10 Recommended Foundations

Manufactured home foundations must be designed and constructed to resist gravity, lateral, and uplift loads. Foundation systems provide load resistance by transferring the loads to soils at the site. Load transfer can be accomplished using a single element or a combination of elements. For example, driven piles are an effective foundation element for transferring gravity, lateral, and uplift loads to the soil. Unreinforced masonry piers can be effective at transferring gravity loads, but are not effective in transferring lateral and uplift loads.

This chapter provides descriptions and design recommendations for six foundation systems suitable for use in many SFHAs in the U.S. The six foundation systems presented are: reinforced masonry, wood framed, braced masonry pier, wood H-frame, ground anchors with stabilizer plate, and ground anchor (in-line). These 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.

Also included in this chapter are three foundation designs suitable for all seismic regions in the U.S. The seismic designs can only be used for sites with maximum 90-mph design wind speeds.

Although the foundation 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 be overly conservative in some areas, but would provide inadequate protection in other areas.

10.1 Design Criteria for Recommended Foundations

Criteria used in the design of the recommended 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. Foundation designs provided in this guide are not appropriate for manufactured homes within V zones, Coastal A zones, floodways, and all sites where design event flood velocities exceed 5 fps. The recommended foundations were designed to the following criteria:

- Maximum flood depth of 36 inches above finished grade.
- BFE no higher than the bottom flanges of the home's I-beams.
- Maximum flood velocities of 5 fps.
- No breaking wave forces.

- 3-second gust wind speeds of 90 mph, 110 mph, 130 mph, and 150 mph. The seismic foundations (drawings SP, SM, and SWF in Appendix H) may be used in areas with design 3-second gust wind speeds of 90 mph or less.
- Manufactured home with width of at least 14 feet wide for single units and 28 feet wide for double units. Minimum home length of 48 feet for both single and double units.
- Manufactured home eave heights of 8 feet 2 inches or less.
- Chassis main beam spacing of 82 to 96 inches (for ground anchor foundations).
- Maximum snow loads of 40 psf.
- Manufactured home weight of at least 25 psf and not greater than 40 psf.

Foundations have been designed to resist loads and load combinations calculated using ASCE 7. Where additional design guidance was needed, other documents have been used, including the *Coastal Construction Manual* (FEMA 55). A brief description of each design follows in Sections 10.1.1 through 10.1.5. The drawings are presented in Appendix H.

10.1.1 Reinforced Masonry Perimeter Foundation Walls

(Drawing Numbers: M-1 to M-4)

The reinforced masonry (RM) foundation consists of reinforced masonry walls supported on cast-in-place concrete strip footings.

Reinforced masonry perimeter walls transfer gravity loads to the soil through the bearing pressure imposed on the strip footing. Lateral loads are resisted by a combination of frictional resistance between the strip footing and the soil, and lateral resistance of the soil against the below grade portion of the wall footing. Uplift loads are resisted by a combination of the weight of the footing, soil resistance to vertical failure, and increased bearing pressures in the leeward footing.

RM foundations are likely the most expensive of the recommended foundations that have been developed. For example, properly grouting the masonry wall cores will likely require the home to be crane set on the RM foundation.

Openings or vents, required by the NFIP, are spaced throughout the foundation walls. The openings are designed to automatically allow floodwater to enter the crawlspace and equalize hydrostatic pressures on the foundation walls. Flood openings must automatically open to allow floodwaters to flow and must be installed within 1 foot of grade. Detailed guidance for flood openings is provided in FEMA Technical Bulletin 1: *Openings in Foundation Walls and Walls of Enclosures*, August 2008. A minimum of two flood vents with a total net area of 1 square inch per square foot of enclosed space must be provided (44 CFR 60.3(c)(5)). Vents for moisture control are typically installed at the top of the foundation wall. In areas where high crawlspace moisture levels predominate, additional vents may need to be installed in the upper portions of the foundation walls for adequate ventilation.

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 to WF-4)

The wood framed (WF) foundation consists of 2-inch by 6-inch (nominal) treated framing sheathed with plywood that is treated to resist rot and wood destroying insect damage. The WF foundation walls are constructed over continuous poured concrete strip footings. Like the RM foundation, the WF foundation encloses the underside of the home to create a crawlspace, and flood vents are required to equalize hydrostatic loads and provide crawlspace 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." Footings can be poured prior to placing the home (for installation tolerance, they can be constructed slightly wider), 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 WF 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 and vertical loads from the home to the foundation. Manufacturers should provide connection details specific to their homes.

10.1.3 Braced Masonry Pier Designs

(Drawing Numbers: BM-1.1 to BM-2.2)

The braced masonry pier (BMP) designs utilize materials developed for more typical 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 are used to resist uplift and soil pressure while friction forces resist lateral loads.

Pier construction varies with flood velocity. With low flood velocities, piers can be dry stacked and adhered with surface bonding 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. Increasing design flood flow velocities require that the masonry piers be strengthened to resist higher loads. Section 10.3 outlines flood flow velocity design considerations for several masonry pier configurations.

The metal straps are an integral component in the braced masonry foundation. Failure of any strap will redistribute loads to adjacent portions of the foundation. If straps are loaded to their maximum working load, redistributing the load 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 to HF-2.2)

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

The designs 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 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 that connect the vertical posts to the concrete footing. The design specifies cast-in-place bases 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 to transfer gravity loads.

10.1.5 Ground Anchor Designs

(Drawing Numbers: GASP-90-1.1 to GASP-110/130/150-2.2 and GA-90-1.1 to GA-110/130/150-2.2)

In many areas of the U.S., ground anchors are used as part of the support and anchorage systems for manufactured homes. Anchors are inexpensive, easily installed in many types of soils, and readily available in many portions of the U.S. Despite these advantages, support and anchorage systems using ground anchors do not perform as well as typical foundations. Most of the 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 typical foundation materials provide.

Ground anchors can be effective in resisting uplift and lateral loads. Loads are resisted by mobilizing the soil shear strength along the potential failure surface. The surface area of the potential failure plane is a function of helix area and embedment depth. Mobilization of soil shear strength requires movement along the failure plane. Shallow anchors typically used for manufactured home installations require mobilization of a significant portion of the ultimate soil shear strength, which results in relatively large movements.

Ground anchors used in manufactured home installations frequently use stabilizer plates to enhance lateral load resistance capacity. The stabilizer plates resist lateral loads by mobilizing passive resistance of the soil. Development of soil passive resistance requires deformations, or movement, in the direction of the applied load. As with uplift, the greater the amount of passive resistance mobilized, the larger the horizontal movement required.

Two recommended 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 because fewer 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 with stabilizer plates. One consideration of in-line anchors is that they need to be installed prior to home placement. This requires additional advanced planning of home placement and also requires using installers with experience in the use of in-line anchors.

10.2 Summary of Recommended Foundations

A summary and a comparison of the six different recommended foundation systems proposed in this guide are given in Table 10-1.

Table 10-1. Summary of Recommended Foundations

Type of Foundation	Advantages	Disadvantages
Reinforced masonry (M-1 to M-4)	• Little or no maintenance	• Need crane to set home • Expensive • Need custom feature built into home to accommodate foundation wall • Shear reinforcement needed
Wood framed (WF-1 to WF-4)	• No crane installation necessary	• Need modification to home to accommodate foundation wall • Shear reinforcement needed
Braced masonry pier (BM-1.1 to BM-2.2)	• Typical installation methods	• Adjustment of straps needed after a design event
Wood H-frame (HF-1.1 to HF-2.2)	• Uses common materials • Easily adapted to site conditions	• Need crane to set home • Amount of work under home • Accurate placement of vertical posts at concrete footings

Table 10-1. Summary of Recommended Foundations (continued)

Type of Foundation	Advantages	Disadvantages
Ground anchors with stabilizer plate (GASP-90-1.1 to GASP-110/130/150-2.2)	• Inexpensive • Readily available • Easy to install • Anchors installed after home is in place	• Not as strong as typical foundation • Human intervention needed after a design event • Home likely to move during a design event • Home may need to be lifted and re-centered on foundation
Ground anchor – in-line (GA-90-1.1 to GA-110/130/150-2.2)	• Better performance than anchors with stabilizer plate – uses fewer • Anchors readily available	• Adjustment of straps after a design event • Anchors need to be accurately installed prior to placement of home

10.3 Floodwater Velocity Design Considerations for Pier Foundations

As is noted on the design drawings for the recommended foundations (Appendix H), the design of the pier is dependent on the floodwater velocities. There are four basic pier designs, each of which has a different design flood flow velocity. Furthermore, whether or not a single or double block design is used will also affect the design floodwater velocity. Pier designs and the corresponding recommended limit design velocities are provided in Table 10-2.

Table 10-2. Design Flood Flow Velocity for Concrete Masonry Unit Foundations[1]

Pier Construction	Dry Stack	Dry Stack with Face Mortar	Bonded Stack[2]	Fully Grouted, Reinforced, and Anchored to Concrete Foundation
Single Stack	1.00 fps[3] 1.25 fps[4]	2.00 fps	2.50 fps	5.00 fps
Double Stack	1.25 fps[5] 1.75 fps[6]	3.00 fps	3.00 fps	5.00 fps

[1] Velocities are the maximum design flood flow for each masonry block pier shown. Design velocity applicable to piers up to 36 inches high.

[2] Bonded piers use Type M or S Portland cement and lime mortar to adhere horizontal and vertical joints between block. Polyurethane based masonry adhesive certified by a recognized national testing agency for use in masonry construction in accordance with the IRC and IBC also may be used.

[3] Dry stack pier design velocity of 1.00 fps applies to single stack block piers supported on ABS pads.

[4] Dry stack pier design velocity of 1.25 fps applies to single stack block piers supported on concrete pad or footing

[5] Dry stack pier design velocity of 1.25 fps applies to double stack block piers supported on ABS pad

[6] Dry stack pier design velocity of 1.75 fps applies to double stack piers supported on a concrete pad or footing

Methods of determining flood velocities are presented in Appendix C.

10.4 Recommended Foundation Designs for Seismic Areas

The recommended foundation designs proposed in this chapter are designed mainly for flood and wind loadings. They are not specifically designed for seismic loadings. However, some of the designs have some seismic resisting capabilities. In Sections 10.4.1 through 10.4.3, three recommended foundation designs suitable for seismic areas are introduced. These are designs that have been included in the most recent release of *Model Manufactured Home Installation Standards* (NFPA 225) and are presented in Appendix H.

10.4.1 Concrete Masonry Pier Foundation Designs

(Drawing Numbers: SP-1/2.1 to SP-1/2.2)

This design applies to concrete masonry piers located along and attached to the chassis beams, providing both vertical and lateral force support to a manufactured home. The pier cannot be less than 16 inches square and must be supported on a concrete footing. Each concrete masonry pier must be provided with no less than two No. 4 vertical reinforcing bars located in diagonally opposite corners. Anchorage shall be provided between the support system and manufactured home that is capable of resisting the greater of the load and forces specified in *Standard on Manufactured Housing* (NFPA 501), Table SP-1.2 (Drawing SP-1/2.2), and the reactions specified by the home manufacturer.

The grouting required for pier construction will likely require homes to be crane set on this style of foundation.

10.4.2 Masonry Wall Foundation Designs

(Drawing Numbers: SM-1/2.1 to SM-1/2.2)

This design applies to foundation walls located at the manufactured home perimeter and to provide lateral force support. Foundation stem wall construction must consist of concrete or concrete masonry units supported on a continuous concrete footing. The stem cannot be less than 6 inches thick.

Each concrete or concrete masonry foundation wall must use no less than No. 4 vertical reinforcing bars at a space not exceeding 4 feet with a standard hook of not less than 8 inches in the footing. Anchorage shall be provided between the support system and manufactured home that is capable of resisting the greater of the loads and forces specified in NFPA 501, Table SM-1.1 (Drawing SM-1/2.2), and the reaction specified by the home manufacturer.

10.4.3 Wood Framed Foundation Designs

(Drawing Numbers: SWF-1/2.1 to SWF-1/2.2)

This design applies to continuous wood framed cripple walls located at the manufactured home perimeter to provide lateral force support. The continuous concrete perimeter footing cannot have a width less than 12 inches. Also, the concrete shall extend less than 8 inches above the highest adjacent grade.

When the home length exceeds 60 feet, two interior transverse shear walls with continuous footings must be added with spacing between walls not exceeding 30 feet. Access openings shall be provided at the center transverse interior footings. The height of the cripple walls shall exceed 4 feet above the top of the footing.

The concrete footing shall be provided with not less than two No. 4 horizontal reinforcing bars. Lap splice No. 4 bars no less than 24 inches straight and provide no less than 12 inches bend around corners. Anchorage shall be provided between the cripple wall and manufactured home that is capable of resisting the greater of the reaction forces specified in NFPA 225, Table 13.4.7, the reactions specified in SWF-1.1 (Drawing SWF-1/2.2), and anchorage requirements specified by the home manufacturer. If anchorage requirements from the home manufacturer are not available or if the manufactured home's weight and dimensions are not within the criteria established in these designs, anchorage requirements shall be determined by engineering analysis based on loads specified by ASCE 7.

Anchorage between the cripple wall sill plate and the concrete footing shall be provided not less than 1/2-inch diameter anchor bolts, starting with no more than 8 inches from the end of each foundation wall. Anchor bolts cannot be less than 8 inches embedded into the concrete. Also, anchor bolts shall exceed 16 inches on center for an end wall of single-wide homes, and 32 inches on center for the other walls. Each anchor bolt shall be provided with a steel plate washer dimensions of no less than 1/4 inch by 3 inch by 3 inch that has a hole diameter of 11/16 of an inch that is installed with a standard cut washer.

The wood framed perimeter design should allow the foundation to be built to the dimensions of the manufactured home; therefore, crane installation should not be required.

10.5 Design Drawings

The design drawings for this guide are listed in Table 10-3 and are contained in Appendix H.

Table 10-3. Foundation Drawings

Drawing No.	Title
GN-1.1	Recommended Foundation – General Notes
M-1	Single Unit Masonry Foundation Plan

Table 10-3. Foundation Drawings (continued)

Drawing No.	Title
M-2	Double Unit Masonry Foundation Plan
M-3	Masonry Wall Foundation Detail
M-4	End Wall Foundation 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	Braced Masonry Pier Detail
BM-2.1	Double Unit Braced Masonry Pier Foundation Plan
BM-2.2	Braced Masonry Pier Detail
HF-1.1	Single Unit Braced Wood H-Frame Foundation Plan
HF-1.2	Single Unit Wood H-Frame Detail
HF-2.1	Double Unit Braced Wood H-Frame Foundation Plan
HF-2.2	Double Unit Wood H-Frame Detail
GASP90-1.1	Single Unit Ground Anchor Foundation Plan
GASP90-1.2	Ground Anchor and Pier Detail (Single Unit)
GASP90-2.1	Double Unit Ground Anchor Foundation Plan
GASP90-2.2	Ground Anchor and Pier Detail (Double Unit)
GASP110/130/150-1.1	Single Unit Ground Anchor Foundation Plan
GASP110/130/150-1.2	Ground Anchor and Pier Detail (Single Unit)
GASP110/130/150-2.1	Double Unit Ground Anchor Foundation Plan
GASP110/130/150-2.2	Ground Anchor and Pier Detail (Double Unit)
GA90-1.1	Single Unit Ground Anchor Foundation Plan
GA90-1.2	Ground Anchor and Pier Detail (Single Unit)
GA90-2.1	Double Unit Ground Anchor Foundation Plan
GA90-2.2	Ground Anchor and Pier Detail (Double Unit)
GA110/130/150-1.1	Single Unit Ground Anchor Foundation Plan
GA110/130/150-1.2	Ground Anchor and Pier Detail (Single Unit)
GA110/130/150-2.1	Double Unit Ground Anchor Foundation Plan
GA110/130/150-2.2	Ground Anchor and Pier Detail (Double Unit)
APD-1.1	Alternative Pier Details for Flood Velocities Not Shown on Plans
AS-1.1	Lateral Ground Anchor Spacing
AS-1.2	Longitudinal Ground Anchor Spacing and Anchor Notes

Table 10-3. Foundation Drawings (continued)

Drawing No.	Title
SP-1/2.1	Single Unit Concrete Masonry Pier Foundation Plan
SP-1/2.2	Concrete Masonry Pier Details
SM-1/2.1	Single Unit Concrete Masonry Wall Foundation Plan
SM-1/2.2	Concrete Masonry Wall Foundation Detail
SWF-1/2.1	Single Unit Wood Framed Foundation Plan
SWF-1/2.2	Wood Framed Foundation Detail