducing their load capacity to the point of foundation failure.

Floodwaters with high flow rates and floodwaters that carry a large sediment load create more scour than low velocity or clear water 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 perimeter wall foundations.

Scour removes soil particles from beside and, in severe cases, from beneath foundations. The loss of soil around and/or beneath a foundation affects its capacity to support the design loads. The loss of vertical foundation capacity can result in large settlements and potential collapse. The loss of lateral capacity not only reduces the capacity of the foundation to resist lateral wind and flood loads, but also can reduce the vertical capacity. The loss of lateral support for long thin vertical elements (e.g., single block masonry stack piers) can result in buckling under the design vertical loads.

Piers designed to resist lateral and/or uplift loads must be constructed using mortared horizontal joints between courses and reinforced grout used to fill the vertical cell. The piers must be firmly attached to the supporting footings.

8.3.1.1 Reinforced Pier Systems

Reinforced piers typically have steel reinforcements placed inside of the piers. Reinforced pier systems are commonly constructed of concrete masonry units (CMUs) or cast-in-place concrete (Figure 8-2).

In high-wind areas and in areas exposed to seismic or hydrodynamic loads, piers may require much larger footings to ensure applied loads do not exceed the soil's bearing capacity or allow tensile forces to develop in foundation elements in the upstream and windward side of the home. Laterally bracing the piers can allow the structure to distribute imposed loads to the entire foundation system. Lateral bracing also provides protection against buckling failure of vertical elements due to loss of confining soil from erosion or scour.

Concrete Masonry Unit (CMU) Reinforced Piers

The *International Residential Code* limits the height of solid masonry piers, including hollow concrete masonry units filled solidly with concrete or Type M or S mortar to ten times their least dimension. The height limitation for unfilled hollow concrete masonry unit piers is four times their least dimension (IRC§606.6).

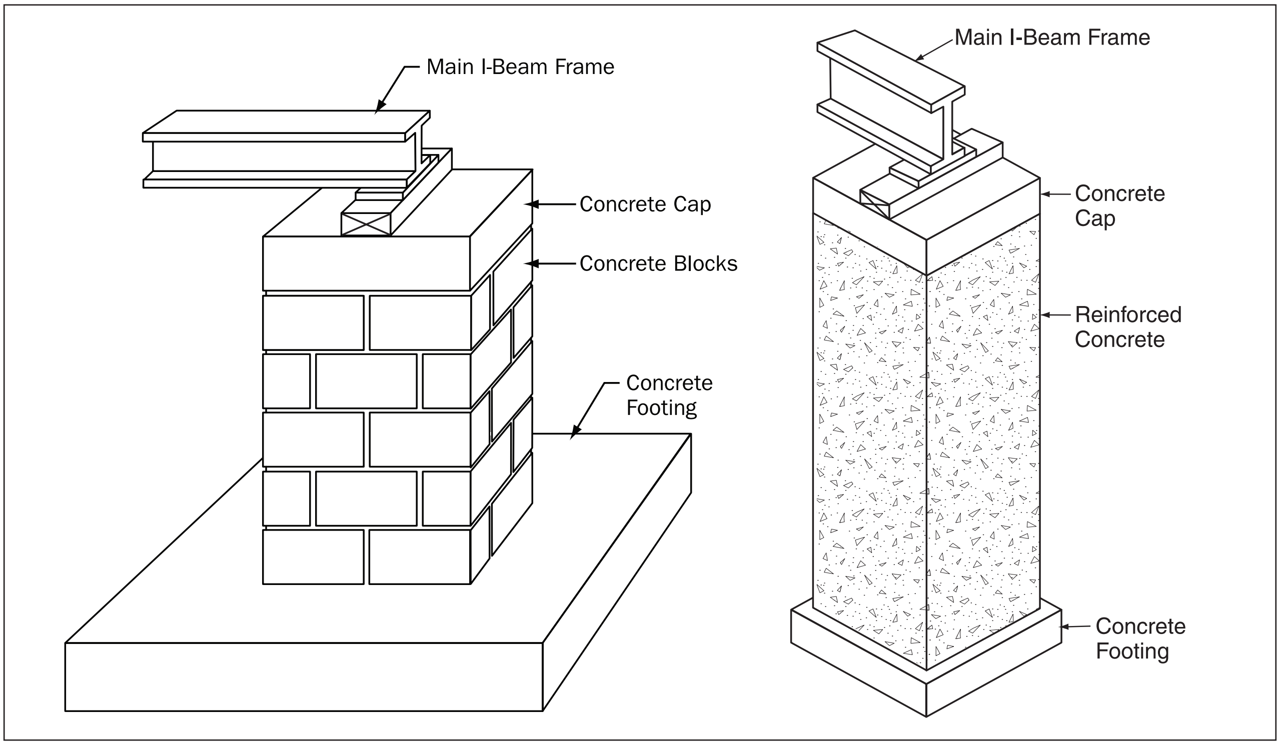


Figure 8-2. Reinforced masonry and concrete piers.

Adequate connections between the piers and the manufactured home are necessary for the manufactured home and its foundation to resist lateral and uplift loads from floods, winds, 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, consult the manufactured home manufacturer to ensure the factory built components are not overloaded. Figure 8-3 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.

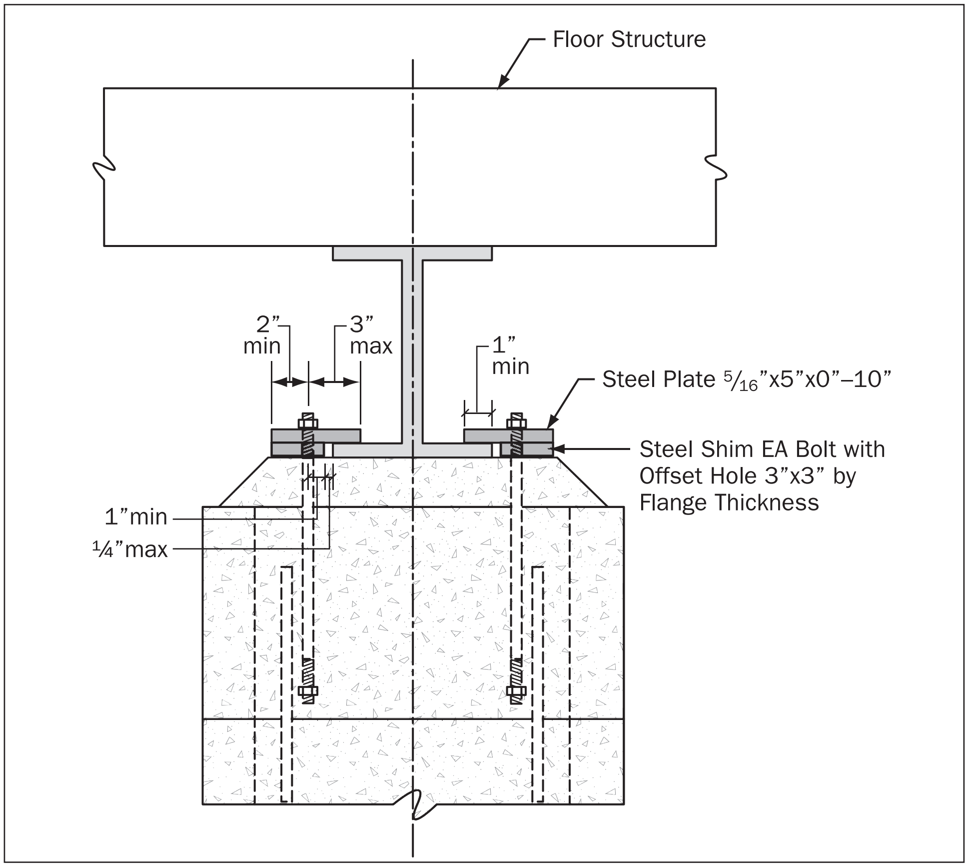
8.3.1.2 Unreinforced Pier Systems

Unreinforced brick or CMU pier systems have no reinforcing steel and, therefore, have very little resistance to overturning, sliding, and uplift. Because of this, unreinforced piers should always be provided with other stabilizing devices like ground anchors.

When used with stabilizing devices, many styles of unreinforced piers are available 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 mortared, grouted block.

> **Dry-Stacked Piers**
>
> Dry-stacked block piers can fail when a home is exposed to combined wind and flooding (ASCE 7, Load Combination #6). Failure results when wind forces lift the manufactured home's frame off its windward piers. Without the weight of the home to stabilize the piers, the piers can easily fail by sliding or overturning.

Figure 8-3. Bolted connection between frame and reinforced pier.



When placed directly on concrete footings or pads, 3-foot tall piers constructed with single, dry-stacked blocks to create an 8-inch by 16-inch pier can only resist flood velocities of approximately 1.0 fps. Three-foot tall (16-inch by 16-inch) double-stacked piers can resist flood velocities of approximately 1.75 fps. Dry-stacked piers or posts supported on ABS pads fail at lower velocities than piers supported on concrete. The failure at lower velocities is due to a reduced frictional resistance between the pier blocks or posts and the ABS pad. The design flood velocity for double-stacked piers on ABS pads is 1.25 fps.

If dry-stacked piers are not fully submerged, they can resist higher flood velocities. This is because the portion of the pier above the water line adds to the pier's stability but does not add to the flood load that the pier must resist. Engineers can calculate the ability of partially submerged piers to resist moving floodwaters or their resistance can be determined by testing.

Applying surface-bonding materials strengthens the piers by increasing their shear resistance. However, surface bonding has limited impact on their resistance to bending moments from lateral loads; therefore, surface bonded piers still need to be used with other foundation components. The increased shear resistance allows 3-foot tall (16-inch by 16-inch) piers to resist hydrodynamic loads from floodwaters moving at approximately 2.0 fps for single-stacked piers and 3.0 fps for double-stacked piers. 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. A FEMA sponsored testing program conducted at the Haynes Coastal Engineering Laboratory, Texas A&M University verified the design values.

The Texas A&M testing program included piers constructed using a polyurethane based masonry adhesive as joint bonding material. The Illinois Tool Works (ITW) TACC Division's Mason Bond was certified by ICC Evaluation Service as meeting the IBC and IRC for Types M, N, O, and S Portland cement/lime mortar. Test results showed the single stack adhesive bonded piers to be the strongest configuration tested.

Mortared block and fully grouted mortared block are much stronger than dry-stacked and surface-bonded piers, but their strengths do not match piers with #3 reinforcing steel bars grouted into the vertical cells. 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.

Unreinforced piers cannot be used in V zones. In Coastal A zones, fully grouted piers may be adequate for low flood velocities, but reinforcing with steel is recommended.

8.3.2 Pile Foundations

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, floodwaters, and seismic events. A properly designed pile foundation can withstand high-wind and water velocities, and can resist erosion and scour around its base if embedded to an adequate depth (Figure 8-4). Because of this, pile foundations meet the NFIP requirements for installation in V zones. Pile foundations are also appropriate for Coastal A zones and for areas exposed to high-velocity riverine flooding.

Figure 8-4. Manufactured home on a pile foundation.

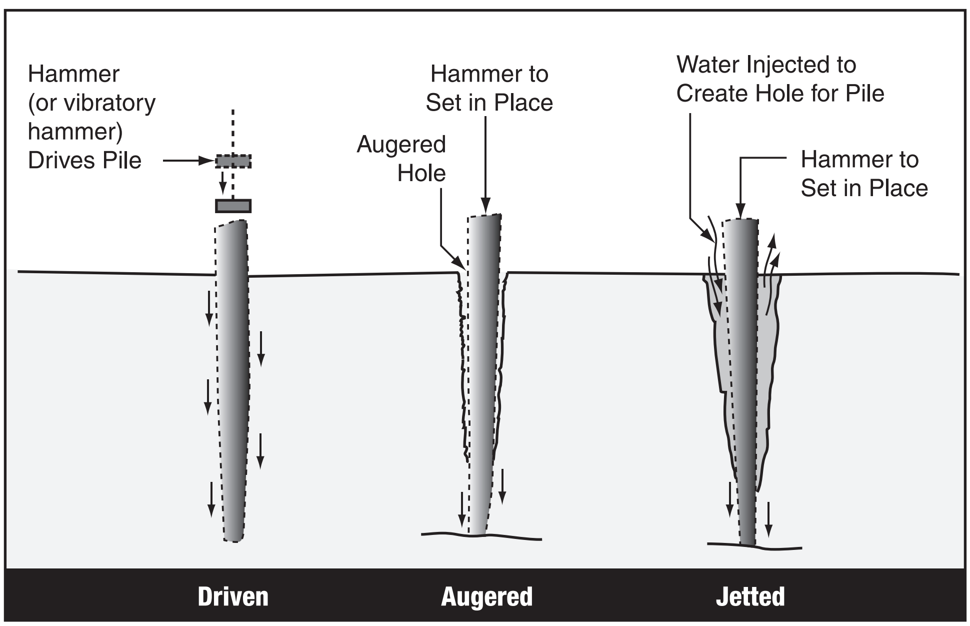
Saturated soils with low bearing capacities are less of a stability problem for a pile foundation than for a pier foundation; thus, pile foundations are preferable in coastal areas. The design of pile foundations requires determining the number, size, length, and location of piles appropriate to the particular manufactured home, soil conditions, and flooding situation at the site. A pile design methodology is provided in the *Coastal Construction Manual* (FEMA 55) that requires input parameters, including soil property and loading information.

Piles are vertical supports similar to posts, but differ in the method and depth of placement. Piles are embedded much deeper than posts and do not rest on footings for resistance. Instead, the piles are driven until they rest on a solid support layer, such as bedrock, or until they are embedded deep enough that the friction between the ground and the piles will enable them to resist the gravity, lateral, and uplift loads expected to act on them.

The most commonly used piles in residential construction are wood. Steel and precast concrete piles are also used. Pile foundations are primarily used in areas where other elevation methods are not feasible, such as V zones.

A major consideration in the effectiveness of pile foundations is the method of installation. Piles are placed into the ground by impact driving, water jetting, augering, or some combination of these methods (Figure 8-5). Piles are often driven by a single- or double-acting diesel hammer or an air/steam hammer. Pile driving is an excellent method due to the strength of the pile and the ability of the pile and its soil interface to resist vertical and horizontal loads.

Figure 8-5. Pile driving methods.



A less desirable, but frequently used method is jetting. Jetting inserts piles into sandy soil by forcing a high-pressure stream of water through a pipe along the side of the pile. The stream of water creates a hole in the sand while the pile is continuously pushed or dropped to the desired depth. Jetting results in a lower load capacity due to loose soils that create 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.

Another method is the use of an auger to pre-drill holes for piles. If the soil is composed of adequate clay or silt, using 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.

Pile installation methods, including driving, jetting, and, to a lesser extent, augering can make precise location control difficult. Also, irregularities in the piles and soil will often prevent the piles from being driven perfectly vertical. When using piles to support manufactured housing, wood beams are typically secured to the piles and the home is secured to the beams.

When soils near the top of a pile are lost due to scour, the pile loses some of its ability to resist vertical and lateral loads. Erosion and scour must be taken into account when determining pile embedment depth and lateral bracing requirements. Due to the variability associated with differing installation methods and erosion/scour potential, a geotechnical engineer should be involved in the design process to verify that intended pile capacities are achieved.

8.4 Bracing

Bracing is often used to lower the point of application of lateral loads to reduce moments applied to the foundation system (cross bracing) or to provide lateral support to resist buckling (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 (Figure 8-6). Unfortunately, with greater strength comes a larger exposure to wave and debris impact. Diagonal bracing is 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.

Steel rods are often 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. Rod bracing offers two important benefits. One, rod bracing can easily be fitted with turnbuckles that allow bracing to be tightened after an event that creates loads in the bracing; two, rod bracing has smaller cross-sections than bracing created with dimensional lumber and thus is exposed to lower flood forces.

Knee bracings are short diagonal braces that run from a vertical support member to a horizontal support member (Figure 8-7). Knee braces can be effective in supporting the pile against the lateral forces of wind and water, Knee bracing increases the strength and stiffness of the extended pile foundation by retraining rotation near the top of the pile and reducing the pile bending length. Knee bracing is not as stiff as diagonal bracing. Knee braces have an advantage over diagonal braces in that they present less obstruction to waves and debris. Knee braces are shorter than diagonal braces and are usually designed for both tension and compression forces. Engineers should be consulted to determine bracing designs, particularly for knee bracing.

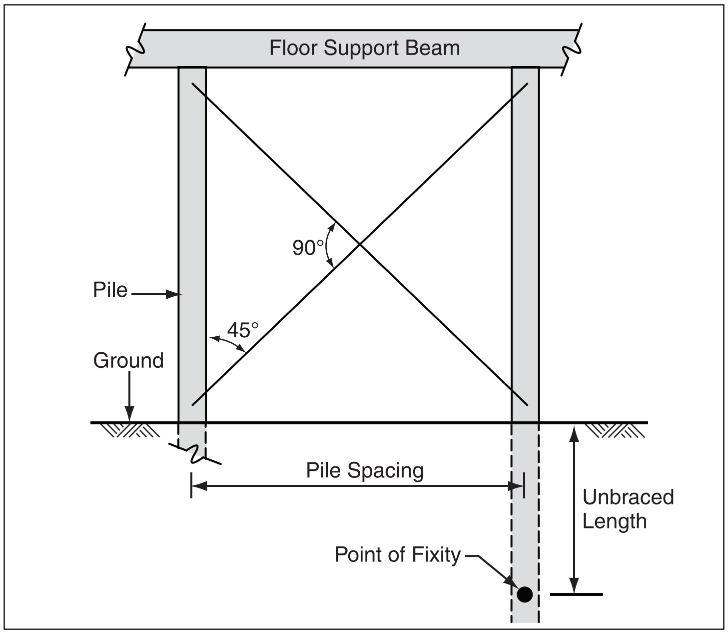
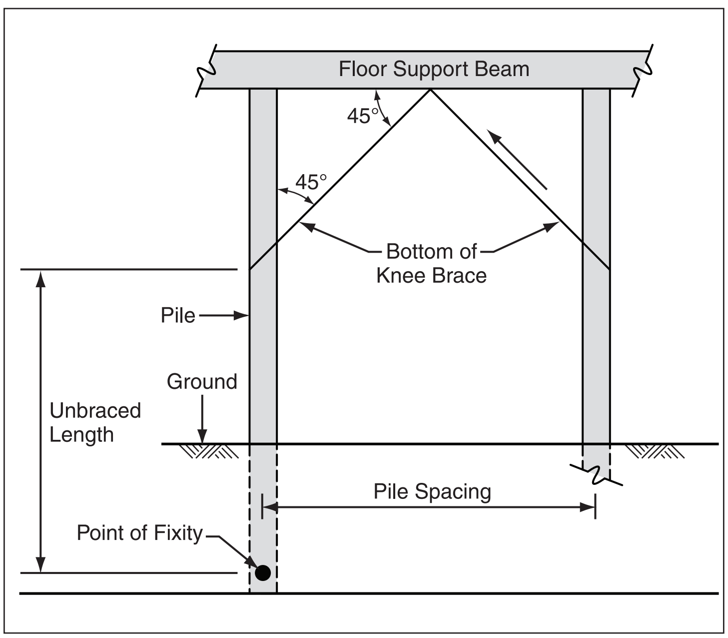


Figure 8-6. Diagonal bracing.



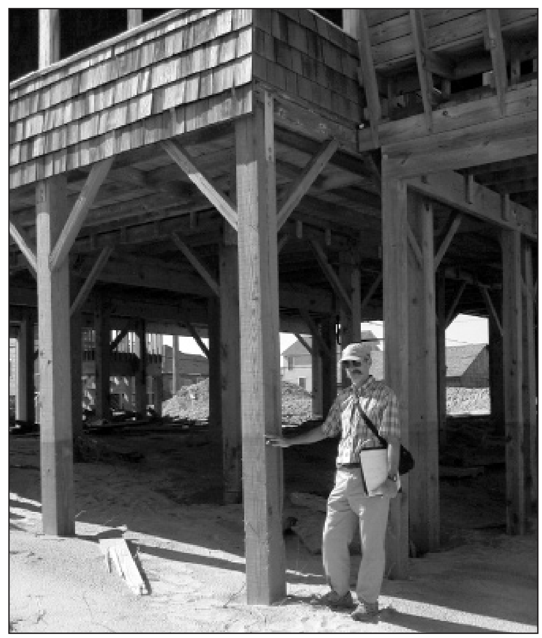


Figure 8-7. Knee bracing.

8.5 Footings

Footings are the components of a foundation system that transfer loads applied to a home to the earth below it. Footings continuously support gravity loads (and are generally well designed for this purpose), but they also must transfer lateral and uplift loads produced by wind events, seismic events, snow accumulation, and moving floodwaters.

The soils below the footings must support the home and resist all the loads applied to the home. When soils are strong, footings can be relatively small and foundation systems relatively compact. When soils are weak, however, the footings become large, complicated, difficult to construct, and quite expensive. Even when placed on firm soils, footings often need to be oversized to provide sufficient weight to resist uplift forces and overturning moments.

The design size of a pier footing is a direct function of soil bearing capacity. Soil bearing capacity can be directly determined by soils tests. In some jurisdictions, approximate bearing capacity can be assessed by soil classification. Model building codes (such as the IBC and NFPA 5000) have presumptive soil bearing capacity values that can be used in the absence of soils test data.

The depth of the footings depends on local frost levels and expected scour depths (whichever is greater). Local codes may provide specific requirements for the depth of footings based on local soil conditions.

8.6 Foundation Materials Selection

As stated in 44 CFR 60.3(a)(3), all structural and non-structural materials at or below the BFE must be flood damage-resistant. A flood damage-resistant material is defined as any building material capable of withstanding direct contact with floodwaters 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 durable and resistant to decay and corrosion.

Some flood damage-resistant foundation material choices include the following:

- Pressure-treated lumber
- Naturally decay-resistant lumber (only for applications above grade)
- Concrete: a minimum 28-day compressive strength of 5,000 lb/in^2 is recommended in coastal environments
- Masonry: reinforced and fully grouted in coastal environments
- Steel: corrosion-resistant
- Closed-cell foam insulation
- Other flood damage-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 in Sections 8.6.1 through 8.6.4. Additional information on materials' durability can be found in FEMA 55 and trade organization publications. FEMA's Technical Bulletin 2, *Flood Damage-Resistant Materials Requirements* (2008) also contains information on appropriate materials used in SFHAs.

8.6.1 Wood Foundations

Wood is a very workable material and one of the most cost-effective; however, it is susceptible to decay, insect infestation, marine borers, and weathering. Wood must be adequately maintained to ensure the foundation's integrity. All wood used in foundation piles, girders, beams, braces, and walls must be pressure-preservative treated or, when not in direct contact with the ground, naturally decay-resistant. 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 used in pressure treating wood for foundation applications; e.g. piles, piers, and posts, include:

- chromated copper arsenate (CCA)
- pentachlorophenol
- creosote
- copper azole

ACQ- or ACZA-Treated Wood

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.

8.6.2 Concrete Foundations

Concrete is an economical and workable foundation material that is 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 American Concrete Institute (ACI) publication 318, *Building Code Requirements for Structural Concrete*, for minimum concrete cover requirements. Additional protection from corrosion can be achieved by using epoxy-coated reinforcement.

Proper mixing, placement, 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. 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 from 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 guide 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.

8.6.3 Steel Foundations

Prefabricated steel stands are available for 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.

8.6.4 Masonry Foundations

Reinforced masonry has much more strength and ductility than unreinforced masonry for resisting large flood, wind, and earthquake forces. It is recommended that permanent masonry construction in and near coastal flood hazard areas be reinforced and fully grouted regardless of the purpose of the construction and the design loads. Moisture can have a damaging effect on masonry construction. Moisture-borne salts in coastal environments entering the piers through cracks or openings in the masonry joints can cause cracking and spalling of the masonry. Moisture entering piers in cold weather environments can expand upon freezing, causing small cracks to become large cracks. 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 prevention, Type S mortar should be used for below-grade applications and Type M mortar may be used for above-grade applications.

Open Masonry Foundations

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

In addition to Portland cement/lime based mortar, polyurethane based masonry adhesives are now available. Care must be taken in the selection and application of masonry adhesives. As a minimum, the selected adhesive must be certified by a nationally recognized organization as meeting or exceeding the requirements for Types M, O, and S cement/lime based mortar and approved for use in masonry construction designed in accordance with applicable provisions of the IRC and IBC.

8.7 Foundation Selection and Flood Resistance

Flooding can have a dramatic effect on the suitability and stability of a manufactured home foundation. But not all floods are the same, and the type of flooding, along with its char-acteristics and severity at a site, will eliminate many foundation types. Sections 8.7.1 through 8.7.5 provide guidance (for installers, owners, community officials, and designers) on selecting foundations suitable to different flood types and site conditions.

8.7.1 Flooding Types

Flooding can be divided into seven major types: coastal, riverine, flash flood, alluvial fan, mudflow, lake or pond overflow, and poor drainage. Unique hazards are associated with each of these flooding types.

- **Coastal** flooding is usually accompanied by waves, high velocity flow, and erosion. Damages to structures are usually the results of erosion and scour, and direct impact from wave action.
- **Riverine** flooding is associated with dominant hazards, including velocity, depth, and duration. These hazards are determined by several factors, including the slope of the channel and watershed, land uses within the watershed, and the extent, intensity, and duration of precipitation. (Both coastal and riverine flooding can transport damaging debris. Debris impact can weaken a structure and make it more vulnerable to damages from flooding.)
- **Flash floods** are accompanied by rapidly rising water and extreme flood velocities, with high debris carrying potential. Although they are generally of short duration, the forces exerted on structures by the high velocity floodwaters and debris can cause extensive damage in a very short time.
- **Alluvial fan** flooding is distinct in that the region of greatest flood hazard is not well-defined, and floodwaters can follow many different paths across a normally dry area. Alluvial fan floods usually occur in arid areas at the base of steeply sloping terrain, and can have extreme flood velocities and debris loads.
- **Mudflows** are proximately caused by flooding and can be considered a river of liquid and flowing mud on the surfaces of normally dry land areas. Mudslides usually offer little warning and can be very destructive due to their debris load and velocity.
- **Lake or pond overflow** is rarely as hazardous as coastal or riverine flooding, and is usually limited to inundation by slowly moving or standing water.
- **Poor drainage** can lead to backups and generally results in ponding type flooding. Poor drainage is usually caused by a lack of topographic relief to allow for natural drainage from a site, or it might be the result of a specific hindrance such as blockage of a drainage ditch or an undersized culvert. In areas where drainage impediments become severe, they can compound risk and damages from other types of flooding such as riverine or flash floods.

8.7.2 Flood Characteristics

The flood source, its proximity to a site, and the flood hazard zone will provide information about flood characteristics. However, historical flood events at and near the site can also provide important clues about expected flood conditions at the site. All should be considered when home foundations are evaluated.

High velocities, large waves, and large floating debris can cause many home installations to fail, especially those on stacked masonry block, crawlspace, slab, shallow pier, and post foundations. Large flood depths can float or wash homes off their foundations. Long-duration floods can weaken soils, foundations, and anchor systems. Refer to Section 5.2 for more information on flood characteristics.

8.7.3 Flood Hazard Zones

Table 8-1 is provided as general guidance for the selection of foundation systems for manufactured homes located at different flood hazard zones, Different flood hazard zones are represented on FIRMs by different zone designations. Detailed information pertaining to flood hazard zone designations and current NFIP regulations is provided in Chapter 3.

8.7.4 Proximity to Flood Source

Proximity to the flood source will, to a large extent, determine whether a home site is in a more or less hazardous location. As discussed in Chapter 4, sites in a floodway or closest to a river or stream will be subject to the greatest flood depths, highest velocities, and greatest debris potential. Sites outside the floodway and far from a river or stream and closer to the landward limit of the floodplain will be subject to reduced flood hazards (e.g., shallow flood depths, lower velocities, low erosion potential, and only small debris).

Sites in a V or Coastal A zone will be subject to the highest waves, greatest flood velocities and depths, greatest erosion potential, and largest debris. Sites outside the V zone and far from the shoreline will be subject to reduced wave, velocity, depth, erosion, and debris conditions.

Closeness is a relative issue, however. Therefore, it may be useful to look at the location of a home site relative to the flood source or floodplain boundary. Two approaches may be useful, a distance approach and a floodplain width approach.

1. The **distance approach** relies on a distance measurement between the home site and the stream or river bank or floodway (in the case of a riverine flood source), or between the home site and the V zone boundary or shoreline (in the case of an A zone in a coastal area).
2. The **floodplain width approach** considers the relative position of the home site within the floodplain. (See Figure 4-2, which is a schematic of a floodplain/floodway.)

For riverine areas outside the floodway:

1. **Distance approach**: If a home site lies within a few hundred feet of a river or stream or floodway, it should be considered "close," and foundations should be appropriate to sites with greater flood hazards.
2. **Floodplain width approach**: If a home site lies within the third of the floodplain closest to the river or stream or floodway, it should be considered "close," and foundations should be appropriate to sites with greater flood hazards.

For Coastal A zones:

1. **Distance approach**: If a home site lies within a few hundred feet of the V zone boundary (or shoreline, if a V zone has not been mapped), it should be considered "close," and V zone foundations should be used. Beyond that point, A zone foundations may be suitable.
2. **Floodplain width approach**: If a home site lies within the half of the floodplain closest to the V zone boundary (or shoreline, if a V zone has not been mapped), it should be considered "close," and V zone foundations should be used. Beyond that point, A zone foundations may be suitable.

8.7.5 Foundation Selection Guidance

The recommendations contained in Tables 8-1 through 8-3 should be evaluated in light of specific soil, terrain, and base flood conditions at a home site. The pier information contained in the tables is appropriate for piers used in foundation systems that contain other components (like ground anchors) that are properly selected, designed, and installed to resist flood and wind forces on the manufactured home itself. The pier construction styles listed are those required to resist flood forces on the piers themselves.

Areas exposed to flash flooding, alluvial fans, and mudslides pose unique (and often not specifically known) hazards. Foundations for homes in those areas should be developed by licensed engineers working closely with local floodplain managers.

Table 8-1. Recommended Manufactured Home Foundation Selection for Lake/Pond Flooding (for very low velocity less than 1 fps)

Lake/Pond Flooding (standing water; maximum flood flow velocity 1.00 fps)		
Flood Zone/Foundation Type		**A, AE, A 1-30, AO/AH**
Steel pier		✓
Dry-stacked masonry block	Single block stack	✓
	Double block stack	✓
Dry-stacked masonry block with surface-bonded mortar	Single block stack	✓
	Double block stack	✓
Mortar or adhesive-bonded masonry block	Single block stack	✓
	Double block stack	✓
Reinforced and grouted masonry block	Single block stack	✓
	Double block stack	✓
Fill/slab		✓
Posts		✓
Perimeter foundation walls		✓
Piles		✓

✓ = OK

fps = feet per second

Single block stack (8 inch by 16 inch) on concrete footing or ABS pad

Double block stack (16 inch by 16 inch) on concrete footing or ABS pad

Table 8-2. Recommended Manufactured Home Foundation Selection for Riverine Flood Zones (and maximum flood flow velocity)

Riverine Flooding			
Flood Zone/Foundation Type		**Floodway[1]**	**A, AE, AE1-30, AO/AH**
Steel pier			✓ V_{max}=1.00 fps
Dry-stacked masonry block	Single block stack	Do Not Use	✓ V_{max}=1.25 fps[2]
	Double block stack	Do Not Use	✓ V_{max}=1.75 fps[3]
Dry-stacked masonry block with surface-bonded mortar	Single block stack	Do Not Use	✓ V_{max}=2.00 fps
	Double block stack	Do Not Use	✓ V_{max}=3.00 fps
Mortar or adhesive-bonded masonry block	Single block stack	Do Not Use	✓ V_{max}=2.50 fps
	Double block stack	Do Not Use	✓ V_{max}=3.00 fps
Reinforced and grouted masonry block	Single block stack	Do Not Use	✓ V_{max}=5.00 fps
	Double block stack	Do Not Use	✓ V_{max}=5.00 fps
Fill/slab		Do Not Use	✓
Posts		Do Not Use	✓[4]
Perimeter foundation walls		Do Not Use	✓
Piles[5]		✓	✓

1 Any construction in the floodway requires certification that the construction will not cause a rise in flood levels.

2 V_{max} shown for single stack block on concrete pad or footing. V_{max} = 1.00 fps for single stack block on ABS pad.

3 V_{max} shown for double stack block on concrete pad or footing. V_{max} = 1.25 fps for double stack block on ABS pad.

4 Scour protection is recommended around shallow foundations where velocities exceed 2 fps.

5 Pile foundations are suggested for all sites exposed to flood velocities greater than 5 fps unless designed by a licensed engineer or architect.

✓ = OK

V_{max} = maximum design flood velocity (ft/sec) for foundation type

Single stack (8 inch by 16 inch)

Double stack (16 inch by 16 inch)

Table 8-3. Recommended Manufactured Home Foundation Selection for Coastal Flood Zones

Coastal Flooding				
Flood Zone/Foundation Type		**V, VE, V1-30**	**A, AE, A1-30, AO/AH** (LiMWA area)[2]	**A, AE, A1-30, AO/AH** (Outside LiMWA area)[2]
Steel pier		Do Not Use	Do Not Use	✓ where V_{max}=1.00 fps
Dry-stacked masonry block	Single block stack	Do Not Use	Do Not Use	✓ where V_{max}=1.25 fps[3]
	Double block stack	Do Not Use	Do Not Use	✓ where V_{max}=1.75 fps[4]
Dry-stacked masonry block with surface-bonded mortar	Single block stack	Do Not Use	Do Not Use	✓ where V_{max}=2.00 fps
	Double block stack	Do Not Use	Do Not Use	✓ where V_{max}=3.00 fps
Mortar or adhesive-bonded masonry block	Single block stack	Do Not Use	Do Not Use	✓ where V_{max}=2.50 fps
	Double block stack	Do Not Use	Do Not Use	✓ where V_{max}=3.00 fps
Reinforced and grouted masonry block	Single block stack	Do Not Use	Do Not Use	✓ where V_{max}=5.00 fps
	Double block stack	Do Not Use	Do Not Use	✓ where V_{max}=5.00 fps
Fill/slab		Do Not Use	Do Not Use	✓
Posts		Do Not Use	Do Not Use	✓[5]
Perimeter foundation walls		Do Not Use	Do Not Use	✓
Piles[1]		✓	✓	✓

[1] Pile foundations are suggested for all sites exposed to flood velocities greater than 5 fps unless designed by a licensed engineer or architect.

[2] The Limit of Moderate Wave Action (LiMWA) is the inland limit of the area affected by waves greater than 1.5 feet.

[3] V_{max} shown for single stack block on concrete pad or footing. V_{max} = 1.00 fps for single stack block on ABS pad.

[4] V_{max} shown for double stack block on concrete pad or footing. V_{max} = 1.25 fps for double stack block on ABS pad.

[5] Scour protection is recommended around shallow foundations where velocities exceed 2 fps.

✓ = OK

V_{max} = maximum design flood velocity (ft/sec) for foundation type

Single stack (8 inch by 16 inch)

Double stack (16 inch by 16 inch)