PART TWO: FOUNDATIONS

Manufacturers' installation instruction manuals describe at least one way to perform a routine set-up of the home. Common variations are typically addressed: different soil strengths, special considerations for Wind Zones II and III, different pier and footing materials, and different heights of piers. General instructions are given about adding piers to the perimeter of the home and under the marriage wall, with specific sizes and locations marked on the home itself by some manufacturers.

Beyond the simple variations noted in installation instruction manuals, the installer is largely on his own in dealing with other than routine set-ups. This part of the manual tries to provide the essential principles behind foundation design. Because many of the important details are rather technical, these are placed in "Background" panels, with the main text summarizing the key points. The installer is urged to read and digest these technical discussions, because fully understanding how weight, wind, people, snow, and earthquakes cause a home to push or pull on its foundations will help the installer spot dangerous or unusual situations and correct them before they occur.

> ***Tip***
>
> *Most of the weight the foundation has to carry is not there when you set up the unit. Heavy as it is, the unit is only an empty box. In the future, the foundations have to carry the design live load (people, furniture, and other possessions), the design wind load, the design snow load, and any earthquake loads. These can double or triple the weight on a pier, and both pier and footing are designed to carry this larger load, not the load you are working with.*

While the purpose of this manual is to improve and clarify ordinary pier and ground-anchor set-ups, other forms of foundations are highly recommended whenever the budget allows. Ordinary set-ups can and do provide ample security in most cases. The installer must learn to spot cases where they don't work, and should encourage every buyer who wishes to invest in a permanent foundation.

CHAPTER 6: RESISTING WINDS AND EARTHQUAKES

1. Steps Covered

- ☐ HUD-Code wind zones
- ☐ Homes in Wind Zone I
- ☐ How a Home Can Become Unstable Under Wind Zone I Wind Loads
- ☐ Homes in Wind Zones II and III
- ☐ Why Side Anchors Must Be Attached to the Top of a Chassis Beam in Wind Zones II and III
- ☐ All HUD-Code homes require some form of restraint
- ☐ How earthquake loads differ from wind loads
- ☐ Which loads are greater, earthquake or wind?
- ☐ Wind and earthquake loads on accessory structures
- ☐ The advantages of load-bearing perimeter foundations

2. Understanding the Issues

The most basic requirement for installing a HUD-Code home is simply to follow the manufacturer's instructions. This manual assumes you have done that, and are still puzzled about how or why you should do something. One important tool in answering the "hows" and "whys" of installation is to understand what loads wind and earthquake can impose on a home.

<u>HUD-Code Wind Zones</u>

The HUD Code defines three wind zones, each with wind loads that must be resisted by the home. These wind loads, are known as "design wind loads," because the foundations must be designed to resist them. They are expressed in terms of pounds per square foot (psf) of area on which the wind acts, based on an assumed maximum sustained wind speed. The wind from the side (lateral wind load) is assumed to press only on the side wall of the home, assuming the roof slope is no greater than 20° (about 4-1/3 in 12). If the roof is steeper than that, it's height must be added to the height of the side wall. The skirting under the home is ignored in the calculation.

In each zone, an uplift load is defined. This load acts upward on the entire roof, exactly opposite the weight of the home. In Zones II and III, this uplift load exceeds the weight of the home, so that if the home is not tied to the ground, it will leave its foundations, even before the "design wind load" is reached. Because of this large uplift load, Zones II and III will be considered separately from Zone I.

Here are the loads for each zone:

- In Zone I, which covers most of the U.S., the maximum sustained wind speed to be be resisted is 65 mph, resulting in a design lateral wind load of 15 psf, and a design uplift wind load of 9 psf.
- In Zone II, which covers a band along the Gulf and Atlantic coasts, the wind speed to be resisted is 100 mph, with a design lateral wind load of 39 psf, and a design uplift wind load of 27 psf.
- In Zone III, which covers the southern Florida coast, the area around New Orleans, the area around Cape Hatteras, the entire Alaskan coast, and various U.S. territories, the wind speed is 110 mph, the design lateral wind load is 47 psf, and the design uplift wind load is 32 psf.

Section 305 of the HUD-Code standards lists Zones II and III by county.

<u>Homes in Wind Zone I</u>

There are thousands of manufactured homes, set on piers without any form of tie-down, that have remained comfortably in place for years. In areas where wind loads are seldom severe, highly reputable installers do not tie their homes down. Why do these homes remain undamaged?

The answer is that in some areas, the 65 mph design wind speed that is assumed in the HUD Code for Zone I seldom occurs; and many homes are protected from high winds because they are nestled among other homes and trees. Nevertheless, a 65 mph wind can occur in any area of the country, and the HUD Code requires that the home be set to resist a wind of that speed.

There may be some unusually heavy three-section homes that can stand on concrete block piers without tie-downs and still resist a 65 mph wind. However, these are rare exceptions: for all practical purposes, no home of any kind can stand on a stack of concrete blocks and resist a 65 mph wind.

The surprising reason is that the home will slide off its piers. This happens because the uplift from the wind takes some of the home's weight off the piers. Its friction against the piers is directly related to its apparent weight: lighten the home, and the friction goes down. Then the lateral wind load pushes the home sideways off the piers.

Ordinary tie-downs using ground anchors are the usual protection against this sliding force, because they are economical, and more important, they solve a host of other problems that arise. To show why, consider an obvious way to stop the sliding problem: pin, clip, or otherwise restrain each layer in the foundation from sliding against the one below. One can easily imagine a foundation system that does this using a special footer that fits up into the holes in the block, plastic inserts between the blocks, and a simple clip between the pier and the chassis beam.

However, a new problem arises: the piers will topple over if they are too high. What "too high" means varies in each case, but in general, a 16" wide pier will topple sideways if it is more than 36" high. A relatively short home section will topple endwise if the blocks are only 8" wide in that direction, although a long home will not. Again, what constitutes "long" and "short" depends on the individual case, but the dividing line will be somewhere around 50' long.

This exercise shows that, using 16" by 16" piers, not more than 36" high, with special measures to prevent them from sliding, most HUD-Code homes will resist the 65 mph wind in Zone I without tie-downs. This design should work for piers higher than 36", but should not be used in those circumstances without engineering analysis.

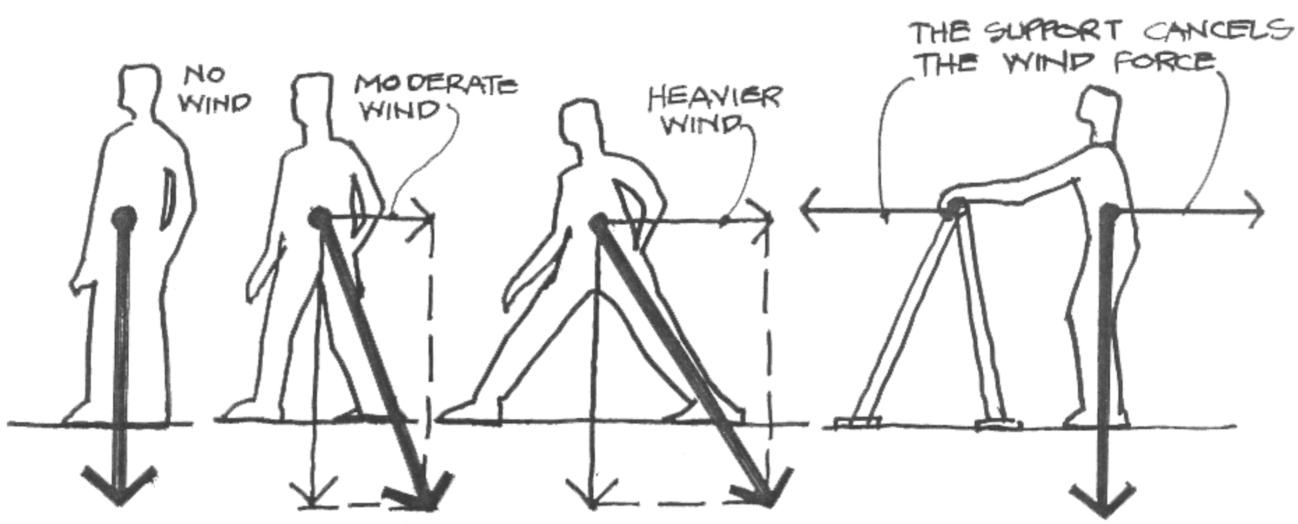
Chapter 8: Anchoring the Home covers ground anchors in detail. Chapter 9: Alternative Foundation Systems briefly covers various alternatives to piers and ground anchors.

<u>How a Home Can Become Unstable Under Wind Zone I Wind Loads</u>

The following diagrams show some of the ways in which a home can become unstable under Zone I wind conditions. Note that in all cases, the uplift load is less than the home's weight; when it is greater, the "resultant" load is upward, and the home must be anchored to the ground. These Zone II and III cases are not diagramed, but are discussed above.

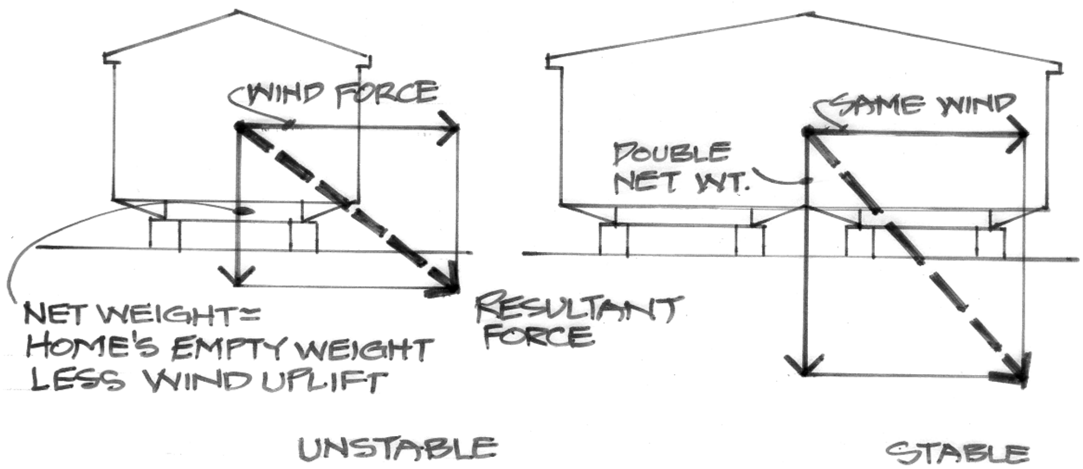
In the diagram below, the heavy line shows what is technically called the "resultant" force, which is the combination of the wind force from the side and the object's "net weight." In the case of a home, the net weight is the actual (empty) weight of the home, less the uplift from the wind. These diagrams only apply to Wind Zone I, because in Wind Zones II and III, the uplift is greater than the home's weight, and the resultant actually points up and to the side! Uplift is like a big balloon that tries to lift you off the ground. If it succeeds in lifting you off the ground, it doesn't matter how far apart your feet are -- you must hang onto something to avoid being blown away.

In the diagrams on the following pages, the home is assumed to be sitting on its chassis beams on a parking lot. The beams are not tied down, but there is a curb next to the beams preventing them from sliding (see discussion above about the need to control sliding). The home is unstable if the resultant force does not stay inside the chassis beams. Here are some factors that can change a stable home into an unstable one:

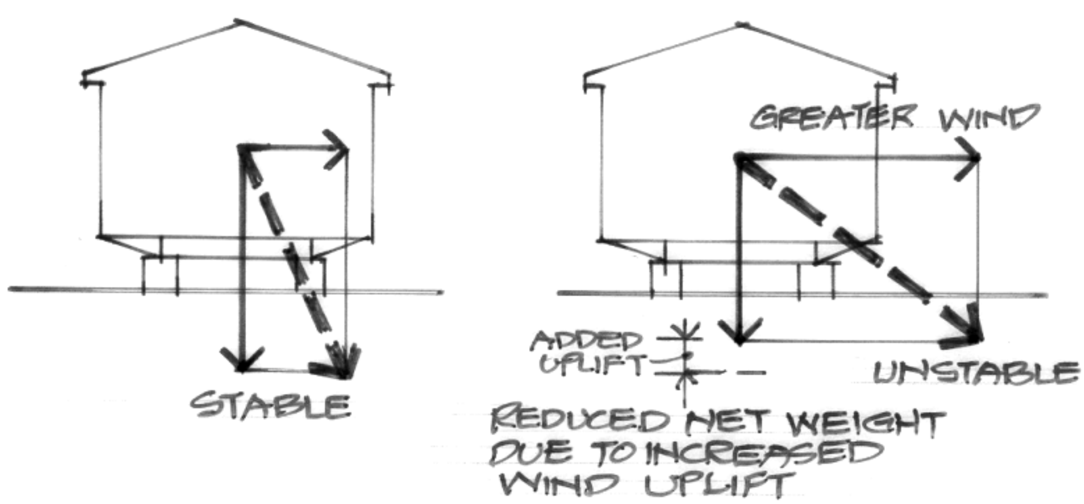


As the wind pushes on an object, such as the person pictured above, the force of the wind combined with the person's weight is transferred into the ground. Unless the person's base (his stance) is wide enough, or unless he hangs onto something, he will topple over. Applied to a home, its supports must be far enough apart to prevent toppling, or the home must be anchored to the ground.

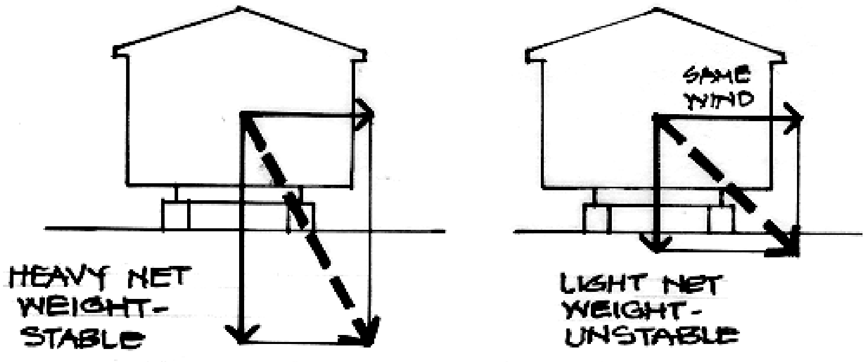
" The single-section home on the left has a narrow base, while the double-section home on the right has a wide base, and is almost twice as heavy. This makes the double-section home much more stable.



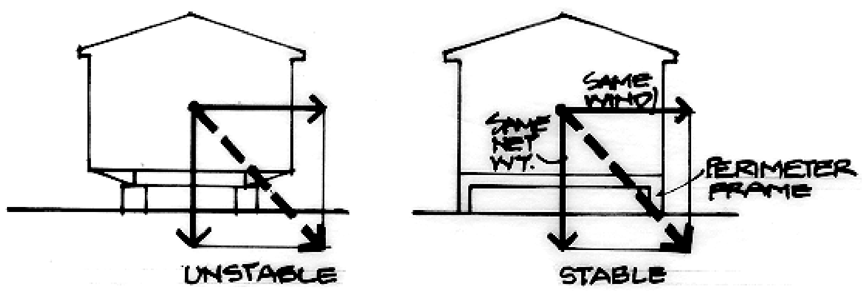
" As the wind grows stronger, the home sooner or later becomes unstable. Not only does the wind push harder from the side, but the net weight goes down as the uplift increases. In this situation, if the home is prevented from sliding, it will tip over before the wind is strong enough to lift it off the ground.



- A heavier home is more stable than a lighter one, because the weight (arrow down) is larger, making the resultant stay inside the beams.

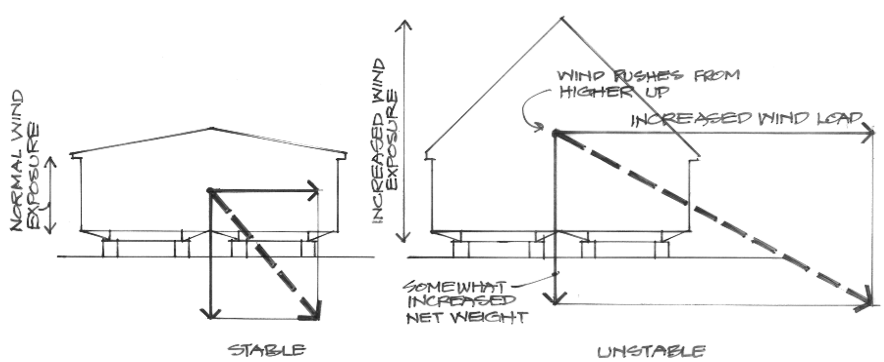


- A single-section home with a perimeter chassis is substantially more stable than one with the chassis beams in the usual position, because its base is wider.

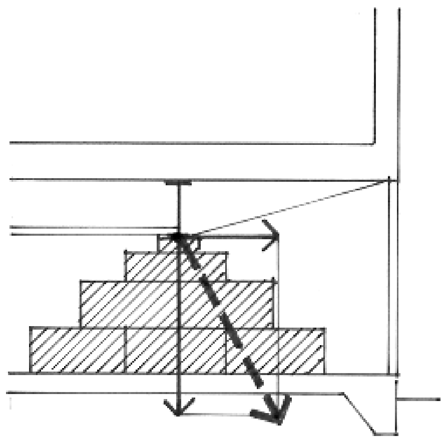


- A home that stays low to the ground is more stable than a home with a high side-wall, or one with a roof steeper than 20°, for two reasons:
  - There is more surface for the wind to push against
  - The wind is pushing higher up, which makes the resultant force worse

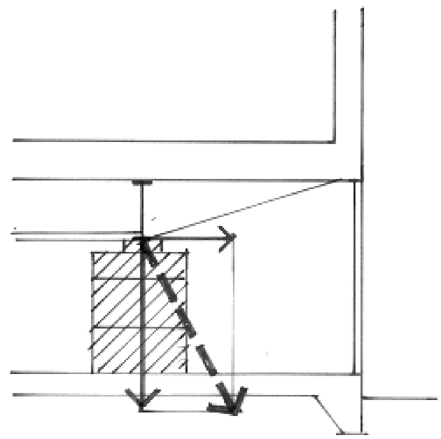
Naturally, a two-story home will be more unstable than a one-story home.



If the home is now set on top of piers, and prevented from sliding by some form of restraint at each layer of the pier, the pier itself must be stable, or it will topple over. Several factors that determine whether the pier is stable:



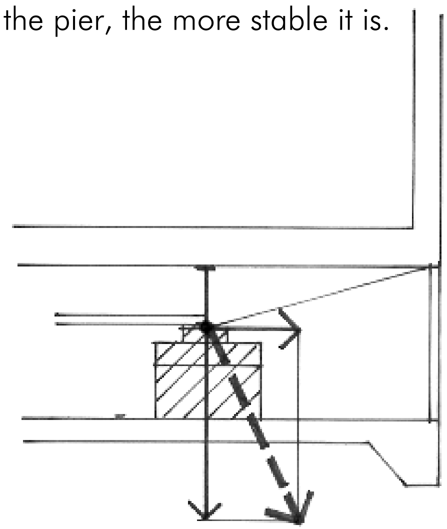
If sliding is prevented, a pier of this design will resist Zone I winds for many homes without tie-downs.



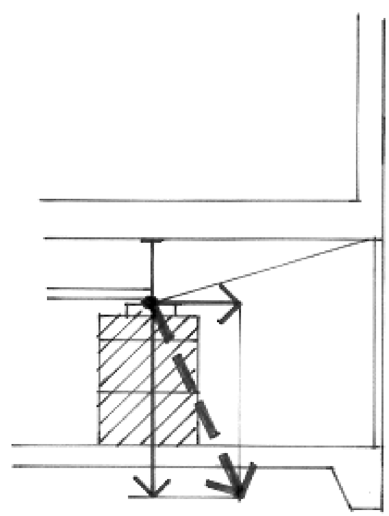
An ordinary pier will topple under most circumstances if not restrained.

" The wider the pier's base, the more stable it is.

" The shorter the pier, the more stable it is.

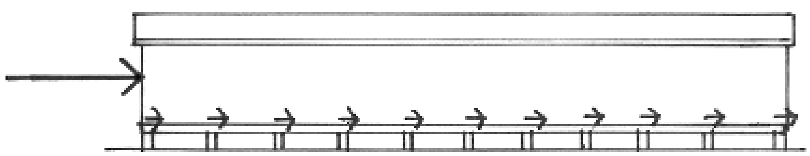


Under the same wind load, a one-block pier might work...

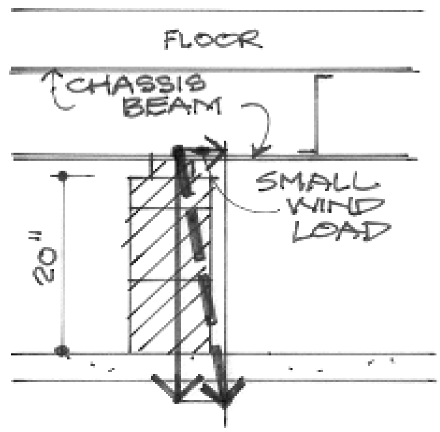


while a two-block pier topples

- Homes that are stable against winds from the side are often unstable against winds from the ends, because the piers are only 8" thick front-to-back.

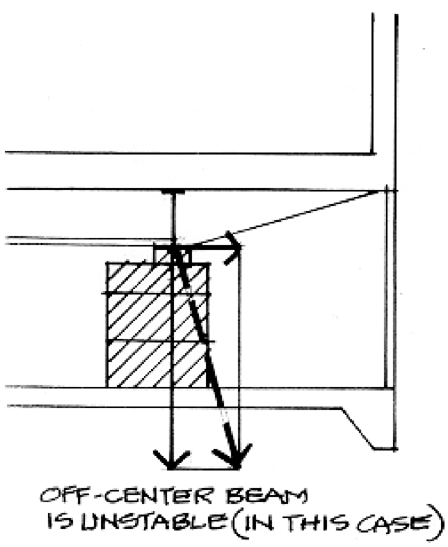


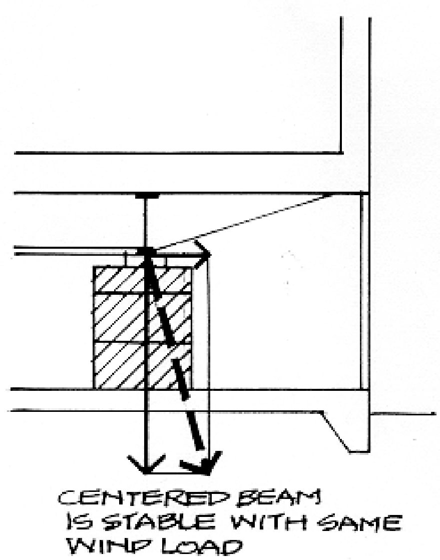
The longitudinal wind load on each pier is small, because many piers share the load.



Even so, ordinary 8" wide piers usually will topple without longitudinal tie-downs

- If the chassis beam is not centered on the pier, the pier can become unstable.





Homes in Wind Zones II and III

In addition to the strong sideward forces in these hurricane wind zones, the uplift on the home is greater than the home's weight. There are at least five ways to cope with these combined problems:

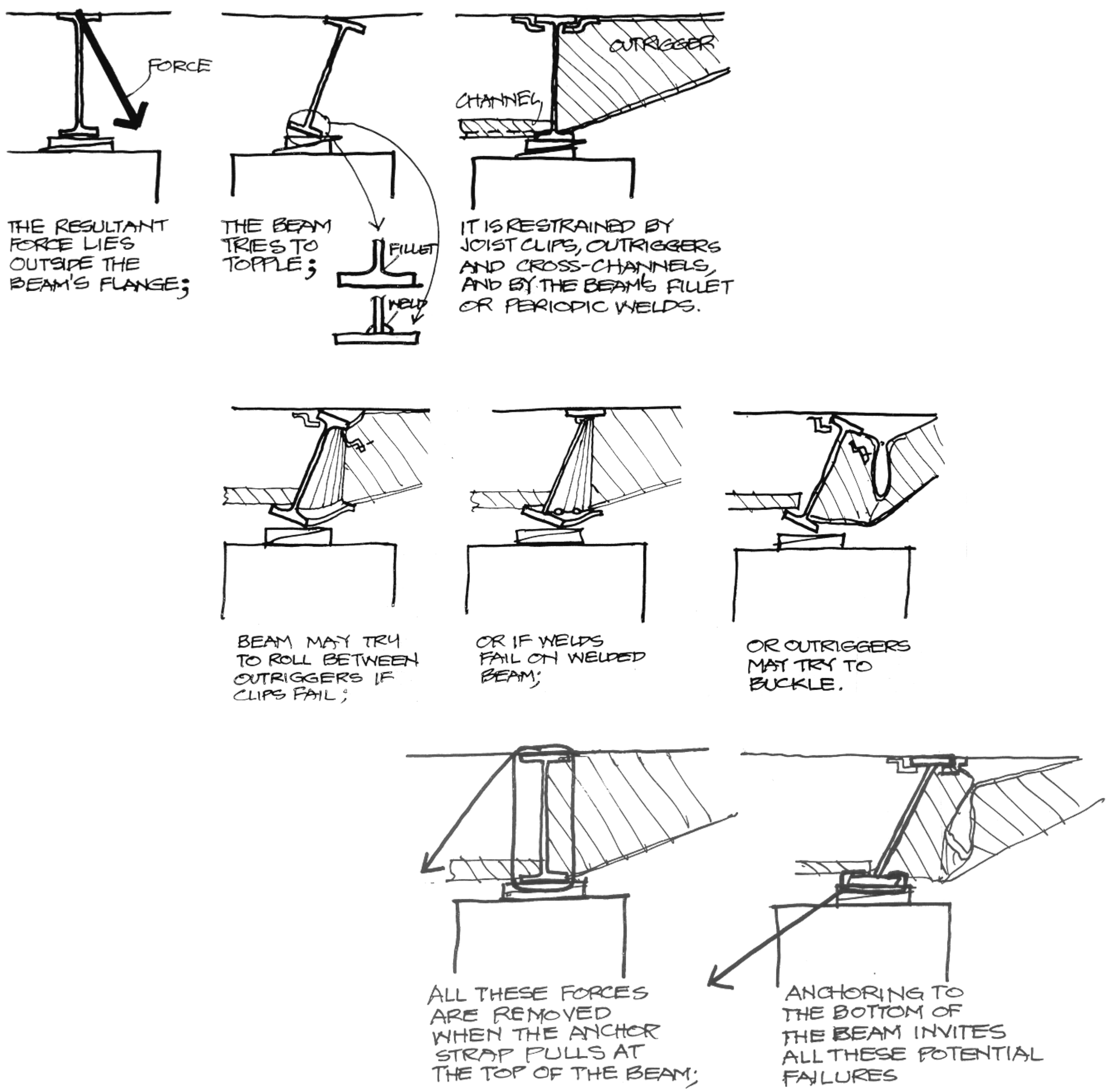
- Bury in the earth anchors that pull on enough earth to resist the combined uplift and lateral loads; then connect these anchors to the home with cables or straps. This is the usual method used in setting HUD-Code homes.
- Insert pilings into the ground and secure the home to the pilings. A piling resists uplift in three ways:
  - by friction between the surface of the piling and the earth around it, which causes the piling to work against the weight of a cone of earth around the piling
  - in pilings with flared bottoms, by the weight of the cone of earth pressing on the projecting part of the piling
  - by the weight of the piling itself (a substantial weight if the piling is concrete)

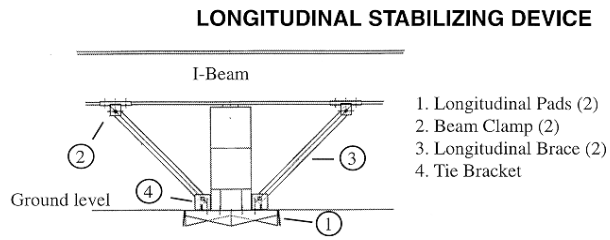
  A piling resists lateral movement by bending, as does a telephone or light pole. To prevent excessive sway, tall pilings are often cross-braced for added stiffness.
- Pour a full slab or strips of slab and attach the home securely to the slab(s). The weight of the slab(s) must be sufficient to resist uplift, with enough weight left over to create friction against the earth for resisting lateral movement.
- Build a permanent foundation that, through a combination of friction and dead weight, resists uplift and lateral wind load.
- Anchor the home to rock or other solid material.

Why Side Anchors Must Be Attached to the Top of Chassis Beam in Wind Zones II and III

The diagrams show why, in Wind Zones II and III, a side anchor attached only to the bottom of a chassis beam can cause the beam to tip or deform when the resultant force lies outside the beam flange (first diagram). The beam tries to tip over, but is restrained by a combination of the outriggers, the cross-channels between beams, the clips that hold the beam to the joists, and the beam's own cross-wise strength.

In the bottom diagrams on this page, if clips fail, and if the cross-channels and outriggers can't hold the beam in place, it may be able to roll over. Even if the clips hold, the beam may deform if it is welded out of plates or is a very light section.





Longitudinal anchors that resist wind blowing on the end of a home can be attached to the bottom of the beam, because they pull against the length of the beam, the direction in which it is very strong.

Observation of damage to homes after high winds has shown that a crucial factor in saving the lives of a home's occupants is to keep the home on its foundations. Trapped in a home during a hurricane or tornado, occupants can find some protection within an intact home, and can hang onto elements of the homes structure (such as doorframes) during the worst wind gusts. If the home leaves its foundations, however, its occupants are in much greater danger.

The wind force on a home is not simply proportional to the speed of the wind, but increases geometrically. To dramatically illustrate this, the chart below lists the wind force on the side of a 76' home with 8' sidewalls under various wind conditions (to the nearest 1,000 pounds):

- Zone I (65 mph) 9,000 pounds
- Zone II (100 mph) 24,000 pounds
- Zone III (110 mph) 29,000 pounds
- Hurricane Andrew sustained winds (140 mph) 47,000 pounds
- Hurricane Andrew worst gusts (200 mph) 95,000 pounds

<u>All HUD-Code Homes Require Some Form of Restraint</u>

The HUD Code, in Section 3802.306, states that all homes "when properly designed and installed, will resist overturning and lateral movement." All homes need either to be tied down to properly designed and installed ground anchors, or installed upon a foundation that is engineered to resist the loads specified in the HUD Code. *It is not possible to resist the wind load requirements for any Wind Zone by simply setting a home on a stack of concrete blocks.*

Background: Understanding Types of Loads

Loads are usually divided into three kinds:

Gravity loads are those caused directly by gravity and always press down. These in turn are divided into:

- *Dead load: The actual, permanent load caused by the weight of the building and its foundations.*
- *Design Snow load: The code-mandated temporary live load caused by the weight of snow and ice on the roof. These are considered separately from other live loads because wood trusses can hold more weight over a short time than they can over a long time. Snow loads are sometimes called "intermittent loads."*

People squeezed together for a family portrait can easily create a 40 psf live load.

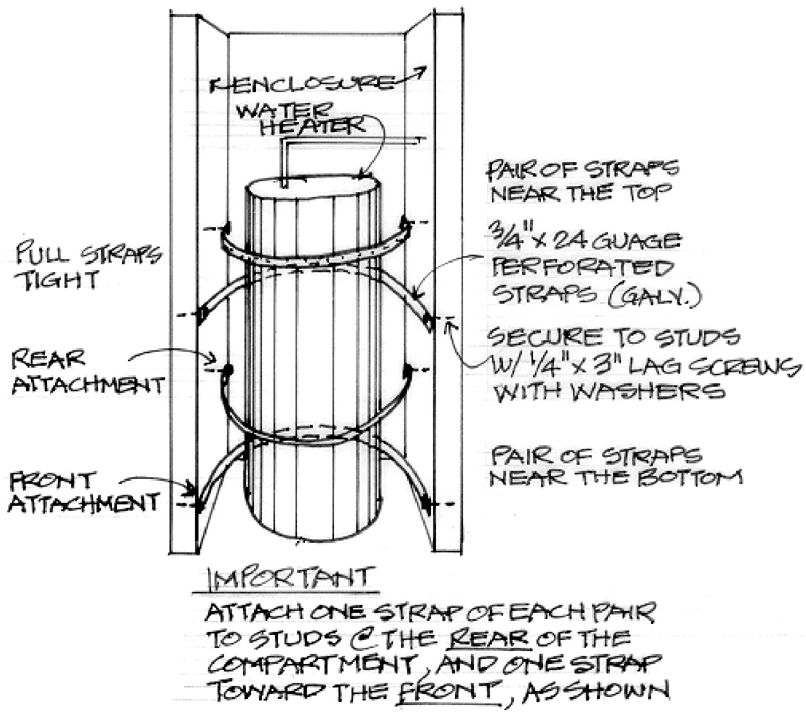
- *Design Floor Live load: The code-mandated temporary load caused by the occupants and their belongings. Floor live loads vary so much that all codes set a reasonable number that is about the weight of a group of people gathered together — 40 psf. Since people and furniture can be concentrated almost anywhere in a home, the HUD Code requires the floor to hold up 40 psf everywhere on the floor. This large load is not there when the home is installed, but it must be anticipated in sizing supports.*
- *Point loads: The live load caused by an especially heavy object. A 10" deep waterbed, for example, will not add more than 40 psf if you consider the empty area around it, but a 15" deep waterbed will. An upright piano, tall bookcase, or a tall stack of books in boxes, can all overload the floor. The installation manual often requires the installer to set an extra pier under any known point loads. The trick is finding out where they will be.*

Lateral loads are those that cause the unit to move sideways. These are divided into:

- *Design Wind Load: The code-mandated intermittent load caused by the wind in the area. These loads tend to increase near the corners of buildings, an issue addressed in Section 3280.306 of the HUD Code.*
- *Design Earthquake Load: The loads that must be resisted by the home and its foundations, caused by the vertical and horizontal motion of the home and its contents during an earthquake. Unlike wind loads, earthquake loads are complex to calculate. Earthquake loads seldom exceed wind loads in one-story HUD-Code homes on low foundations. The HUD Code does not require homes to be designed or installed to resist earthquakes, although some states have such requirements.*
- *Tie-downs cause the lateral loads to increase the vertical loads on the leeward piers. This increase is almost always less than the occupant live load, and is therefore ignored when designing the piers.*

Uplift loads are those caused by wind passing over the home and creating a suction upward, similar to the lift caused by air passing over the wing of a moving airplane. These loads vary, and can be much higher on overhangs and at roof edges. The HUD Code addresses these variations in Section 3280.306.

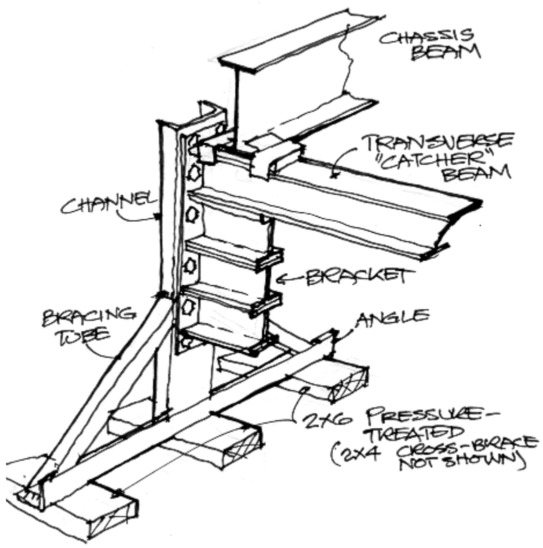
Transportation loads are those to which the unit is subjected during its movement to the site. These are very complex, involving impact (potholes, etc.), twisting, periodic vibration, wind pressure, suction, fatigue, etc. Calculations are impractical, so a home is typically road-tested to determine whether it can meet transportation load requirements.



How Earthquake Loads Differ from Wind Loads

While earthquakes cause some of the same effects as high winds, wind loads and earthquake loads are very different in nature. Earthquakes move the ground under the home suddenly back and forth, as well as up and down, in contrast to the more slowly changing sideward and upward pressure of the wind. Here are some of the practical consequences of these differences:

- In an earthquake the home is easily jolted off its supports.
- Tall and heavy items within the home, particularly the water heater and high bookcases, must be well-secured to the structure to prevent collapse during an earthquake.
- The resistance of a ground anchor to earthquake loads may be very different from its resistance to wind loads. For example, it may hold less well in sand and better in clay, and is likely to move several inches before taking up the load.
- For this reason, some earthquake resistant bracing systems (ERBS) do not rely entirely on restraints. They are required to catch the home's chassis, typically on cross-rails, before the home has dropped more than 2", should it fall off the supports. This will prevent the serious damage that occurs when the piers penetrate through the floor, and will help prevent broken gas service lines, which feed the fires that are a major cause of earthquake-related losses.
- Because the weight of the home is usually not evenly distributed over the supports, homes tend to rotate during earthquakes, putting severe loads on a few outlying piers.

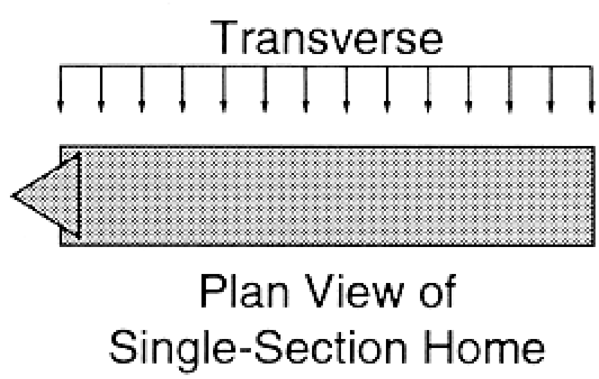


Sure-Safe Industries
"Seismic Isolator"™

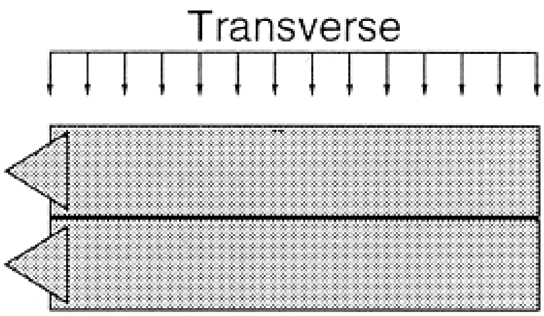
- An accessory structure or projecting wing is likely to shake and rotate at different rates from the house. See discussion below and in Chapter 15.
- The various sections of a multi-section home are likely to shake at different rates. They should be strongly connected together at marriage lines so they will shake as a unit.
- Homes on tall piers are at extreme risk in earthquakes. Procure a design from the manufacturer or a registered engineer for any home partially or entirely set on piers over 3' high in Earthquake Zones 3 or 4.
- Since the building's weight resists wind loads by pressing down on the foundations, wind damage is greatest to an empty building with no snow on the roof. Since the building's weight contributes to earthquake damage, earthquake damage is greatest to a heavily loaded building. However, since earthquakes can also bounce the home up and off its foundations, the weight of the home cannot be counted upon to resist lateral movement by friction.

<u>Which Loads are Greater, Earthquake or Wind?</u>

These results apply only to Wind Zone I. In those few cases where high winds coincide with severe earthquakes, special analysis is necessary to determine which load is greater.

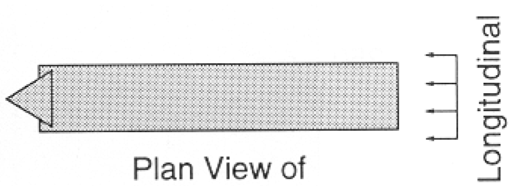


For a single-section home, the wind load from the side is greater than the earthquake load from the side in most cases, and the foundation can be designed for wind loads without considering earthquake loads. The only exception is a home in Earthquake Zone 4, where the snow load is 30 psf or greater. Then the earthquake load from the side exceeds the wind load, and the foundation must be designed for earthquake loads.

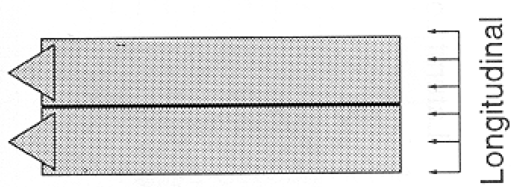


Plan View of
Double-Section Home

For a double-section home, the wind load from the side is also greater than the earthquake load from the side in most cases, and the foundation can be designed for wind loads without considering earthquake loads. The only exception is a home in Earthquake Zones 3 or 4, where the snow load is 20 psf or greater. In these cases, the earthquake load from the side exceeds the wind load, and the foundation must be designed for earthquake loads.



Plan View of
Single-Section Home



Plan View of
Double-Section Home

For any home in Wind Zone I, the earthquake load in Earthquake Zones 3 or 4 on the end of the home is always greater than the wind load, and the foundation system should be designed for earthquake loads. For other combinations of wind and earthquake severity, each case must be examined individually.

<u>Wind and Earthquake Loads on Accessory Structures</u>

Accessory structures (carports, garages, screened porches, sunrooms) can cause severe damage to the home in high winds and earthquakes. There are two strategies to prevent this damage:

- Support the accessory structure separately from the home and separate it from the home by several inches, with a weathertight joint covered by a material that can flex or bend.
- Attach the structure firmly to the home (whether or not the structure has its own supports). In this case, the attached accessory structure *changes the structure of the home*, requiring that the combination of accessory structure and home must be engineered to resist winds and earthquakes.

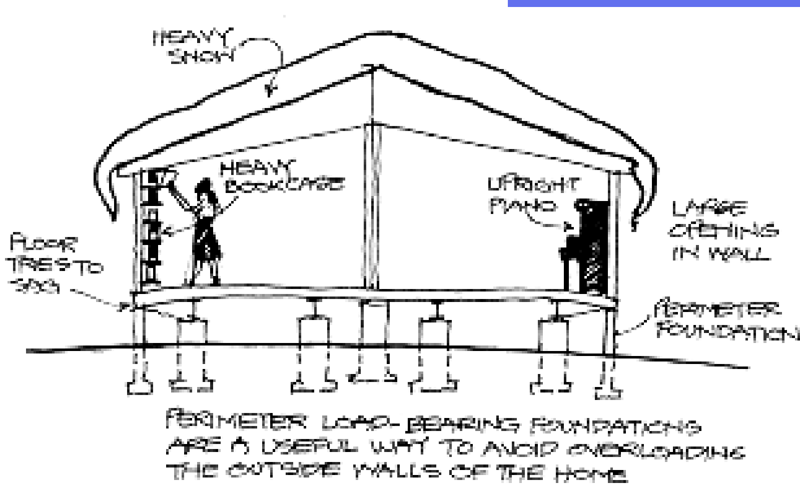
See a longer discussion on these issues in Chapter 15: Accessory Structures.

The Advantages of Load-Bearing Perimeter Foundations

A properly designed perimeter foundation is effective in many ways:

- It can help resist overturning and sliding, and if properly designed, can provide resistance to uplift
- It can support heavy snow loads from the roof
- It can support unexpected concentrated loads at the walls of a home, such as high bookcases added later by the homeowner
- It enclosed the crawlspace with a permanent and attractive foundation wall that resembles a site-built foundation

While ordinary light-weight skirting is much less expensive than a masonry or concrete perimeter foundation, some homeowners upgrade to masonry skirting, typically at a



cost of several thousand dollars. In these cases, it makes a great deal of sense to use this masonry to help support the home. Several issues need to be addressed:

- Be sure the outriggers are held back far enough to receive the perimeter foundation.
- Contact the manufacturer's engineering department for proper attachment between the home and the foundation, and for any other concerns.
- Like any foundation, a perimeter foundation must extend below the frost line.
- If the perimeter foundation is used to resist lateral loads, it must be properly engineered to do so, and possibly will need bracing walls or pilasters to do so.

CHAPTER 7: FOOTINGS AND PIERS

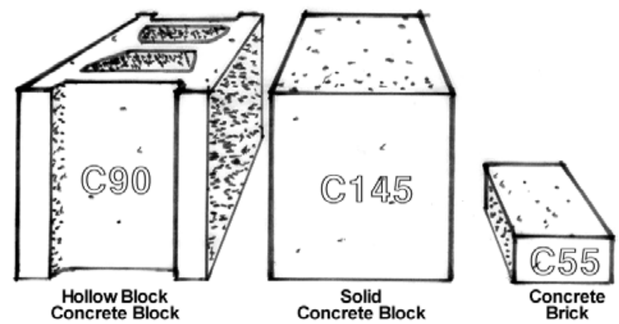
1. Steps Covered

- ☐ Selecting the correct type of concrete block
- ☐ Practical issues in selecting and spacing footings and piers
- ☐ Three approaches to sizing piers and footings
- ☐ Clearance under chassis beams
- ☐ Footings and the frost line
- ☐ Stacking layers of footings

2. Understanding the Issues

Selecting the Correct Type of Concrete Block

Manufacturers' instructions typically require that hollow structural concrete block meet standard number C-90, published by the American Society for Testing and Materials (ASTM). These structural blocks are much stronger than the blocks intended only for use in decorative garden walls. Many installers are tempted to use the cheaper decorative blocks, since they are lighter in weight, but their use violates the written instructions of the manufacturer. To avoid lugging around blocks weighing 40 pounds, light-weight structural blocks, with aggregate ranging from cinders to expanded slag, are available in weights down to 25 pounds per block. Remember ASTM C-90, the national standard for structural concrete block. If you are using solid concrete blocks, the comparable standard is C-145; and for concrete bricks, the standard is C-55.



Practical Issues in Selecting and Spacing Footings and Piers

In this chapter is a detailed discussion of three approaches to sizing and spacing footings and piers, taken from the installation instruction manuals of three different HUD-Code home manufacturers.

With the exception of manufacturer A, these manuals assume that every combination of soil type, footing, pier size and spacing is possible. In practice, this is seldom the case. A set-up contractor goes to the site with standard concrete blocks, footers of a certain size, or perhaps with an auger to drill a hole of a fixed size for a cylindrical footer. Many codes do not allow a home to be set on soils with a bearing capacity of less than 2,000 psf.

The set-up contractor starts with the soil bearing capacity and a given size of footing. On this soil, this size footing will carry up to a certain limit. The chart below shows a few typical examples:

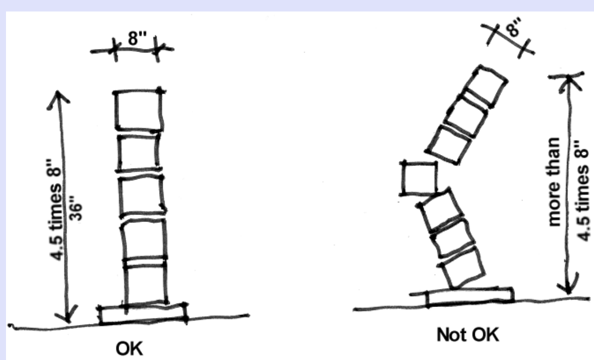
Soil bearing capacity (psf)	Size of footing	Maximum load the footing can carry
2,000	16" x 16"	3,600 pounds
2,000	24" x 24"	8,000 pounds
2,000	30" x 30"	12,500 pounds
2,000	12" diameter	1,600 pounds
2,000	16" diameter	2,800 pounds
2,000	24" diameter	6,300 pounds

- For 1,000 pound soil, use half the allowable load shown.
- For 3,000 pound soil, add half again to the amount of the load.
- For 4,000 pound soil, double the load.

Armed with these simple numbers, the problem is to decide how far apart the piers will be. By matching your footing size and soil capacity with those listed in the charts, you can find the spacing. Notice that manufacturer A has done all this work for you. All footings are 24" x 24"; all soil is 2,000 pounds. The only variable left is the spacing.

Background: How Slender Can a Pier Safely Be?

If a column is continuous, like a wood or steel pole, or like a stack of grouted and reinforced concrete blocks, it can be taller and more slender than one made of individual pieces stacked one on the other (calculating exactly how slender is complicated). An important rule of thumb: the height of an unreinforced and unbraced stack of blocks should always be less than 4-1/2 times its smallest thickness dimension. Given a nominal 8" by 16" block, the stack must not be more than 36" high (four 8"-high blocks plus a 4" cap). A 16" by 16" column made from cross-stacked pairs of blocks can be 80" high.



Three Approaches to Sizing Piers and Footings

Manufacturers in their installation instructions set a maximum safe load that can be carried by a dry (unmortared) single stack of 8" by 16" structural concrete block at between 7,500 and 10,000 pounds. As the stack gets higher, the pier becomes unstable in the short dimension. At a certain height (typically 36"), the instructions will require a 16" by 16" pier, and sometimes require that the pier be filled with concrete and reinforcing steel. Some manufacturers allow the double-stack pier to carry double the load of a single-stack pier,

Pier Sizing Criteria by Three Manufacturers			
	A	B	C
8x16 dry laid pier allow.load#/allow.height"	7,500/36	10,000/36	8,000/36
16x16 dry laid pier allow.load#/allow.height"	7,500/36	20,000/60	16,000/80
16x16 reinforced and grouted pier allow.load#/allow.height"	7,500/80	20,000/80	not required
footer size	24x24x6	16x16x4 thru 30x30x6	many charts for different footing types
soil capacity	2,000	1,000 - 3,000	1,000 - 4,000
maximum distance between piers carrying chassis beams	12'-6"	8'-0" without perimeter piers; 12'-0" with perimeter piers	8'-0" at 8" beams 10'-0" at 10" beams 12'-0" at 12" beams
	1 plan each showing spacing for 14', 16', 26', 28', 28' w/finished drywall, 32', 32' perimeter frame and triple wide	1 plan; tables of spacings of I-beam and perimeter piers based on frame type, snow load, soil capacity and unit width for 2 sizes of footings (separate table for footing sizes at marriage wall)	○ Chart pages of footing spacing for each width of home without perimeter piers; second set for same with perimeter piers ○ Each page has separate chart for each footing size, varied by soil capacity, snow load, main beam size, and number of pads in footing ○ Separate set of tables in different format for larger footings ○ Separate charts for ridge beam posts ○ Separate chart of footing capacity for selected footing sizes ○ Pier sizes based on footing capacity ○ Separate procedure for sizing porch footings

while others don't. Installation manuals differ from one another in many such details.

All three of the manufacturers discussed below are highly reputable, but one takes a more conservative approach than another on each issue. The more conservative the design, the more kinds of unexpected events the system will withstand. In foundation design, more is almost always safer and stronger — and almost always more expensive. The added expense of a conservative design is a low-cost form of insurance for the homeowner, and is likely to reduce call-backs.

Manufacturer A's Approach

Manufacturer A uses a very simple, conservative, and easily copied approach to foundation design. Every pier is designed to carry 7,500 pounds, no matter what size it is. A 16" by 16" pier reinforced with steel rods and filled with concrete can stand up to 80" high. A pier formed of a dry-laid stack of 8" by 16" blocks can stand up to 36" high. Manufacturer A does not discuss dry-laid 16" by 16" piers; if the pier is over 36" high, the instructions imply that it has to be reinforced. Add a few details about the cap, blocking and shims, and the reader knows how to build piers for any occasion.

Manufacturer A makes another helpful simplification: the soil shall support 2,000 psf. If the actual soil doesn't meet this standard, the installer is required to fix it until it does, and is told how to do this. Manufacturer A does not care if the soil is stronger than 2,000 psf in sizing footings. This is how most site-built house foundations are sized, except that careful structural engineers size them for the actual soil bearing capacity, although codes rarely allow for capacities below 2,000 psf.

Putting these together, it is easy to see that the load from a pier can be carried by a 24" by 24" footing; so all footings are that size, period. Manufacturer A requires all footings to be 6" thick, instead of the 4" allowed by other builders (See Background: Stacking Layers of Footings). Now all that is left to decide is how far apart to place the piers.

With a light roof load and a narrow floor, the calculations might call for piers under the chassis beams at, for instance, a 14' spacing. This won't work, because the chassis beams will sag between the supports. So a maximum spacing is set that the chassis beams can handle. Manufacturer A limits this to 12'-6". The diagrams that show the required maximum spacing choose the smaller of these two dimensions, one limited by the load, the other by the structure.

Manufacturer B's Approach

Manufacturer B shows the same pier types as Manufacturer A, but assigns them more carrying capacity. An 8" by 16" pier up to 36" high is allowed to carry up to 10,000 pounds, compared with Manufacturer A's 7,500 pounds; and a reinforced 16" by 16" pier up to 80" high is allowed to carry 20,000 pounds, compared with Manufacturer A's 7,500 pounds. In addition, Manufacturer B allows the use of a dry-laid 16" by 16" pier, with the blocks criss-crossed by layer, up to 60" high, also rated at 20,000 pounds capacity.

With all this extra weight allowed on the pier, the footings become an issue: a simple 24" by 24" footing won't carry the pier's rated load in most soils. So the Manufacturer B installation manual contains charts showing either the spacing of the piers, or the load that can be carried, for various combinations of soil strength and footing sizes. The two charts really show the same information, except that the pier-spacing charts convert the load-carrying-capacity into pier spacing for various widths of floors, and for various snow loads on the roof. This means the installer doesn't have to make these calculations.

Manufacturer B adds another complication: if there are piers under the perimeter to pick up the roof load, then the piers under the chassis beams can be farther apart. Without perimeter piers, the spacing under the chassis beams is limited to 8'; with piers, the spacing can go up to 12'. This compares with 12'-6" for Manufacturer A homes without perimeter piers. In this case, Manufacturer B is more conservative than Manufacturer A.

Manufacturer C's Approach

Manufacturer C shows only two pier configurations, both dry-laid: single and double. Unlike Manufacturer B and Manufacturer A, Manufacturer C allows the installer to build a dry-laid pier without concrete fill or reinforcing steel up to 80" high. Manufacturer C uses yet another set of allowable loads: 8,000 pounds for a single-block stack, 16,000 pounds for a double-block stack.

Manufacturer C greatly expands the number of charts, which show footing spacing instead of pier spacing, for various footing sizes, floor widths, soil strengths, snow loads, all in two versions (with or without perimeter supports). Once the footing size and spacing are set, another chart indicates the load each size of footing can carry, which in turn determines the pier size. Manufacturer C expands the number of charts to cover more combinations, but its charts contain essentially the same information as Manufacturer B's. They show the required spacing for various footing sizes, floor widths, soil strengths, and snow loads. Manufacturer C's limits on the maximum distance between piers varies depending on the depth of the chassis beam — one foot of spacing per inch of beam depth.

Clearance Under Chassis Beams

Typically, installation manuals require that there be a minimum of 12" under chassis beams, and that the average be 18". The height is a tradeoff among three concerns:

- The home should be far enough from the ground to allow easy inspection and maintenance under the home
- The home should be close enough to the ground to minimize steps up and improve its appearance
- The home should be close to the ground to minimize wind loads

Building up the ground around the home is one way to maintain clearance under the beams while keeping the home closer to the ground. This is discussed fully in Chapter 5: Drainage. Also, perimeter foundations help solve this problem. These are discussed in Chapter 12: Closing In The Home and in Chapter 9: Alternative Foundation Systems.

Footings and the Frost Line

Many manufacturers require that all footings rest on ground that is below the "frost line." This conforms with the model codes governing site-built and modular foundations. Unless permanent foundations incorporate the recently approved "Shallow Frost-Protected Foundation" (SFPF) system, or unless the foundation rests on solid rock, this rule is sacred throughout the home-building industry. The frost line depth is found in the local building code.

There are two types of frost heaving. In the more mild form, the entire ground rises slightly as the water trapped in the soil freezes and expands. The heaving is limited in scope, and occurs over an entire section of ground, so that the home will rise and fall as a unit.

The rule requiring footings to extend below the frost line addresses the more serious form of frost heaving, that which causes “ice lenses.” These form when a continuous supply of water flows into freezing soil and builds up a thick lense of ice. Those who have driven on mountain roads in the winter are familiar with the irritating “speed bumps” that form across the road. These are caused by ice lenses that push up on the pavement as they grow thicker.

If a footing stands above the frost line, and an ice lense forms under it, the ice can lift the footing by 4" or more relative to the other footings. Needless to say, a 4" rise in an isolated spot can create serious damage to the home. Extending a footing below the local frost line will prevent ice lenses from forming under the footing. An ice lense can adhere to the surface of a foundation wall and heave it up, regardless of how deep it is, but this is a rare occurrence. In general, the bottom of all footings should extend below the local frost line.

Many installation instructions and state regulations allow the “footing” to be made of gravel instead of concrete. A hole is dug down to the frost line and filled with gravel or crushed stone. You can place an ordinary footing on the surface of the gravel. This design works in the short run, but is not recommended as a long-term solution. Over the years, fine material may filter into the gravel, filling up the voids that allow the gravel to drain. This material may become saturated and may freeze, causing the footing to heave. Even if filter fabric is placed around the gravel, the pier may sooner or later fill up with fines. A gravel pier encased in filter fabric will probably work well for 5 to 10 years, or even longer if very little water flows into the gravel.

Background: Surface Footings in Freezing Climates

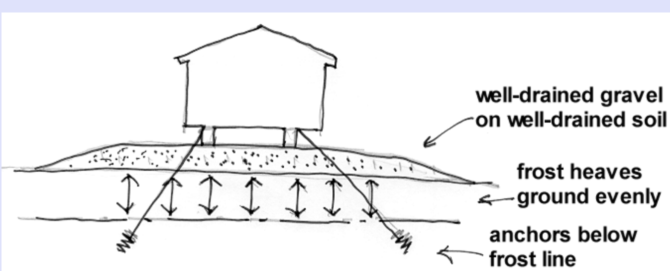
In Canada, where the frost line can be 6' or more below grade, single-story homes, both manufactured and site-built, are allowed to use an alternative system. All organic material is removed, and at least 18" of properly sized gravel is brought in and carefully compacted with machinery, in 6" layers. Both the underlying soil and the top of the gravel are pitched a minimum of 1 foot in 50' (2%), draining to a lower point. Footings can then be placed directly on the top of the gravel bed. If proper drainage isn't possible on the site, you can't use the system and have to dig down below the frost line. Maine, at the same latitude as southern Canada, permits similar systems for manufactured home installations.

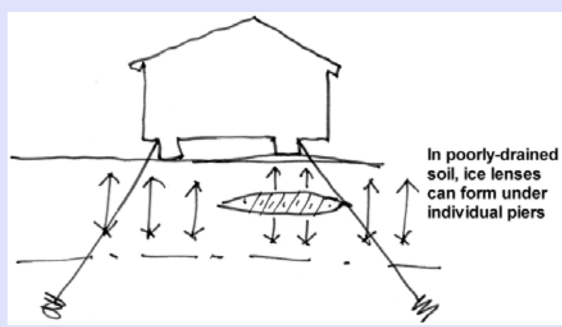
This system works by eliminating heaving caused by ice lenses, but does not eliminate the milder type of heaving caused by the expansion of water trapped in the soil as it freezes. Because of this mild form of heaving, tie-downs in this kind of installation must be left slightly loose. The ground anchor is secured below the frost line, the home rests on the surface, and in between, the ground expands slightly. If the tie-down were taut, it would either break or pull the anchor out, since the pressure of expanding water is not to be resisted.

Installers in Maine and Canada, and the installer of any home that has to be placed on the surface of a pad in a land-lease community where freezing weather is common, will run into the need to leave the tie-downs loose to allow the home to move up and down. Yet a consensus is growing within the industry not only that tie-downs be taut, but that the anchors be pre-tensioned, to properly resist high winds. More important, most manufacturers' installation instruction manuals void the warranty if the straps are not tightened. Obviously, these requirements are in direct conflict.

Luckily, locations where frost-heaving occurs in conjunction with winds over 65 mph (the limit in HUD Wind Zone I) are rare. The coast of Maine is one such location, where "winter hurricanes" or "nor-easters" can occur during very cold weather. In these locations, footings must rest below the frost-line or on solid rock, with no exceptions.

There is a good solution that avoids the conflict between the need to keep the tie-down straps loose, and the need to keep the home from moving during a windstorm. Grade the site as noted above, then pour a reinforced concrete slab on the gravel, with a thickened edge in which are embedded slab anchors. Secure the home to the slab anchors with pre-tensioned anchor straps. The slab will float up and down as the ground heaves evenly, but the home will remain securely tied to the slab through tense anchor straps.

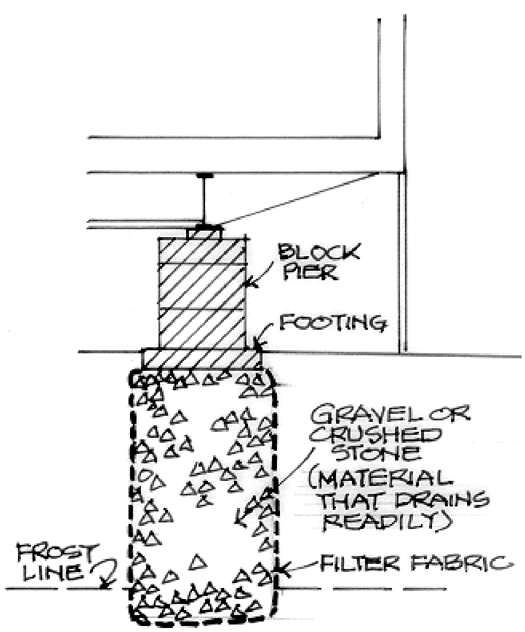




Background: Surface Footings in Freezing Climates, Continued

If permission from the manufacturer can be secured to allow installation of the home on the surface in freezing climates, take these precautions:

- *Loosen the tie-downs only just enough to account for frost heaving.*
- *Be sure the anchor can resist its required load of 3,150 pounds without moving more than 3" horizontally or 2" vertically. Pretension the anchor before releasing the tension (see* ***Background: Pretensioning Anchors****). Otherwise, the combination of anchor movement plus tie-down extension may cause the home to slide off its piers.*
- *The pier design and utility hookups should take account of the extra distance the home will have to slide before the anchor tie-downs can resist a high wind load.*
- *Check all these homes after major windstorms, and reset them if necessary. This maintenance cost should be borne by the owner, who benefits from the less expensive set-up.*



In time, a gravel pier may fill up with silt and become subject to frost heaving. To prolong its life, line the hole with fiberglass "filter fabric."

There is a myth that gravel can "compress" and take up frost pressures. If gravel or stone is properly compacted, it acts like any solid material: push on it from below and it will push on whatever is above it by the same amount. Uncompacted gravel may indeed shift or settle; that is why it must be compacted before a home is placed on it. It is the water in the soil that freezes and not the soil itself. In locations with extremely well-drained gravel soil, no pier needs to be founded below the frost line, despite the cold weather. This example shows that whenever you can be sure that no water will ever occur in the first 5' or 6' under the home, a surface set with tight anchor tie-downs will work fine.

Note that if you have to dig deep footings filled with concrete, you might want to consider building a conventional foundation.

Stacking Layers of Footings

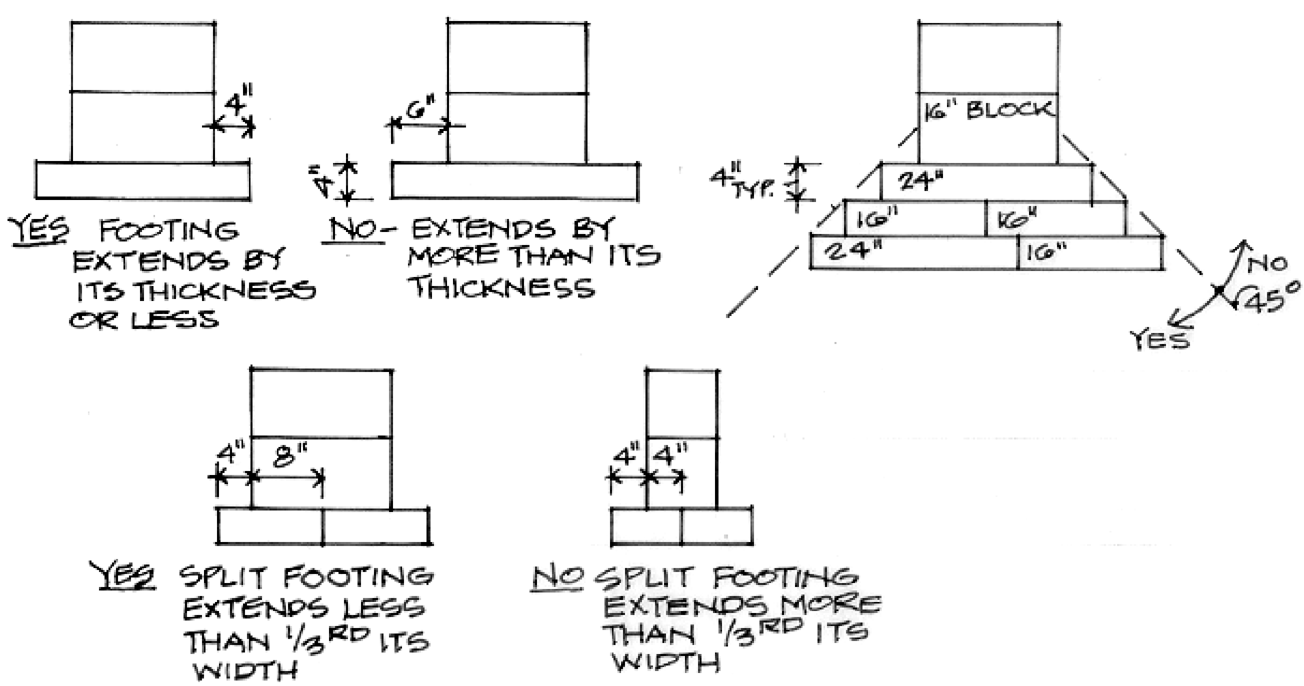
There is a simple lesson to be learned from long experience in site-building homes, and it should be applied to every installation of wood or unreinforced concrete footings:

The layer below should never extend beyond the layer above by more than its thickness.

As shown in the diagram, a simple way to remember this rule is that footings need to spread out in a pyramid with 45° angle (or steeper) sides.

The reasoning behind this rule is very simple. You need the whole bottom layer to spread the imposed loads. If one side sticks out too far from the layer above, it is liable to break (shear) off. Also, if a layer is made of two or three pieces, at least 2/3rds of each piece needs to be under an upper layer: otherwise, it will tilt. Although reinforcing a thin footing slightly increases the distance it can extend beyond the pier, for practical purposes this can be ignored.

These considerations do not apply to ABS plastic pads (see Part Four: Resources) that have been engineered, tested, and rated for strength and deflection. These durable and light-weight products are effective in many applications.



CHAPTER 8: ANCHORING THE HOME

1. Steps Covered

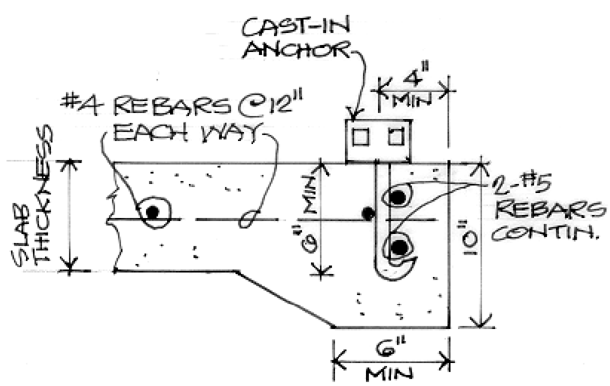
- ☐ Seeking engineering advice on tie-downs
- ☐ Ground anchor straps
- ☐ Using helical ground anchors
- ☐ Pre-tensioning helical ground anchors
- ☐ When to set anchors
- ☐ Supplemental tie-downs

2. Understanding the Issues

The details of how winds and earthquakes can damage a home or move it off its foundation are found in Chapter 6: Resisting Winds and Earthquakes. In severe earthquake zones and in Wind Zones II and III, careful engineering is called for. Embedding an anchor in a concrete strip footing or slab is the best way to be sure it won't pull out.

Securing Engineering Advice on Tie-Downs

If the required information for properly tying down a home is not available from the manufacturer or from a state regulating body, the installer must seek it from a registered design professional. Rather than get advice for each installation, which may well not be feasible, the installer might choose to have a few standard set-ups pre-engineered, covering unusual installations that occur repeatedly in the installer's territory. For example, if many homes are set on hillsides, the installer might work out a set of standard bracing details that will cover such



Area of slab needed to resist pull from each anchor:

4" slab - 95 sf
6" slab - 65 sf
8" slab - 48 sf

Reminder: All HUD-Code homes require some form of restraint

The HUD Code, in Section 3802.306, states that all homes "when properly designed and installed, will resist overturning and lateral movement." All homes need either to be tied down to properly designed and installed ground anchors, or installed upon a foundation that is engineered to resist the loads specified in the HUD Code. ***It is not possible to resist the wind load requirements for any Wind Zone by simply setting a home on a stack of concrete blocks.***

installations. Another approach is to insist that engineered permanent foundations be used for installations not covered by standard pre-engineered set-up details. What should never be done is to use practices intended for routine set-ups in unusual situations.

> ***Background: How Much Force Can an Anchor be Counted on to Resist?***
> *The HUD Code requires that each element of a tie-down system be able to resist a 3,150-pound working load from any angle, with a 50% safety factor (the safety factor makes it possible to test each component to its required working load without breaking it). If there are two tie-downs connected to one anchor, the anchor need only resist the worst-case combined (or "resultant") load of 3,150 pounds, not a load of 3,150 pounds on each tie-down.*

<u>Ground Anchor Straps</u>

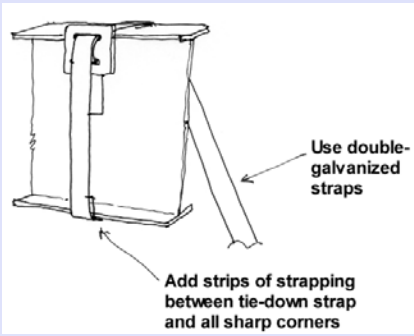
The straps typically used with helical ground anchors can fail before reaching their full design load of 3,150 pounds ("early failure") in a number of ways:

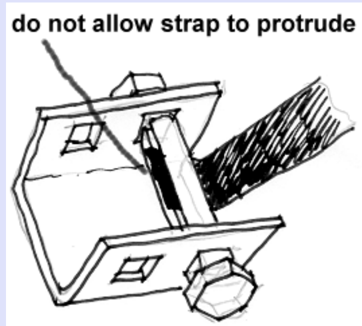
- If bent over a sharp corner, the strap is likely to fail early at the bend.
- If, when inserted into the split bolt on the anchor head, the end of the strap projects outside the bolt, it will crease the strapping wrapped around the bolt, causing early failure.
- If the strap corrodes or rusts, it will fail early. For this reason, all strapping used in seaside locations should be galvanized with a zinc coating of 0.60 ounces per sf on <u>each</u> side, for a total of 1.20 ounces per sf. As this adds little cost, it is prudent to use straps galvanized to these standards on every project.
- If the strap is made of ordinary steel, it will fail at about a third of the required design load, or about 1,000 pounds. Never use any strap that does not have the identification of the ASTM D3953 standard stamped on the strap.

<u>Using Helical Ground Anchors</u>

Tests performed to date by testing laboratories (see Part Four: Resources) indicate that ground anchors often fail to resist their design loads. The HUD-Code industry is performing more extensive tests to determine the performance of ground anchors in various actual conditions. While this testing is likely to continue for some time, preliminary data, combined with ordinary engineering practice and common sense, indicate the following:

Recommended Practice: Choosing and Using Anchor Straps





To avoid trouble with anchor straps, follow these recommendations:

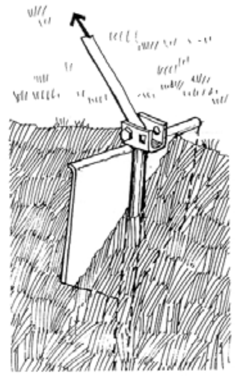
- *Protect the strap with pads made of short strips of metal at all sharp corners.*
- *Do not let the end of the strap extend out of the split in the anchor-head bolt.*
- *Use only straps galvanized with 1.2 ounces of zinc per sf.*
- *Use only straps that are stamped as meeting the ASTM D3953 standard.*
- *Attach the strap only to the top of the chassis beam, not to clips at the bottom.*
- *The first strap must be within 2' of the end of the section, per HUD Code.*
- *Space the straps evenly along the length of the home.*
- *If in doubt, install the straps at close to a 45° angle with the ground.*
- *The HUD Code requires a vertical tie at each angled tie, in Wind Zones II and III.*

- No tests have been performed showing that ground anchors will resist their design load in fully saturated soil, and much anecdotal data suggest that they do NOT work in saturated soil. For this reason, ground anchors should not be relied upon to tie down the home if the anchor will ever be in saturated soil, since it is not unusual for major windstorms to occur after saturating rains. Note that the HUD Code anticipates this problem by requiring the anchor to be at least 12" above the water table.
- Helical ground anchors do not perform as well in wet (but not saturated) soils as they do in dry soils. Do not rely on test data unless the tests are performed in wet soil.
- Section 306(b)(2) of the HUD Code requires manufacturers' installation instructions to indicate that anchors be buried below the frost line and 12" above the water table, and that stabilizer plates should be used.
- Anchors embedded diagonally must be longer than those embedded vertically, to pull on the same volume of earth.

" When pulled from the side, helical ground anchors without stabilizers mounted near vertical cannot resist more than a few hundred pounds of force. Whenever an anchor is pulled from the side, it must be equipped either with a properly engineered concrete or masonry collar, or a large (minimum 15", and preferably 18", wide), heavy-gauge stabilizer plate.

" Longer is stronger, providing the anchor's components are sized to carry the increased load. However, longer anchors pulled from the side require wider stabilizer plates to make up for the added flexibility of the anchor shaft.

" Double-auger helical anchors are slightly better than single-auger anchors, because the two augers are pulling on the same soil. You can't replace two single-auger anchors with a double-auger anchor of the same length.



If anchor is pulled to the side, use large (15" to 18") stabilizer plate (ground shown cut-away)

" A helical ground anchor pulled sideways with its head sticking out of the ground more than 1" or so will not resist its design load. The further out the head projects, the less the anchor will resist.

" The part of a ground anchor shaft at ground level is likely to rust, and the entire portion above the ground is subject to rusting. Hot-dipped galvanized ground anchors are highly recommended. Existing non-galvanized anchors must be inspected and refinished regularly, including those portions just below grade.

Recommended Practice: Helical Ground Anchors

- *Do not use in soil that can become saturated.*
- *Make sure test data was performed in wet soil.*
- *When side-loading, use a large stabilizer plate or a properly engineered masonry or concrete collar.*
- *When in doubt, use a longer anchor.*
- *Do not substitute a short double-helix anchor for a long single-helix anchor.*
- *Make sure the anchor head is flush with the ground.*
- *Whenever possible, load the anchor directly in line with its shaft.*
- *Periodically inspect the portion of the anchor at ground level, and repaint when appropriate.*

Pretensioning Helical Ground Anchors

An anchoring system should take up its load without allowing the home to move more than 2" vertically and 3" horizontally. Pre-tensioning causes the anchor to compress the soil, move, and take up its required load BEFORE the wind tries to move the home sideways. Although there are still questions to be resolved concerning how long pretensioning maintains its effect, it is definitely better to pretension. Pretensioning an anchor cannot place any stresses on the home that would not occur when the anchor is resisting a wind load.

Pretensioning up to about 1,000 pounds can be accomplished by torqueing up the anchor head bolt with long-handled wrenches. If the anchor is being pulled in line with the shaft (recommended), simply torque up the bolts. If the anchor is being pulled to the side, drive the stabilizer plate into the ground about 2" away from the anchor shaft, on the loaded side. Then pretension the strap. This will draw the anchor head tightly against the stabilizer plate. Be sure to pretension evenly on opposite sides of the home, to avoid pulling the home off its piers.

Assume that every major windstorm will pull the anchor out a little farther. After every major windstorm, inspect the home, adjust the tie-downs, and if necessary, slide the home back over the center of its piers. Even in the absence of major winds, the straps will probably lose their tension over time, and should be periodically checked, and retensioned if necessary.

For cases where the home is expected to rise and fall, and the anchors cannot be kept in a tense position, pretension as above, then back off the bolt to provide the minimum necessary slack in the straps. This should NOT be done outside of Wind Zone I. (See further discussion in **Background: Surface Footings in Freezing Climates,** Chapter 7).

It is not desirable to pretension a vertical supplemental strap more than a few hundred pounds, since this will draw down the outside wall of the home. If vertical pretensioning is desired, insert a post at the anchor to keep the floor level.

> ***Safety Alert***
> *Whenever you drill holes in the ground for footings, or screw ground augers into the ground, WEAR ELECTRICIAN'S INSULATING GLOVES. More than one installer has been hurt by drilling into a high voltage line. You should also CALL THE LOCAL DIGGERS HOTLINE. Even then, you should use the gloves, because:*
> - *The hotline people can only spot the line within a couple of feet.*
> - *Someone might cover up the marks or flags.*
> - *In a park set, there might be abandoned lines under the home site that are still connected to the service entry.*

When to Set Anchors

A properly set anchor should be pulled within a few degrees of straight out. This means the anchors must be set before the floor is rolled into place. The alternative is to install them afterward, but this means that they cannot be tilted in toward the chassis beam, and will be pulled from the side. If the anchor must be installed afterward (for example, to secure an existing home), it is essential to use a large stabilizer plate or properly engineered concrete or masonry collar, and to pre-tension the anchor about 500 pounds against the stabilizer plate or collar. Alternative systems, such as the Vector Dynamics System described in the next chapter, can also be used in retrofit situations. Another highly recommended strategy for retrofit is to pour strip foundations across the unit, and embed the anchors in the strip slabs. This system is also described in the next chapter.

Supplemental Tie-downs

Where required by the manufacturer or by state wind-protection regulations, the installer is required to tie down the outside wall with vertical, "supplemental" tie-downs. These are typically attached to a second bolt on the anchor head, and the angle of the anchor adjusted so that the resultant combined pull by the two straps is approximately in line with the anchor shaft. As noted above, do not strongly pretension the supplemental strap without inserting a support pier.

CHAPTER 9: ALTERNATIVE FOUNDATION SYSTEMS

1. Steps Covered

Designing, evaluating, and Installing:

- ☐ Alternative anchors and tie-downs
- ☐ Strip footings and slabs
- ☐ Braced systems
- ☐ Embedded pier systems
- ☐ Perimeter foundations

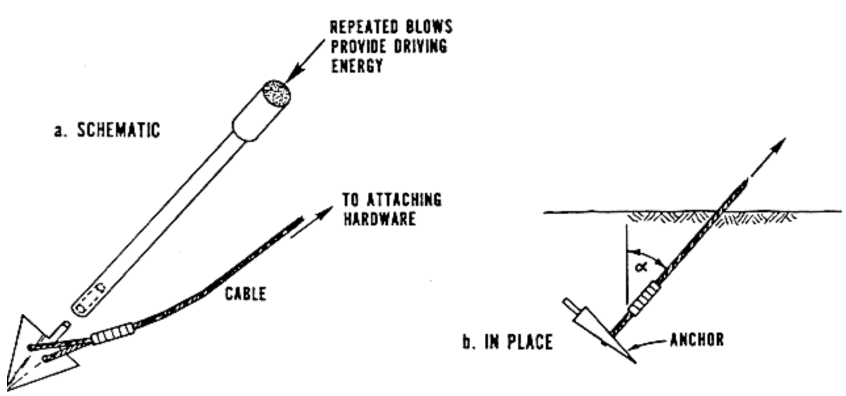
2. Understanding the Issues

Alternative Anchors and Tie-Downs

For several years there have been available highly effective ground anchors with cable tie-downs that easily meet or exceed the HUD-Code standard for pull-out resistance. In these designs, an arrowhead-shaped or "duck-bill-shaped" anchor is driven into the ground with a detachable steel rod. A cable attached off-center on the anchor is withdrawn, causing the anchor to rotate and embed, like a boat anchor. Setting the anchor requires that it be pretensioned, thus proving its capacity. Unlike steel straps, the cable can be sized to provide protection against future corrosion. An alternative design with a fixed steel rod instead of a cable is available.

The great advantage of this design is that the anchor can be driven to a greater depth than a helical anchor, allowing it to pull up on a much larger cone of earth. Another advantage is that the anchor cannot be pulled on except in line with the tie-down, so that the whole assembly is working in direct tension. This alignment requirement means that the anchors cannot be used in retrofit applications, unless the ties are connected at ground level by a compression strut.

These anchors are in regular use in Canada, but are not widely used in the U.S., possibly because the hard caliche and coral soils in the Sunbelt, where many HUD-Code homes are located, make it difficult to drive the anchor deep enough. However, the same problem occurs (but to a lesser extent) with helical anchors in hard soils. The



Typical arrowhead anchor

superior performance of arrowhead and duck-bill anchors indicates that they should be re-evaluated as tie-downs for HUD-Code homes where soils permit.

Strip Footings and Slabs

A full concrete slab is an ideal base for a HUD-Code home. Even in freezing climates, a properly designed and reinforced slab laid on 18" of well-drained gravel or stone will stay level, although it may rise and fall as the moisture in the soil freezes and thaws. The weight of the slab provides excellent resistance from uplift and from sliding, provides a level footing for the piers, and most important, provides a solid anchorage for slab-embedded ground anchors, which can then be kept properly tensioned. Working under the home is made easy, encouraging the frequent inspections that are necessary to maintain a home properly. Placing a vapor barrier under the slab guarantees that no ground moisture will rise up under the home. Slightly pitching or arching the slab will direct surface water out and away from the home.

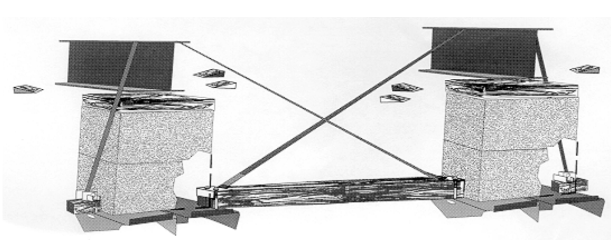
If the edges of the slab are thickened to form a footing (see illustration in Chapter 8: Anchoring the Home), and a supporting masonry or wood wall is built under the sidewall of the home, a fully enclosed crawl-space is created, which if insulated can improve comfort conditions in the home by keeping the floor warmer in the winter and cooler in the summer. A foundation of this design may qualify as a permanent foundation.

A less expensive but effective alternative is to build only a partial slab, in strips running either long-wise under the chassis beams, or cross-wise. These strip slabs are sometimes called “footings.” Many of the advantages of a full slab are preserved, but the integrated action of a full slab is not: each strip can rise and fall on its own. The strips must be sized to provide the required tie-down resistance.

If a full slab is engineered to “float” on the ground, it can provide a stable base for a home set on expansive clay soils, and in many other locations. The foundation acts like a shallow boat, and eliminates the constant need to re-level the home as the ground becomes alternatively wet and dry, swelling and shrinking during each cycle. A floating foundation may cost several thousand dollars, as it may have to be pre-stressed (post-tensioned); but it also may be the only way to maintain a level home on expansive clay soil. Civil engineers in areas with expansive clay soils are familiar with cost-effective ways to build floating pre-stressed slabs.

Braced Systems

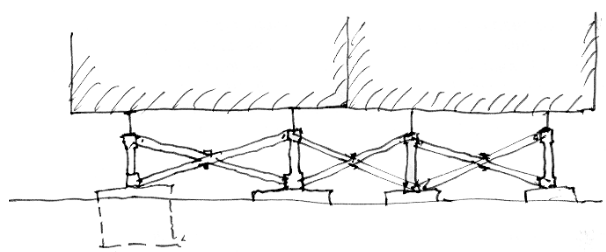
If the piers under the home are designed to be braced to prevent them from toppling, and if they bite into the earth with enough friction to prevent lateral movement, vertical ties will hold the home in place, without the need for diagonal tie-downs. Many systems of this design are commonly used as earthquake-resistant bracing systems (ERBS). Verify that the system has been approved for its intended use, and obtain, read, and follow the instructions published by the system manufacturer.



Single-section version of the Vector Dynamics System™ by Tie-Down Engineering

Embedded Pier Systems

A number of innovative systems are available based on the idea of making the footing heavy enough to avoid the need for ground anchors, and then attaching adjustable piers to these footings. The idea is sound, but these systems should be compared in cost with a full concrete slab, combined with piers and slab-attached strap anchors. Verify that the system has been approved for its intended use, and obtain, read, and follow the instructions published by the system manufacturer.



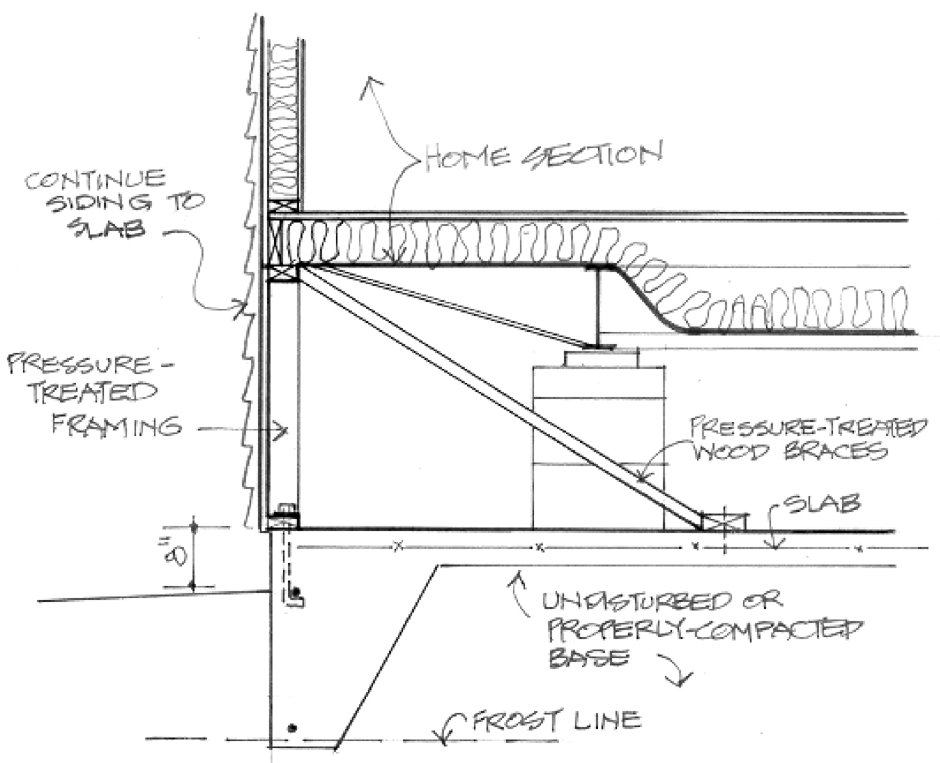
Typical braced ERBS
(Stabilizer Systems, Inc.™)

Perimeter Foundations

Replacing the skirting around the home with a continuous load-bearing foundation is highly recommended. Many installers routinely build such perimeter foundations for homes on private land. This is the easiest way to support a HUD-Code home with a perimeter frame. The wall can be made of CMU, brick, concrete or pressure-treated wood. Some of the advantages of a perimeter foundation over skirting are:

- Increases comfort in the home by keeping the crawl space warmer.
- Keeps pests out from under the home more effectively.
- Carries any loads at the perimeter, such as point loads at the jambs of doors, or heavy bookcase loads at the outside walls.
- Can function as a tie-down and wind bracing.
- Eliminates the tell-tale "skirting" in favor of a masonry foundation, or provides a support for extending the siding down near the ground.
- If made in accordance with HUD's "Permanent Foundations Handbook," the home may qualify for conventional mortgage financing.

Generally, local code approval is needed for a perimeter stemwall.



With properly engineered fastenings, anchors, and clips, this design can resist most earthquake and wind loads

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