

## Anchorage

Lateral forces and flood forces are less likely to overturn or uplift posts if the posts are anchored to a foundation. Two ways to anchor posts are to embed them in concrete or to fasten them to metal straps, angles, plates, etc., that are themselves anchored in concrete footings, piers, or pile caps.

Figure 4.11 shows one method of anchoring wood posts in concrete. Large (5/8- to 3/4-inch in diameter) spikes or lag bolts are driven into the post around its base. The post is placed into the hole and secured to bracing restraints to prevent movement through the footing while the concrete sets.

The metal fastening method of anchorage can be used above or below ground. Figure 4.12 shows a square wood post lag bolted to a metal shoe that is anchored in a pier. In Figure 4.13, heavy gauge galvanized steel straps are used to anchor the wood post to a concrete pad.

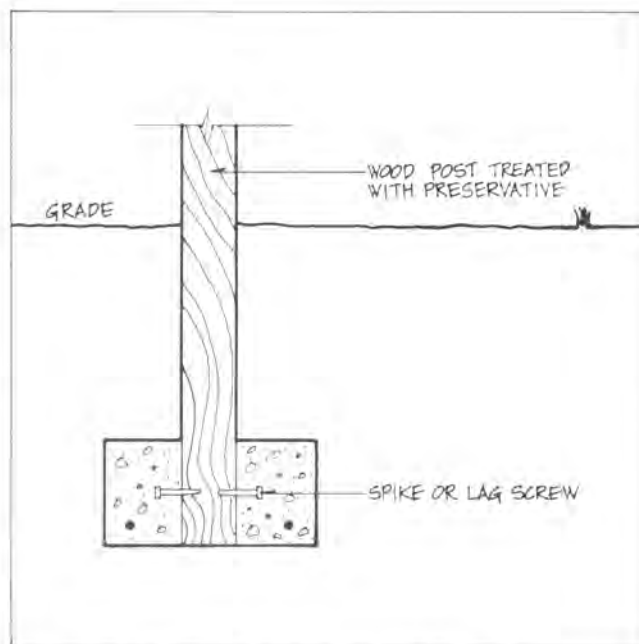


Figure 4.11. Spike Anchorage of Post

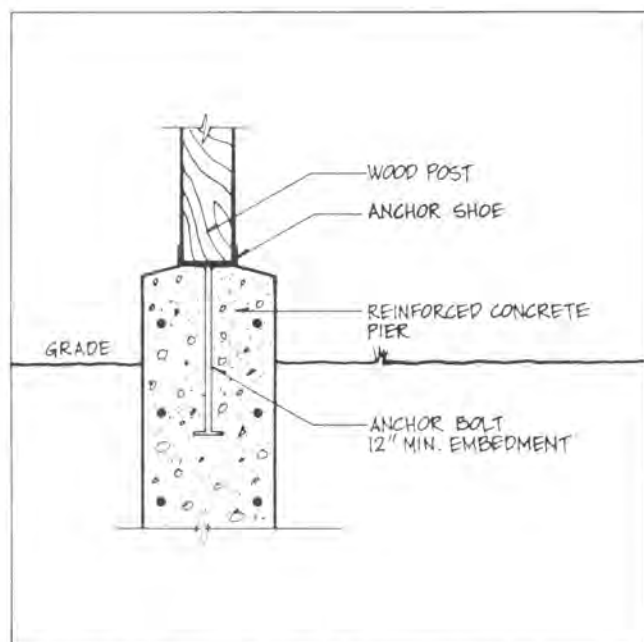


Figure 4.12. Metal Angle Anchorage Detail

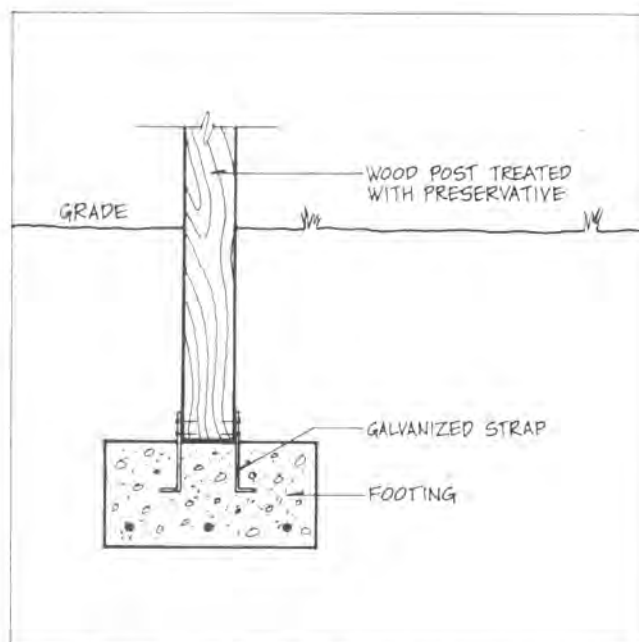


Figure 4.13. Galvanized Strap Anchorage Detail



Figure 4.14. Pile Foundations

## PILES

Pile foundations (Figure 4.14) use long, slender wood, steel, or reinforced concrete piles that are driven or jetted into the ground. Vertical loads can be carried by driving piles to a load-bearing layer, such as rock (end-bearing piles), or by driving the piles deep enough into the earth to develop enough friction between the surface of the piles and the surrounding soil to carry the load (friction piles). Friction piles, which can also have an end-bearing component, are most often used for typical light residential loads.

Piles are structurally stronger than posts and are therefore more suitable for the extreme wind and water forces and erosion in coastal V Zones. Piles in V Zones should be designed in accordance with *Design and Construction Manual for Residential Buildings in Coastal High Hazard Areas*, cited in the Preface.

### Pile Materials

Piles can be concrete, steel, or wood. In coastal areas, where steel piles are not desirable because of corrosion problems, concrete piles can be particularly good when combined with precast concrete floor beams; such structural systems can be efficient, economical, and flood resistant. Concrete piles can be particularly suitable for buildings of more than two stories.

The vulnerabilities of different pile materials to environmental conditions are discussed in the materials section later in this manual.

Wood piles are probably the most widely used foundation for elevated residential structures. In some locations, square timbers are preferred over round piles because of cost, availability, and ease of framing and connecting the structural floor beams to the piles. The most popular suitable sizes (in inches) are 10 x 10 and 8 x 8 square roughsawn members.

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Round timber piles are also frequently used. Generally, round piles are available in longer lengths than square timbers, and for lengths greater than about 25 feet round piles are frequently the only piles available. Round piles are often preferred because they can provide greater cross-sectional area, peripheral area, and stiffness than square sections, particularly the 8 x 8 timbers. A minimum tip diameter of about 8 inches, and a butt or top diameter (at the floor beam level) of about 11 inches or more are recommended for round piles.

### **Pile Embedment Methods**

A major consideration in the effectiveness of pile foundations is the method of inserting piles into the ground. This can determine the amount of the piles' load resistance. It is best to use a pile driver, which uses leads to hold the pile in position while a single- or double-acting hammer (delivering about 10,000 to 15,000 foot-pounds of energy) drives piles into the ground. A pile driver should be used for precast concrete piles and steel piles.

The pile driver method, while cost-effective for a development with a number of houses being constructed at one time, can be expensive for a single residence. An economical alternative, the drop hammer, consists of a heavy weight (several hundred pounds) that is raised by a cable attached to a power-driven winch. The weight is then dropped 5 to 15 feet onto the end of the pile. Drop hammers must be used with care because they can damage wood piles.

Disadvantages of pile driving include difficulties with alignment and with setting a driver up on uneven terrain. The advantage is that the driving operation forces soil outward from around the pile, compacting the soil and causing increased friction along the sides of the pile, which provides greater pile load resistance. A much less desirable but frequently used method of inserting piles into sandy coastal soil is "jetting." Jetting involves passing a high pressure stream of water through a pipe advanced alongside the pile. The water blows

a hole in the sand into which the pile is continuously pushed or dropped until the required depth is reached. Sand is then tamped into the cavity around the pile and the end of the pile pounded with the heaviest sledge hammer or other weight available. Unfortunately, jetting loosens not only the soil around the pile but also the soil below the tip. Therefore, only low end and side friction load capacity is attained, and the piles must be inserted deeper into the ground than if they were driven.

If the soil is sufficiently clayey or silty, a hole can be excavated by an auger or other means. The hole will stay open long enough to drop in a pile. Some sands have enough clay or silt to also permit the digging of a hole. Then sand or pea gravel can be poured and tamped into the cavity around the pile. Again, this does not provide as good load resistance as driving the pile into the ground, and longer piles are necessary. With short wood piles, some final driving with a sledge hammer can be helpful.

#### Soil Conditions and Embedment Depth

Local building codes often specify the required embedment depths of piles, e.g., to at least 6 feet below grade. Such codes often do not take into account the conditions at specific sites; a soils engineer should be consulted in doubtful situations. In addition, *Design and Construction Manual for Residential Buildings in Coastal High Hazard Areas*, cited in the Preface, provides useful information on this subject.

The required depth of pile embedment depends primarily on the number of piles used, the size and weight of the structure, and the type of soil at the building site. The pile depth is also influenced by the lateral forces from flooding and wind and debris impact, the manner in which the piles are inserted into the soil, and the need to allow for erosion of the soil that supports the piles.

In riverine environments the soil types and the anchorage provided by the frictional force of the soil against the sides of the pile vary widely. Sand is the dominant soil component in most coastal areas, but in some areas there may be



Figure 4.15. Pier Foundations

an underlying layer of several feet of clay. Generally, clay soils provide greater load-bearing capacity with less penetration than sandy soils.

Clay soils are also less susceptible to erosion. The depth of erosion of sandy soils caused by wave action is virtually impossible to predict. Piles supporting residential structures on sandy coastal shorelines should penetrate the ground deeply enough to provide resistance to wind and water loads even after extensive erosion has occurred.

Posts are often backfilled partly with concrete to improve their resistance to lateral forces. The same technique can be used with piles. After piles are driven, the area around each pile is dug out and a thick concrete collar is poured, extending several feet below grade. Such collars provide protection from minor erosion, add some deadweight to the structure, and increase piles' pull-out resistance.

## PIERS

Pier foundations (Figure 4.15) are suitable in areas away from a river or coastline where flood waters move with low velocity and erosion will be minimal.

Pier foundations use brick, concrete masonry blocks, or poured-in-place concrete to elevate structures. To resist horizontal wind and water forces, piers should rest on substantial spread footings or a grade beam, with reinforcing steel rods extending from these elements through the full height of the piers to resist tensile stresses.

### Pier Materials

The vulnerability of pier materials to environmental conditions is discussed in the materials section later in this manual.

### Brick and Concrete Masonry Piers

Brick piers and concrete masonry piers should be a minimum of 12" x 12" and reinforced with steel rods (Figures 4.16 and 4.17). Hollow concrete masonry units should be filled with concrete.

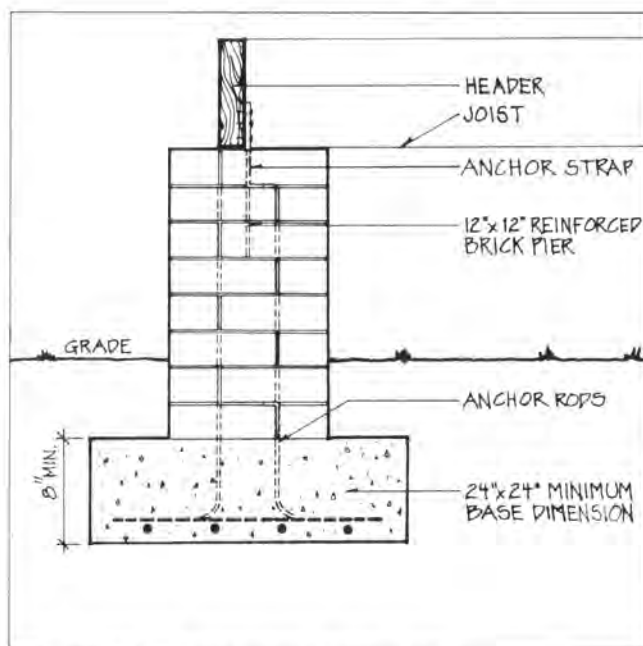


Figure 4.16. Reinforced Brick Pier

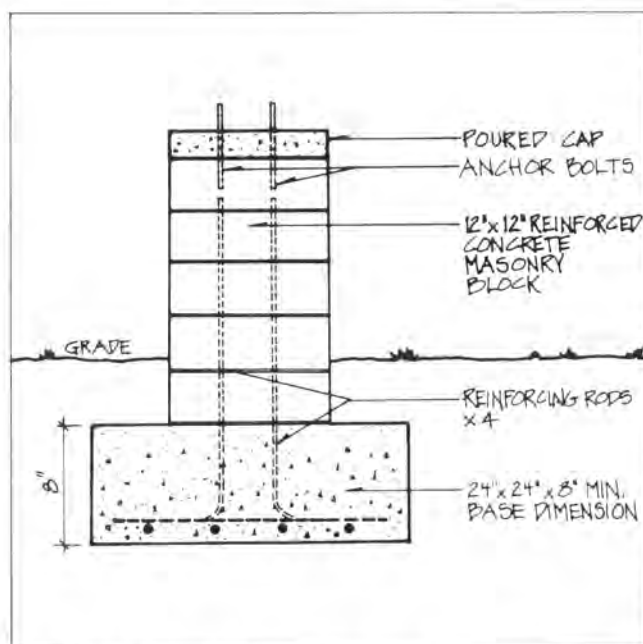


Figure 4.17. Reinforced Concrete Masonry Pier

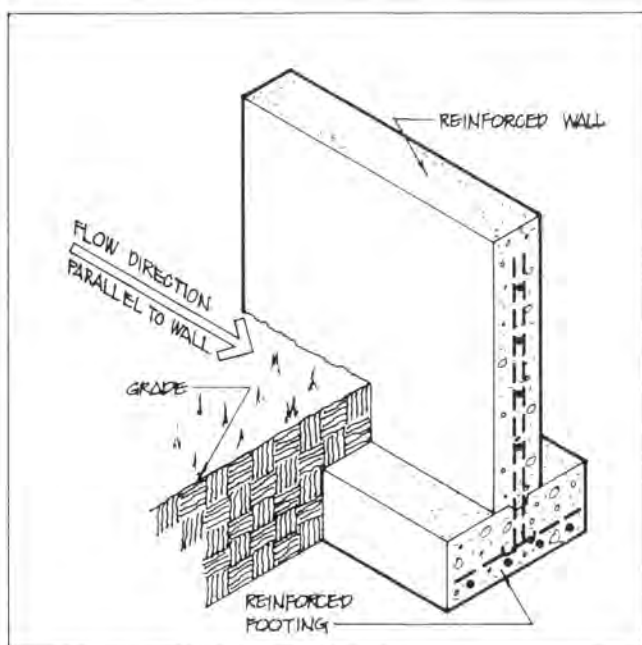


Figure 4.18. Wall Foundation

Reinforced brick piers can be used to elevate structures 1½ to 6 feet off the ground. Concrete masonry piers are effective for elevations of 1½ to 8 feet. In general, the height of reinforced concrete masonry piers should be limited to a maximum of ten times their least dimension. Square piers are preferable. If the piers are rectangular the longer dimension should not exceed the shorter dimension by more than 50 percent.

According to the National Concrete Masonry Association, the allowable working stresses for concrete masonry piers are the same as those for the design of concrete masonry walls. The pier masonry should be laid with type M or S mortar. The association also recommends that the spacing between piers supporting floor joists not exceed 8 feet in the direction perpendicular to the joists, nor 12 feet in the direction parallel to joists.

These minimum requirements apply whether the pier is free standing or laterally braced. In cases where exceptionally large loading conditions may exist, the pier cross-section should be increased and/or additional reinforcement added. A larger cross-section can be obtained by using piers several feet in length. The long dimension should be placed parallel to anticipated flood flow, as in Figure 4.18. In coastal areas, however, flood forces may come in at an angle, loading such a pier adversely, so alternatives should be considered.



## Poured-in-Place Concrete Piers

Poured-in-place concrete piers are essentially reinforced concrete columns. They are cast in forms set in machine- or hand-dug holes. The holes can be widened or belled at the base to form a footing integral with the pier, or, as shown in Figure 4.19, a separate footing can be poured. If soil conditions are appropriate the footing can be eliminated and loads left to end bearing and friction between the soil and pier (Figure 4.20). Poured-in-place piers of the latter type can be particularly effective for larger homes or developments of single-family homes and townhouses.

Poured-in-place concrete piers can be used to elevate a structure 1½ to 12 feet or more. The dimensions, reinforcement, and spacing of concrete piers depend on the type of building framing used and on building and environmental loads; structural analysis is required.

### Pier Footings

Pier footing sizes are a direct function of soil bearing capacity and loading, and can be computed on the basis of local codes. Depth of pier footings depends on local frost penetration levels and expected flooding, wind, and erosion levels. Footings in areas with soils of high volume change potential can be unstable, and should be designed with the guidance of a soils engineer.

## BRACING ELEVATED FOUNDATIONS

Elevated foundation elements must be braced when analysis indicates that their size, number, spacing, and embedment will not be sufficient to resist lateral forces. Even in areas where low-velocity flooding is anticipated, bracing can provide added assurance that the structure will withstand the impact of floating debris or greater-than-expected flood or storm forces. Although bracing placed underneath a structure may be struck by floating debris, the effects of this on a structure's survivability are generally outweighed by bracing's beneficial effects.

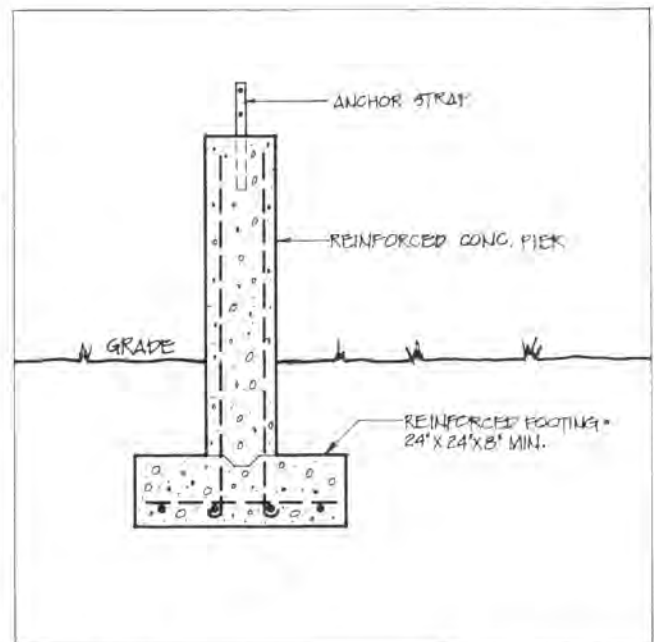


Figure 4.19. Reinforced Concrete Pier

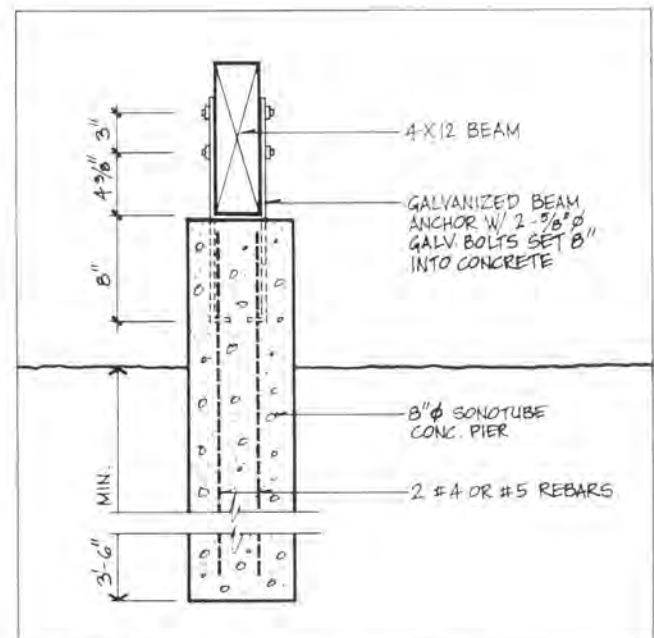


Figure 4.20. Drilled Pier Foundation

### Knee Braces and Diagonal Bracing

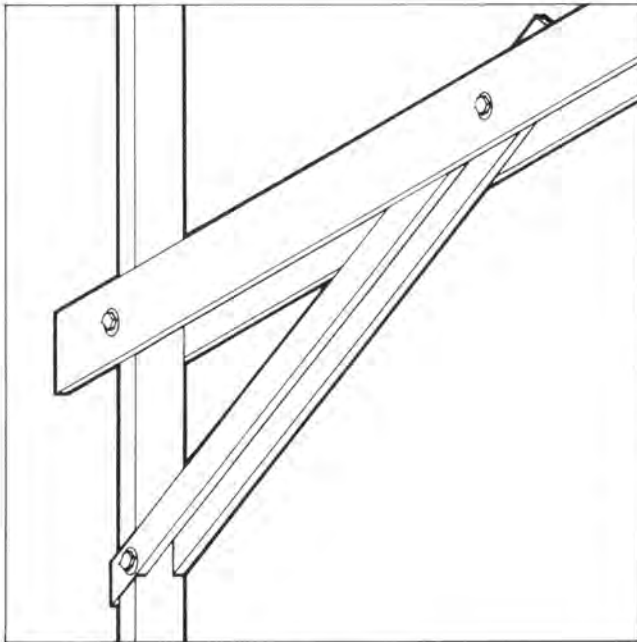


Figure 4.21. Knee Brace

Knee braces (Figure 4.21) and diagonal bracing can be effective in providing lateral strength. Lumber more than 2 inches thick is usually recommended. Bolts are preferred over nails for connecting bracing, because of bolts' greater resistance to pullout forces. Knee bracing is usually bolted between the floor joist and post or pile.

Diagonal bracing (Figures 4.22 and 4.23) is bolted at the base of one post or pile and fastened in a like manner to the adjacent post or pile just below the floor beams. Although diagonal bracing is more likely than knee bracing to be struck by floating debris, this is generally outweighed by the greater lateral stability with diagonal bracing, especially in higher elevated structures. Steel rods can sometimes be used to diagonally brace wood posts or piles. The rods are fitted through drilled holes flooded with wood preservative and fastened with nuts and cast beveled washers. Welded connections or drill holes can be used to provide rod bracing in steel post or pile foundations. Such rods are usually 5/8 to 3/4 inches in diameter. Steel diagonal ties, while effective, require considerably more monitoring and maintenance than wood because of steel's susceptibility to corrosion.

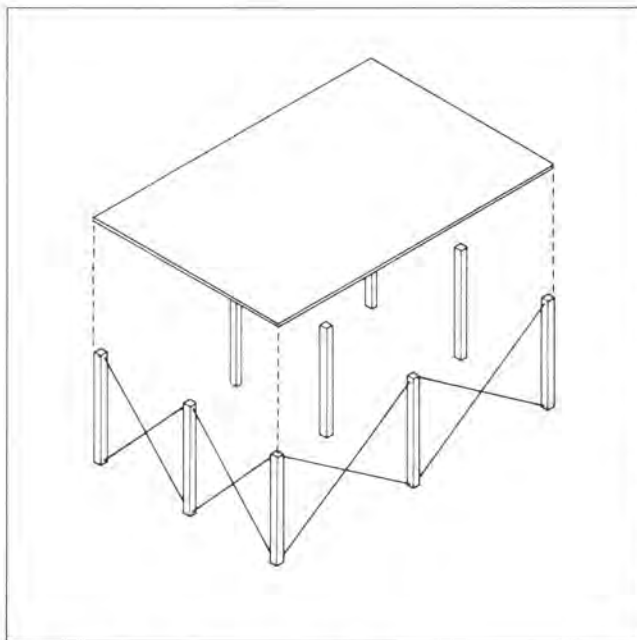


Figure 4.22. Diagonal Bracing



Figure 4.23. Diagonal Bracing



## Shear Walls and Floor Diaphragms

In areas with low- to moderate-velocity flooding, shear walls placed parallel to the flow of flood waters and firmly attached to piles or posts can help brace them (Figure 4.24).

With wood shear walls, the plywood sizes, the strength of wall edges, and the walls' anchorage are all important to effective bracing.

A shear wall can be used in conjunction with a floor diaphragm (Figure 4.25) to transfer horizontal forces or reduce embedment depth when, for example, solid rock is reached when digging foundation holes. A floor diaphragm can be used with either pole frame or platform construction. Floor diaphragms usually call for 1/2- or 3/4-inch plywood.

The severe lateral forces encountered in coastal V Zones can require the use of trusses, grade beams, or slabs to provide adequate support. These are discussed in *Design and Construction Manual for Residential Buildings in Coastal High Hazard Areas*, cited in the Preface.

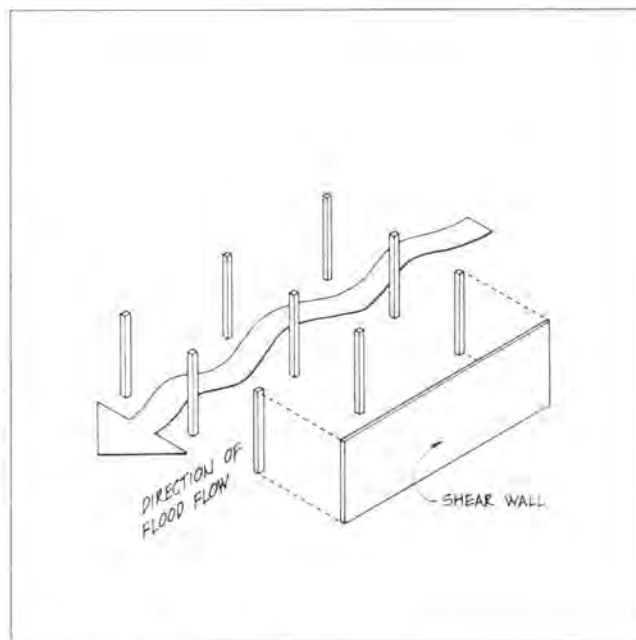


Figure 4.24. Shear Wall Bracing

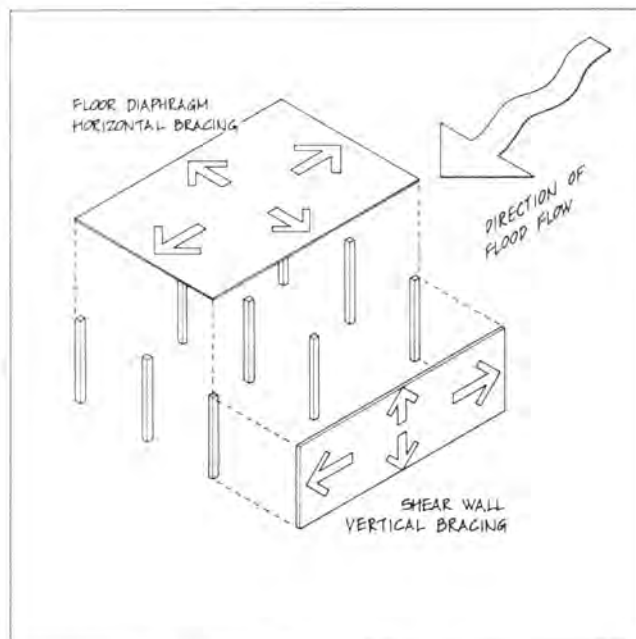


Figure 4.25. Floor Diaphragm Bracing

# Framing Construction and Connections

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The framing construction and framing connections in an elevated home can be critical to its ability to withstand flood forces with minimal damage. Construction in most non-flood areas must support loads imposed by the weight of the building materials (dead load), weight of people and objects (live load), and modest loads imposed by wind. Under normal conditions and with typical methods of framing construction and framing attachment, these loads act downward through gravity to hold the building's structure together.

However, these loads represent only a portion of the loads imposed on any structural system in flood-prone areas, particularly in coastal V Zones. Additional forces can be applied to these structures by floating debris, velocity flooding, extreme winds, and wave action. These buildings' structural system must be capable of withstanding these loads and still support the structure and its contents.

Coastal V Zones are virtually certain to be subjected to the extremes of these forces, and homes there should be designed in accordance with *Design and Construction Manual for Residential Buildings in Coastal High Hazard Areas*, cited in the Preface.

Even in riverine and coastal A Zones, however, prudence suggests that homes be built with a margin of safety beyond that needed in non-flood areas. Consideration should also be given to the possibility that flood forces may be greater than those anticipated on the basis of past floods or hydrologic analyses. Coastal areas pose the additional danger that shifting dunes or other storm-induced topographic changes can transform relatively safe A Zones into V Zones, which experience the full force of ocean storms.

Measures to provide a home with an extra margin of safety to resist these forces are not expensive, e.g., having floor joists 12 inches on center instead of 16 inches on center, or using deformed shank or annular ring nails because of their greater holding ability. Nor are the needed craftsmanship and anchorage methods uncommon to the carpentry trade. Simple nailing, for example, especially end or



Figure 4.26. Toe Nailing Provides Limited Pull-Out Resistance

toe nailing, provides little resistance to flood forces, partially because of the tendency to split the wood in the toe-nailed member (Figure 4.26). Bolts, lag bolts, or nails in metal anchors at right angles to the direction of force (Figure 4.27) are well-known methods of increasing structural strength.

The following paragraphs discuss prudent framing construction and connections practice from the bottom up, starting with the foundation-to-floor-beam connections and floor beam construction and ending with wall-to-roof connections.

## FOUNDATION-TO-FLOOR-BEAM CONNECTIONS

### Post and Pile Foundations

The connection of a post or pile foundation to the framing system of a structure is influenced by the method of framing used and the cross-sectional shape of the post or pile.

*Framing Methods.* Two different methods for framing into post or pile foundations are in common use today: platform construction and pole frame construction.

Platform construction entails simply cutting posts or piles off at the desired elevation and framing them with beams to support floor joists and deck. The platform thus formed serves as the first habitable floor and construction platform for any type of conventional framing structure desired (Figure 4.28).

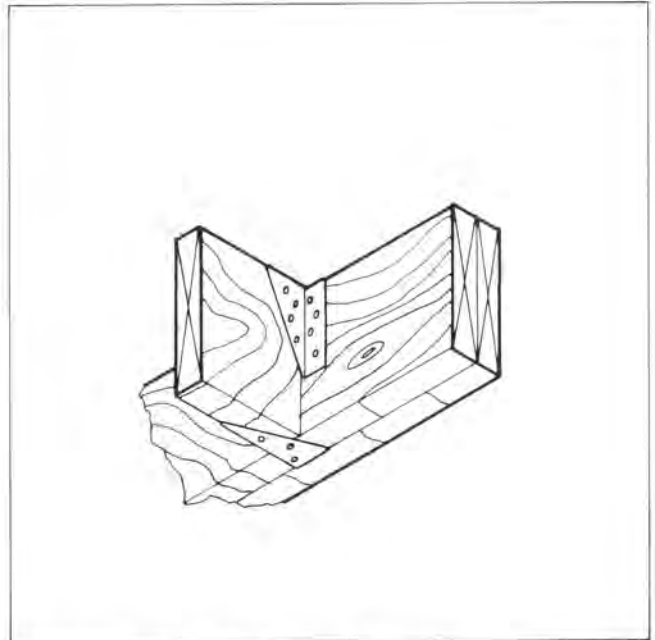


Figure 4.27. Metal Framing Anchors

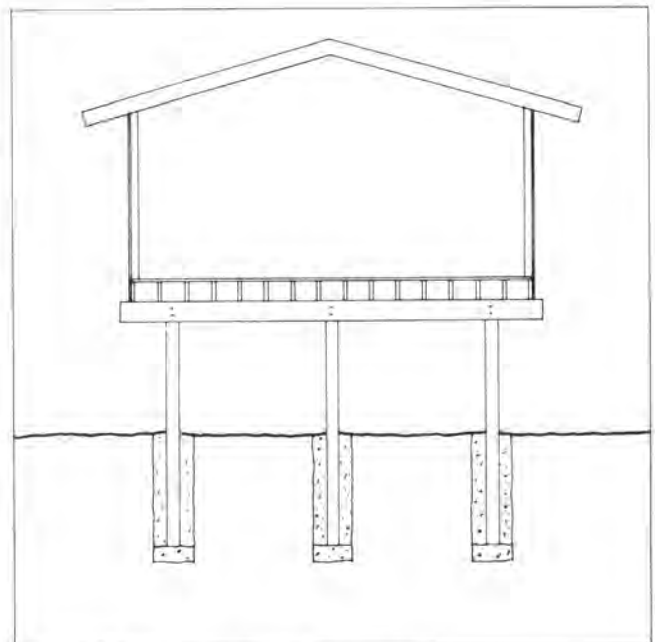


Figure 4.28. Platform Construction

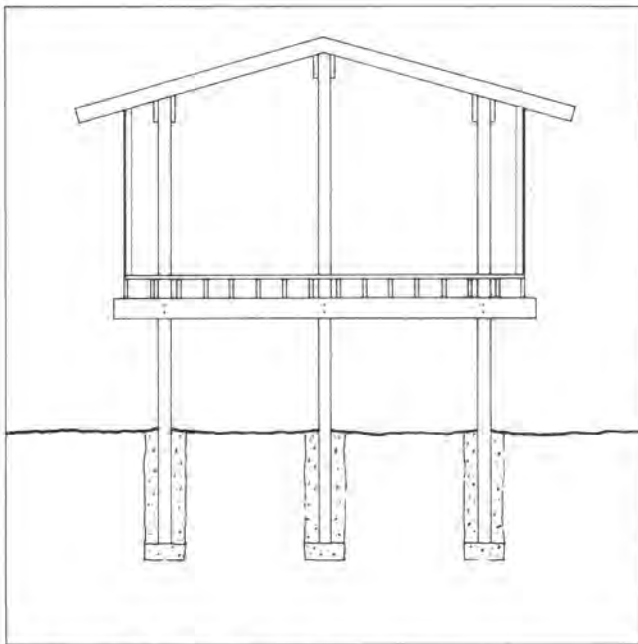


Figure 4.29. Pole Frame Construction

In what is termed pole frame construction, the posts or piles are extended up to or through the roof, with beams framing around them as supports for floor joists and roof rafters (Figure 4.29). This method securely ties the entire structure together and is excellent for sites where lateral forces may be strong.

A basic problem with piles is their alignment. Posts can be plumbed and aligned easily before they are backfilled, but piles must be jacked and pulled into position. This can be more of a problem with pole framing than platform construction. A solution is to locate piles either on the interior or exterior of a structure, not in the walls. Then, as shown in Figure 4.30, allowance can be made for alignment variations.

*Cross-Sectional Shape.* Square posts or piles usually require only conventional framing techniques. With round posts or piles, however, the framing is somewhat more complicated, and it is generally best to frame the posts with a pair of beams, girders, or rafters—one on each side.

The roundness of wood posts is not a problem when using bolted or spiked connections as shown in Figure 4.31. The framing is then the same as for any other timber member.

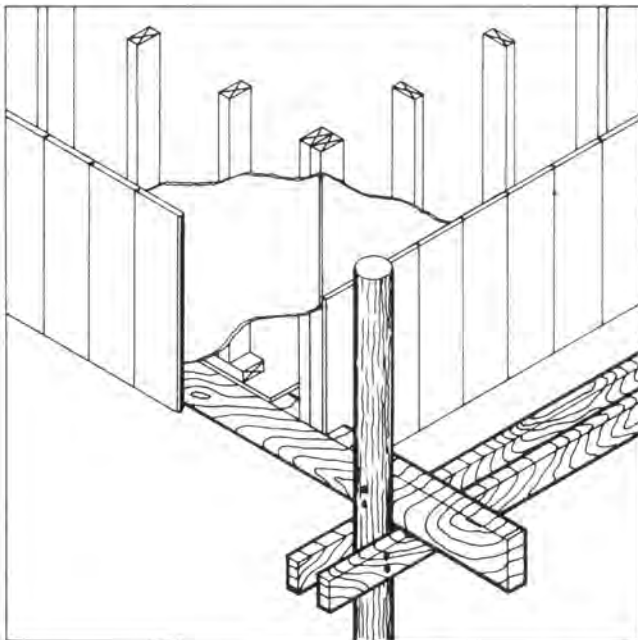


Figure 4.30. Exterior Pole Framing

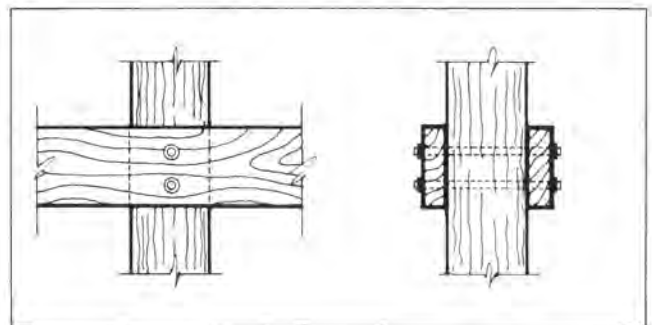


Figure 4.31. Bolted Connection to Round Pole

Another connection method is to eliminate the curve of the post or pile by dapping and then connecting with bolts, gusset plates, or other devices. As Figures 4.32 and 4.33 show, a dapped post will form seats that assist the beams in carrying vertical loads. Posts that are small in section, however, should not be dapped or they will be weakened. Generally, there should be a thickness of post or pile for the bolts to bear on equal to the total thickness of the floor beam. Two bolts should be used to connect beams to each post or pile.

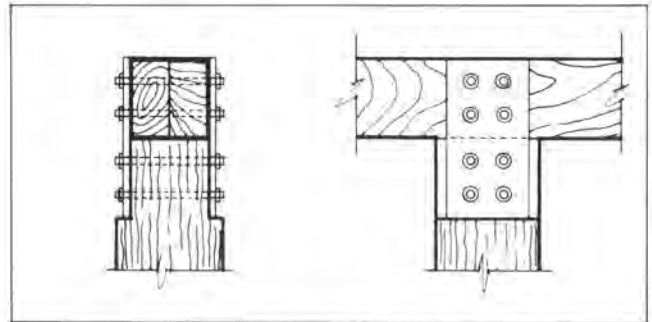


Figure 4.32. Dapped Gusset Plate Connection

Spike grid connections (Figure 4.34), standard in bridge and warehouse construction, are less common in residential practice. A single curved grid inserted between the post or pile and the beam substantially increases the strength of the bolted connection. With the curved side of the grid against the pole and over predrilled holes, a high-strength threaded rod is used to squeeze the two wood surfaces together, forcing the tooth of the spike grid into the grain of both members. The high-strength rod is then replaced with a conventional bolt of the proper size. A flat spiked grid is used to connect two flat surfaces, and a double curved spiked grid to connect two rounded surfaces.

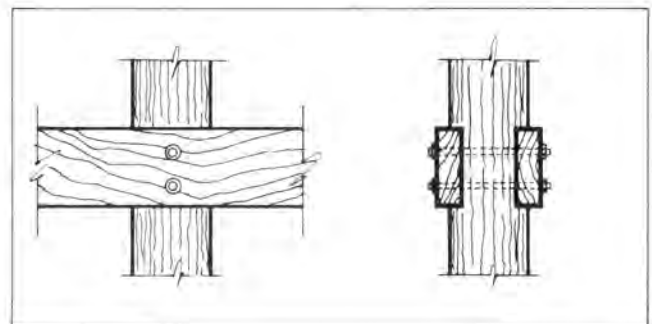


Figure 4.33. Dapped Pole Connection

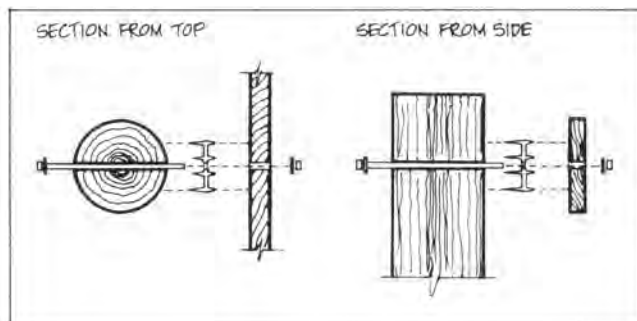


Figure 4.34. Spiked Grid

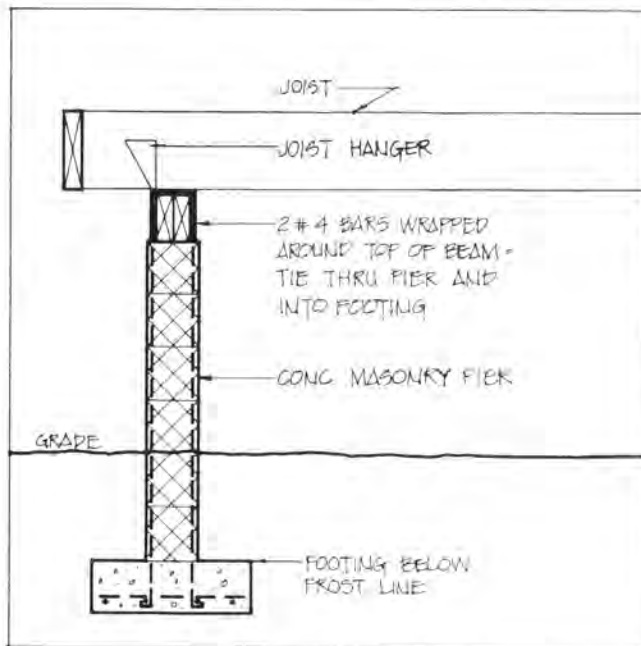


Figure 4.35. Concrete Masonry Unit Pier

## Pier Foundations

Pier foundations are generally used for platform framing construction rather than pole framing construction.

Piers can be connected to floor beams in several ways. A pier's reinforcing steel rods can be extended from the pier and bent over or into the floor beam (Figure 4.35). A metal strap well-anchored in the pier can be bolted through the beam (Figure 4.36). Or (Figure 4.37) steel anchor bolts can be embedded in the pier and bolted through the beams with nuts and large-diameter washers.

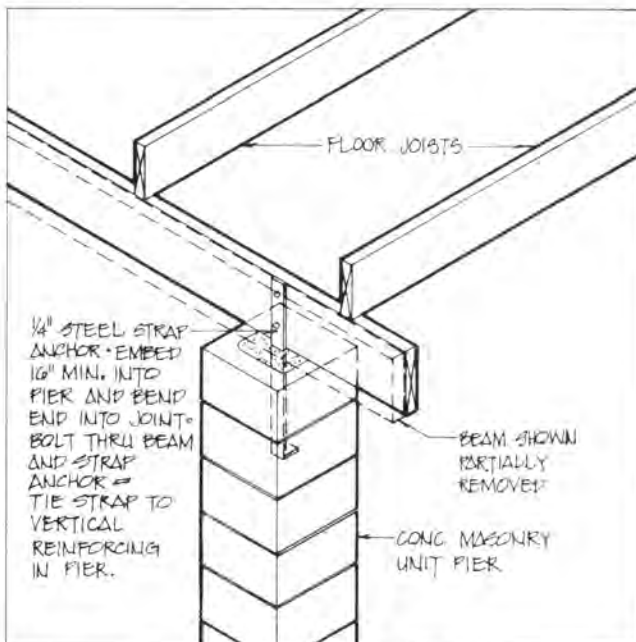


Figure 4.36. Masonry Pier—Strap Anchor

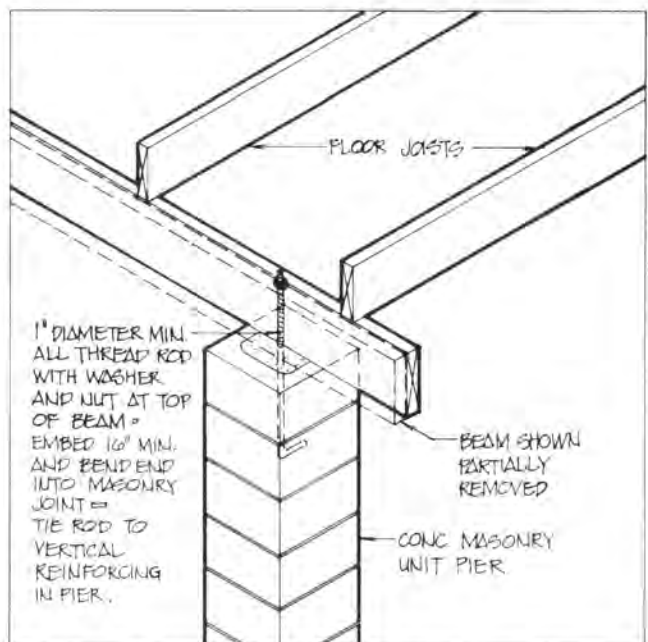


Figure 4.37. Masonry Pier—Bolt Through Beam



The bolts should be at least 1 inch in diameter and embedded at least 12 inches in concrete piers and 16 inches in masonry piers. If two floor beams abut on a pier, each must be anchored separately (Figure 4.38).

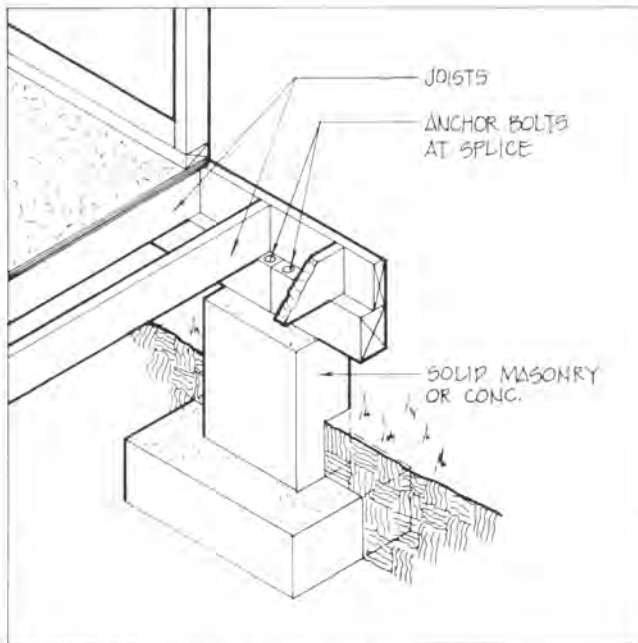


Figure 4.38. Beam Splice on Pier

## FLOOR BEAMS

The floor beams attached to foundation elements in turn carry the floor joists and subflooring. Since floor beams that are as long as the width or length of residential structures are often difficult to find and hard to handle, it is common to use splices. Splices may occur in several places and need not always be located directly over supports.

Floor beams are often 4 x 10's or up to 6 x 12's, but they may be built up using standard framing lumber, such as two, three, or four 2 x 10's or 2 x 12's, spiked or bolted together. Where beams are built up using a good grade of lumber for the laminated members, the strength of the built-up beam can equal that of a solid member. All members of the built-up beam should be continuous between supports, because splices materially reduce strength. Built-up members should include only one splice at any one location. The ends and tops of built-up members should not be directly exposed to the weather.

The primary floor beams spanning between supports should span in the direction parallel to the flow of potential floodwater. This orientation allows the first transverse member perpendicular to flow to be the floor joist. Thus, in the case of an extreme flood the beams would not be subjected to the full force of floodwater along their more exposed surfaces. This also reduces the potential for floating debris to damage the structure, and places the lowest obstacle to flow above the floor beam.

## CANTILEVERS

A cantilever is a projecting beam that extends beyond its support. The beam must be continuous (not spliced) over the last support prior to the cantilevered section, and depends on the vertical load applied for counteracting reactions (Figure 4.39). The practical limit recommended for a cantilever is normally one-third the length of the beam span prior to the cantilever.

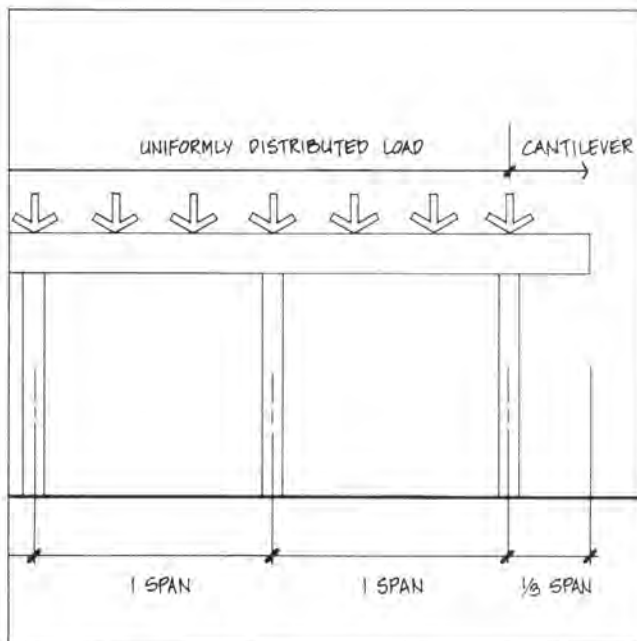


Figure 4.39. Floor Beam with Cantilever Overhang

The advantage of this method is that it can reduce the number of piles, poles, or piers required for a given area, as illustrated in Figure 4.40. Reducing the number of piles can result in potentially lower cost and fewer obstructions to the flow of floodwater and debris. Residences supported in this manner have the additional advantage of having the first row of piles set back, reducing the visual impact of elevating the structure. A cantilever design may use longer spans for the main floor beam and thus may require larger beams.

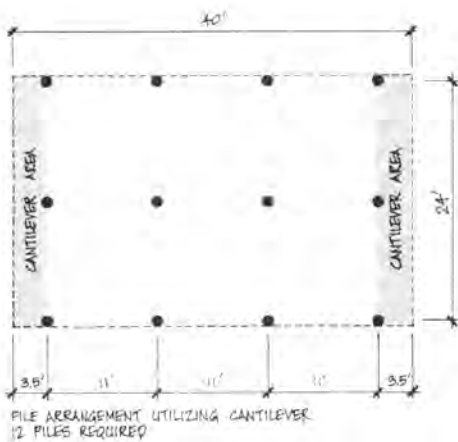
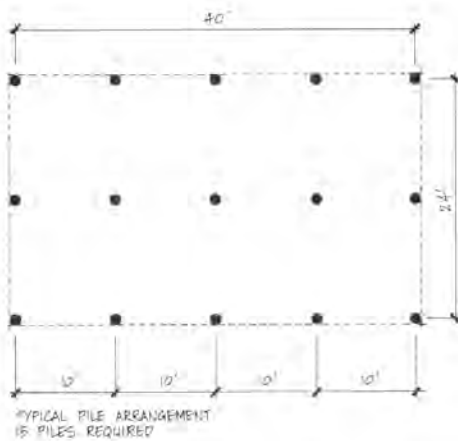


Figure 4.40. Cantilever Used to Reduce Number of Foundation Elements

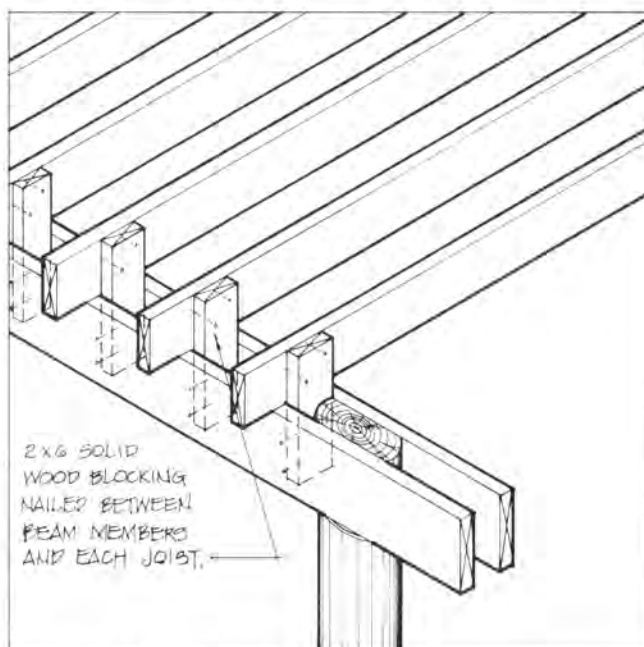


Figure 4.41. Wood Joist Anchors

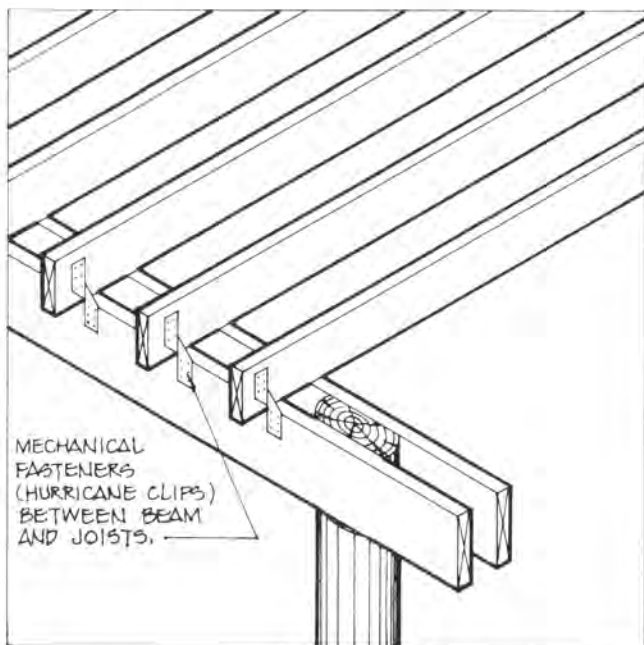


Figure 4.42. Metal Hurricane Clips

## CONCRETE FLOORING SYSTEMS

Recently developed flooring systems using precast, prestressed concrete for floor beams, joists, and/or subflooring can often be useful in elevated structures. Construction and connection techniques for these systems are beyond the scope of this manual.

## FLOOR-BEAM-TO-FLOOR-JOIST CONNECTIONS

A positive connection is also required beneath the first floor level between the floor joists and floor beams (Figure 4.41). Metal connectors now available provide strong positive connection (Figure 4.42). Metal straps can also be used provided proper nailing is done and a sufficient number of straps is installed. At the minimum, every other joist and wall stud should be anchored with a strap, and even more for more severe loads (Figure 4.43). A good wood connector has also been developed. The capacity of these connections depends directly on the number of nails and their individual capacity to resist loads transverse to their axis. Pullout resistance along the axis is not used; rather, the nails are placed at right angles (perpendicular) to the loads being transferred between the wood members. The number of nails counted in figuring the total connection capacity of a given joint is the lower number that exists on either side of the joint. For example, in the connection of a floor beam to a floor joist, if five nails are in the beam and four are in the joist, the capacity of the connection is limited by the four nails on the joist.

## FLOOR JOISTS

Cross-bridging of all floor joists is recommended to stiffen the floor system. The elevation makes the floors (particularly the first floor) more accessible to uplift wind forces, as well as to the forces of moving water and floating debris. Effective cross-bridging requires:

- nominal 1 x 3's 8 feet on center maximum
- solid bridging same depth as joist 8 feet on center maximum.

## SUBFLOORING

Two methods are commonly used for subfloor construction: nominal 1 x 4 or 1 x 6 boards placed diagonally over the floor joists (either tongue-and-groove or square-edge with expansion space between boards) and plywood subflooring used to create a floor diaphragm. When a plywood subfloor is planned, guidelines for thickness and methods of attachment in relation to joist spacing can be obtained from the *Plywood Construction Guide* published annually by the American Plywood Association. A well-constructed, firmly attached subfloor can be an important asset in resisting lateral forces.

Subflooring is typically nailed directly to the floor joists. Nailing with annular ring nails or deformed shank nails is recommended. These nails provide extra strength against pulling out when the floor system is exposed to loads other than gravity.

A system of nailing and adhesive application of plywood with tongue-and-groove joints along the long edges of the sheet avoids the need for blocking along these edges. This produces a more level floor and offers a stronger diaphragm action to resist horizontal flood forces.

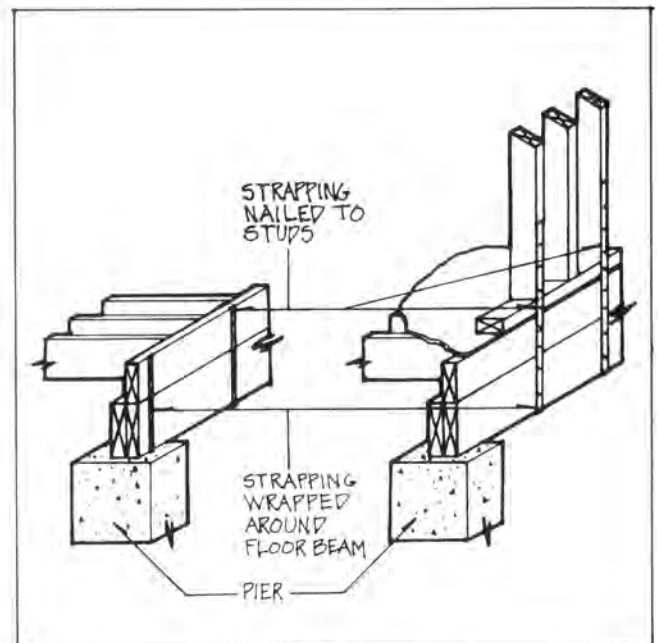


Figure 4.43. Metal Strapping

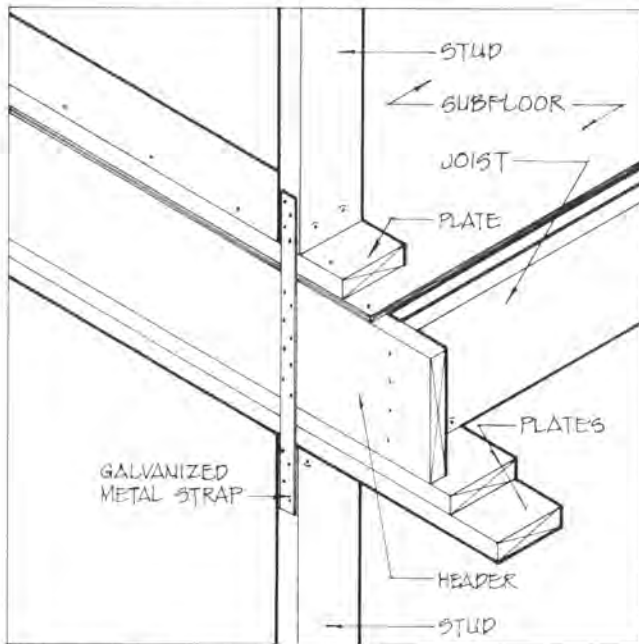


Figure 4.44. Stud-to-Stud Connections

## FLOOR-JOIST-TO-WALL CONNECTIONS

Elevated structures experience increased wind forces because wind speeds increase with elevation. Exterior walls are used as tension members to transfer wind uplift forces at the roof down to resistance provided by the foundation. It is usually necessary to use galvanized metal strap connections from alternate exterior wall studs to the floor joists or floor beams and from first floor studs to second floor studs (Figure 4.44). The capacity of these connections depends on the number of nails used. Manufacturers' brochures can be used to ascertain connectors' capacity and thus the spacing required.

## WALL SHEATHING

Plywood is the most common sheathing in use for exterior walls (Figures 4.45 and 4.46). The major advantages of plywood are that it braces the wall framing to resist racking stresses and it forms a continuous tie from floor beam to top plate when properly installed.

Plywood used for sheathing structures elevated up to 10 feet above the ground should be exterior grade and not less than 1/2-inch thick. Nailing should be with sixpenny nails, spaced 6 inches along the edges of the panel and 12 inches on intermediate studs.

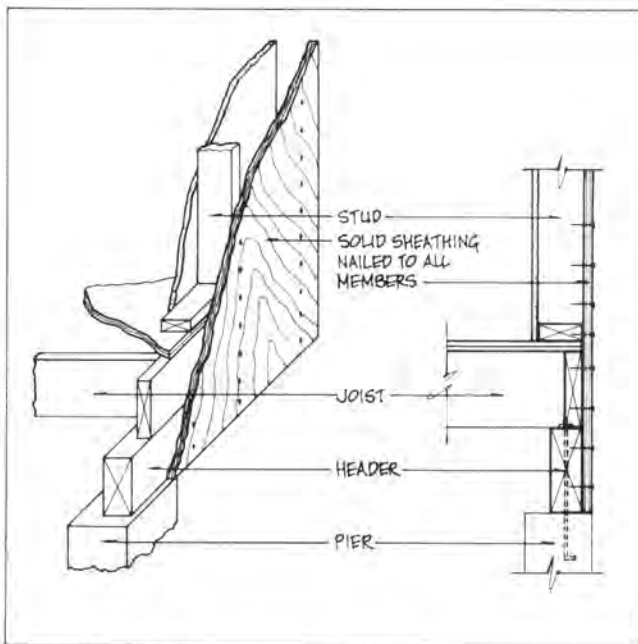


Figure 4.45. Plywood Anchorage



Structures elevated more than 10 feet should be sheathed with 3/4-inch exterior grade plywood, nailed with eightpenny nails, spaced as before. Deformed shank or annular ring nails and plywood with exterior glue are recommended.

## WALL BRACING

Bracing vertical walls against racking is a common building practice, especially for weak materials such as some of the newer insulated sheathing. Wind forces and lateral forces from moving water are also significant factors in determining whether and to what extent to brace vertical walls.

Common wall bracing methods are a let-in diagonal wood brace, diagonal boards and plywood. A common method similar to the let-in diagonal brace is a light-gauge galvanized steel strap nailed diagonally to each stud at the outside corners and framed walls.

## WALL-TO-ROOF CONNECTIONS

Probably the most critical structural connections for wind resistance are those between walls and the roof. For single-family residences, the roof structure is usually roof rafters of 2 x 10's or 2 x 12's or roof trusses built up of 2 x 4's or 2 x 6's. Whether rafters or trusses are used, they should be spaced at about 16 inches or 24 inches on center (16 inches is the more common spacing). Roof connections are critical because these connections are limited in number—at most they can occur at every roof rafter or truss.

A number of available galvanized metal connectors place the nails in an orientation to best resist uplift and lateral forces. Manufacturers' brochures provide the necessary design information.

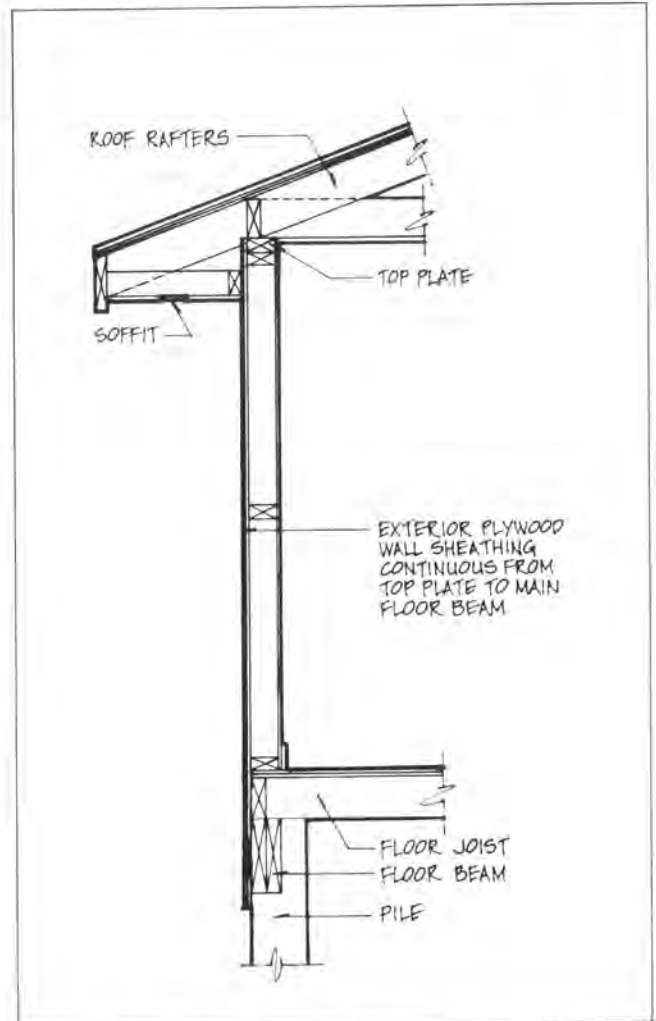


Figure 4.46. Wall Sheathing Tie from Roof to Ceiling

## Related Design Considerations

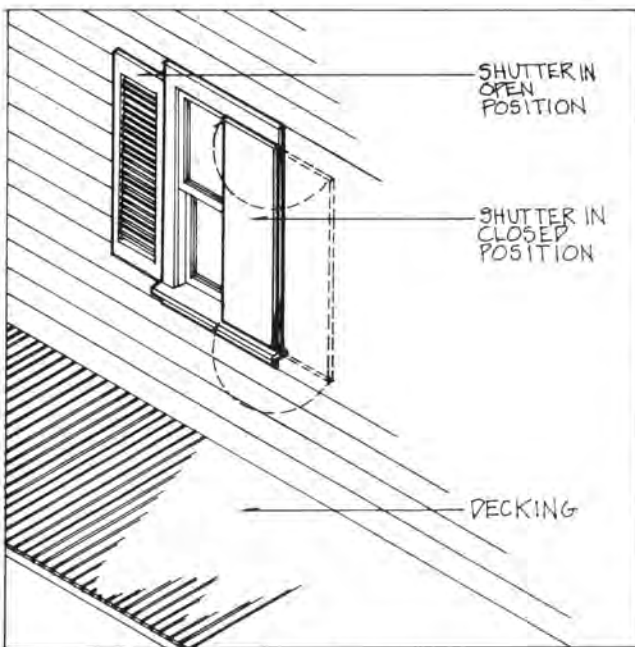


Figure 4.47. Shutters for Window Protection

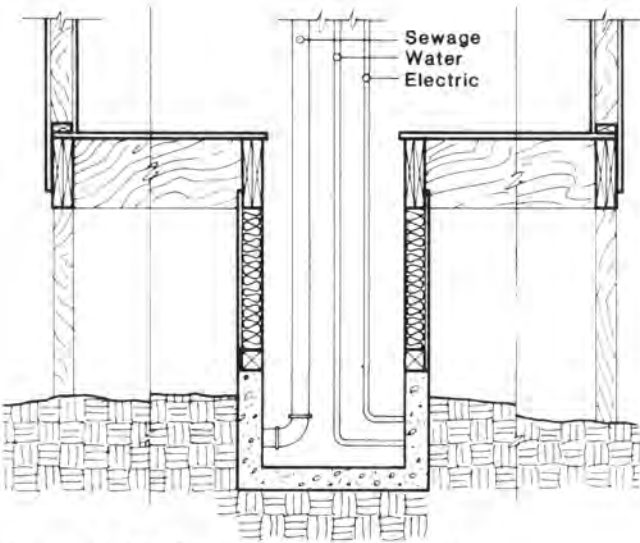


Figure 4.48. Protective Utility Shaft

### GLASS PROTECTION

Even moderate storms or routine high winds can cause large losses of glass in buildings, particularly along a coast. Broken glass may allow rain and floodwaters and high winds to enter the structure. Water damage can ruin furnishings and eventually damage structural members. Wind allowed into an elevated structure increases the uplift load on the structure as it applies pressure to the ceiling and wall surfaces.

Exterior shutters can be used to protect glass. For small openings the traditional louvered shutter offers some protection. Additional protection is possible using 1/2-inch plywood attached to the back of the shutter, which will take the direct forces from the storm (Figure 4.47). This method allows coverage of fairly large areas of glass.

### UTILITIES AND MECHANICAL EQUIPMENT

Structures in flood-prone areas are commonly served by combinations of electricity, water, sanitary sewer, gas (both natural and bottled), and telephone. Typical installations for these utilities expose them to potential damage from flooding and storm action. In the case of an elevated first floor, the connection from an underground utility line to the floor above further exposes the line to possible damage and/or contamination by flooding and storm action. Underground services are also susceptible to damage when erosion of the protective soil cover leaves them exposed during flooding.

Damage to utility lines can lead to contamination of drinking water, discharge of effluent from sewer lines, gas explosions, and fires and/or shock from damaged electrical systems.

The most vulnerable section of any underground utility line is the portion between the ground and the place it enters the elevated first floor. A minimum amount of protection can be obtained by locating these utility risers on the sides of interior elevated foundation elements opposite the direction

of flood water. This can minimize damage from velocity water or floating debris. A more secure method is to place all utility lines coming from underground within a protective, floodproofed shaft under the elevated first floor (Figure 4.48).

If electrical and telephone lines are supplied from overhead service lines, they should be connected through the utility company's meter system above the expected reach of flood waters. However, this requirement is often in conflict with the power company's policy regarding the reading of meters and their location. If this is not possible, the connection should be made within a waterproof enclosure. All distribution panels or other major electrical equipment should also be located above expected flood waters. Branch circuit wiring should be fed from the first floor ceiling downward to minimize wiring on the first floor.

All mechanical equipment (furnaces, hot water heaters, air-conditioners, water softeners) should also be elevated above expected flood waters (Figure 4.49). An attic location, if available, would provide the equipment maximum safety. Heating and/or cooling systems using ductwork to carry tempered air should be provided with emergency openings at their lowest elevations and a minimum slope on horizontal duct runs in order to allow the system to drain in case it becomes submerged. Figure 4.50 illustrates some of these concepts.

Septic tanks should be floodproofed to ensure that flooding does not cause the tank to rise out of the ground if the tank is partially empty, as well as to ensure against discharge of effluent.

## BUILDING MATERIALS

One way to increase the safety of building materials is to elevate the building higher than the minimum floodplain management requirements. Even then, however, flood waters may still reach building materials, so they should be protected.

A building elevated above grade has the underside of its floor area exposed to climatic and flood



Figure 4.49. Elevated Condenser Units

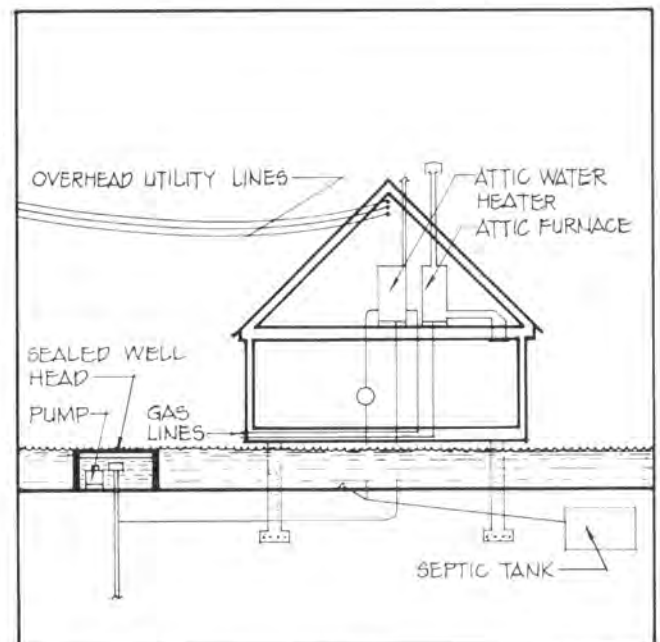


Figure 4.50. Locating Utilities

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conditions, and will require special attention to protecting building materials. The climate and the desired appearance will determine whether the exposed underside of a floor should be sealed. Sealing exposed floors can protect subfloors and joists from the elements, improve insulation, and help conceal utilities.

The material used to enclose floor spaces should be resistant to water damage or inexpensive to replace if it is not resistant to damage. Exterior grade plywood treated with preservatives is water-resistant and can be effective. Gypsum products should not be used unless an acceptable level of performance is assured. Regardless of the material used, some provision must be made to allow water that may find its way into the floor sandwich during storms and flooding to drain out, and for the joist spaces to dry out.

### **Wood**

Wood exposed to the elements should be protected by treatment with any one of a number of chemical preservatives to make the wood resistant to fungi attack, insects, bacteria, and rot. Connections should be designed so that water will not collect on or in them. They can be protected with protective flashing, by treating saw cuts and drill holes with preservatives, and by painting connections. The American Wood Preservers Institute, Tyson's International Building, 1945 Gallows Road, Vienna, Virginia 22180, can provide specific guidelines.

### **Steel**

In riverine areas steel framing and foundation members exposed to the elements should be protected by galvanization or by painting with rust-retardant paints. The need for painting can be eliminated through the use of surface oxidizing steels (high strength low alloy).

In saltwater environments, exposed structural steel shapes, beams, pipes, channels, angles, etc., undergo very rapid corrosion, and their use should be avoided. Small connecting devices such as bolts, angles, bars, and straps should be hot-dipped galva-

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nized after fabrication and coated with a protective paint after installation. Standard galvanized sheet metal joist hangers and other connecting devices deteriorate rapidly despite their galvanized coating and also require additional protective coatings. Small anchoring devices, nails, spikes, bolts, and lag screws should, whenever possible, be hot-dipped galvanized. With sheet metal clips and hangers, the special nails used should also be galvanized. Regular inspection, maintenance, and replacement of corroded metal parts is necessary when steel is used in the coastal environment. Steel rods used to reinforce concrete or masonry piles or piers require special precautions to prevent saltwater from reaching the steel through hairline cracks in concrete or through masonry joints. This is discussed below.

The American Iron and Steel Institute, 1000 Sixteenth Street, Washington, D.C. 20036, can provide specific guidelines.

### **Concrete and Masonry**

The durability of reinforced concrete and masonry block can be improved by the use of chemical additives mixed with the concrete and mortar and by special treatments and coatings. Additives are numerous and vary from those that will prevent spalling due to freezing to those that will improve strength. Surface treatments and coatings, such as silicone and epoxy paints, can be used to reduce water absorption and penetration and to prevent damage by airborne pollutants. Guidance in the use of concrete and masonry can be obtained from the Portland Cement Association, Old Orchard Road, Skokie, Illinois 60076, and the National Concrete Masonry Association, P.O. Box 781, Herndon, Virginia 22070.

### **INSULATION**

Like exposed walls of conventional structures, the exposed floor of elevated residences must be insulated against heat losses and heat gains. Depending on the climate, two factors should be considered. First, elevating a building will expose plumbing; such plumbing must be insulated against



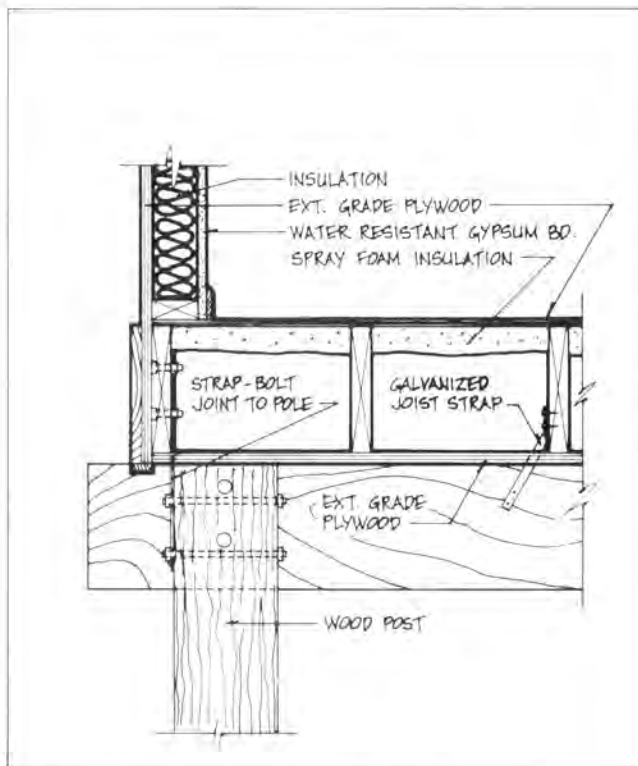


Figure 4.51. Insulated Floor Section, Wood Post Foundation

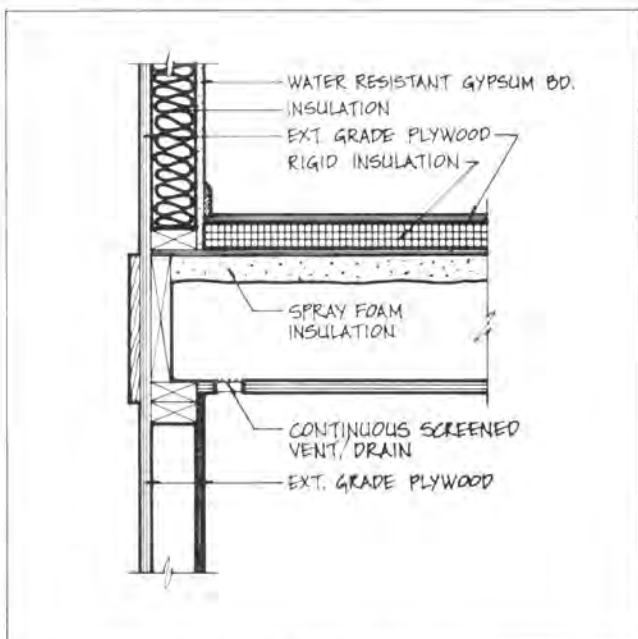


Figure 4.52. Insulated Floor Section, Foundation Wall

freezing. In extremely cold climates, heating cables may be necessary with the insulation. Second, insulated floor decks may be subject to floodwaters and should therefore have either impermeable, closed-pore insulation able to withstand water submersion or insulation that can be replaced economically (Figures 4.51 through 4.53).

## BREAKAWAY WALLS

As indicated in *Design and Construction Manual for Residential Buildings in Coastal High Hazard Areas*, cited in the Preface, the area under an elevated structure in a V Zone must be free of obstructions or be constructed with breakaway walls (e.g., latticework) designed to collapse under stress without jeopardizing the structural support of the building (Figure 4.54). Loads from flood waters and waterborne debris are critical considerations in designing breakaway walls.

## RETROFITTING EXISTING STRUCTURES

Existing residential structures in flood hazard areas can often be raised in-place to a higher elevation to reduce their susceptibility to flood damage. The principal consideration in raising existing structures is often the cost; generally, the technology exists to raise almost any structure, even multistory buildings, but the cost increases as the difficulty increases.

Residential structures have been satisfactorily raised up to nine feet. Aesthetics, intended use, needed flood elevation, and structural stability influence the height selected. Generally, the additional cost to raise a structure an additional foot or so is small compared to the initial set-up cost.

The new foundation for an existing structure should be selected and designed as discussed earlier.

Raising in-place is generally feasible for structures that are 1) accessible below the first floor for placement of jacks and beams, 2) light enough to



be jacked with conventional house moving equipment, 3) small enough that they can be raised in one piece, and 4) strong enough to withstand the stress of the raising process.

Wood frame residential and light commercial structures with first floors above the ground (normally with an 18-inch crawl space beneath the first floor) are particularly suited for raising. Wood frame structures with basements below the first floor are also accessible and lightweight; however, raising the superstructure does not protect the basement, and the basement should be filled with a granular material to provide structural stability for the walls. Brick, brick veneer, and masonry structures, while heavier and more difficult to handle, can also be raised.

Utility equipment located in a basement can often be moved to a higher room, such as an upstairs closet, or an attic. It is important to ensure that the closet or attic floor can support the weight of the equipment. If necessary, an elevated addition can be built to house a furnace, hot water heater, and other equipment formerly housed in a basement. Protecting utility equipment in this way can be useful even if the house itself cannot or need not be raised.

Raising a structure usually involves the following steps:

- Disconnect all plumbing, wiring, and utilities that cannot be raised with the structure.
- Place steel beams and hydraulic jacks beneath the structure and raise to desired elevation.
- Extend existing foundation walls and piers or construct new foundation.
- If a basement exists, remove water heater, furnace, etc., and fill basement with granular material to support basement walls.
- Lower the structure onto the extended or new foundation.
- Adjust walks, steps, ramps, plumbing, and utilities and regrade site as desired.
- Reconnect all plumbing, wiring, and utilities.
- Insulate exposed floor to reduce heat loss and protect plumbing, wiring, utilities and insulation from possible water damage.

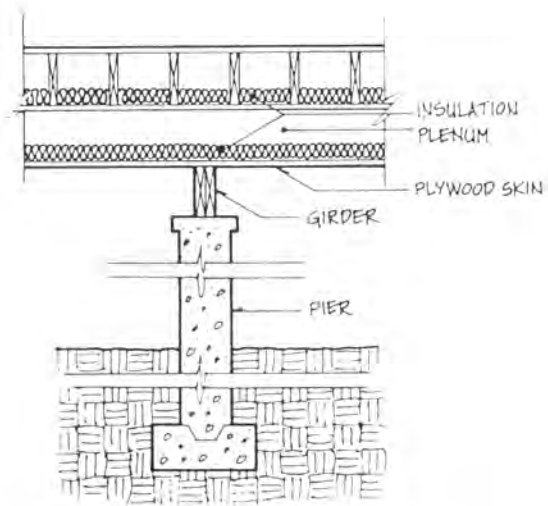


Figure 4.53. Double-Insulated Floor Plenum, Pier Foundation



Figure 4.54. Breakaway Walls

# COST ANALYSIS

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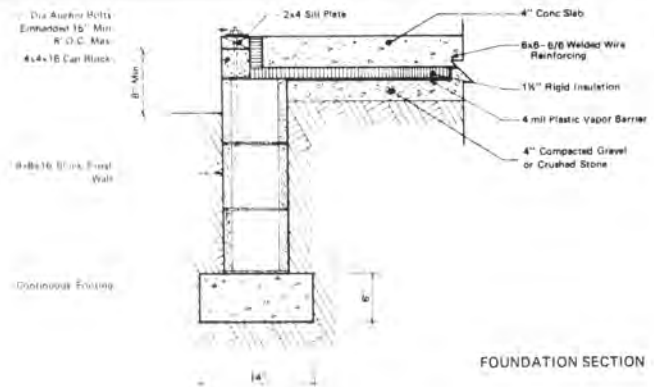
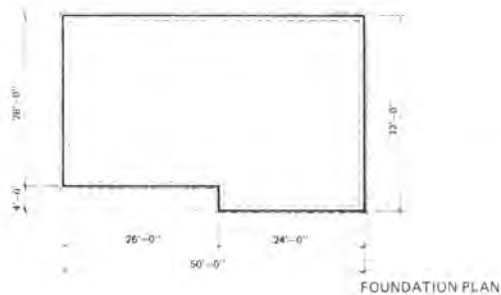


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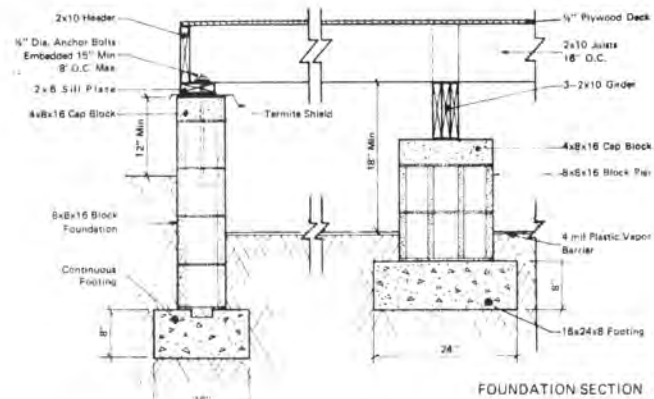
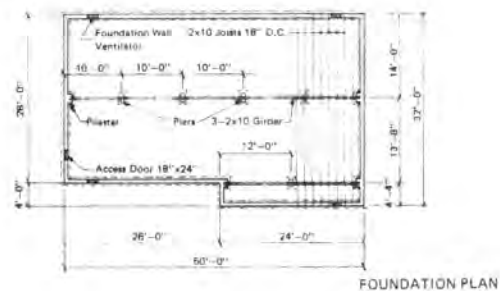
Once a community decides that the economic risk and environmental impact of developing floodplain land for residential use is acceptable, the dollar cost of that development must be evaluated. Two factors bear significantly on any such evaluation: first, the net cost of construction that meets the standards of the National Flood Insurance Program (NFIP) in light of the potential and unpredictable hazard of flooding and the losses that may ensue; second, the cost differentials between construction on elevated foundations and conventional building methods. (Note that standards adapted by local jurisdictions are often more stringent than the NFIP's.)

Repeated studies have shown that the savings that can be realized over the lifetime of a structure by building on a raised foundation are usually considerable when compared with the one-time increase in construction costs for an elevated foundation. This is largely because the one-time foundation costs are generally only five or six percent of the total cost of a residential structure, while the flood insurance savings that can be achieved over the life of a structure by elevating it can be considerable.

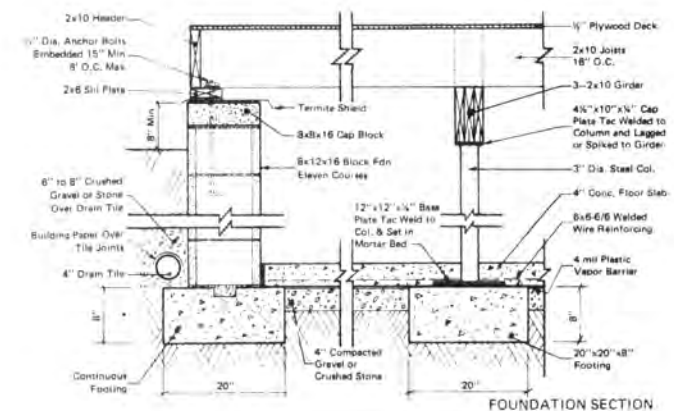
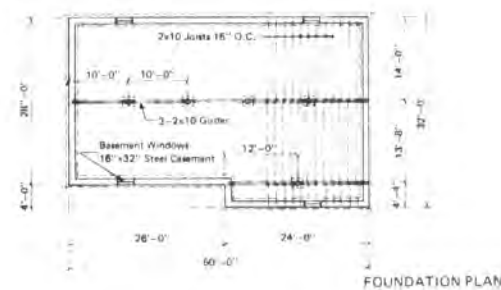
The economic cost to the individual of building a home in the floodplain consists of both flood damages that will occur and the costs of whatever measures are taken to mitigate such damages. The cost of flood damages to the homeowner may be partially shifted to federal, state, and local government through low-interest loans and tax deductions for losses incurred. In communities participating in the NFIP, the owner of a new home can purchase flood insurance. Essentially, flood insurance allows the homeowner to spread the flood risk to others facing the same hazards and, more importantly, permits one to pay for expected flood losses, which are unpredictable as to size and time of occurrence, in predictable annual payments. These are more manageable than unexpected flood losses, especially if more than one large flood happens to occur in a very short time.



**SLAB-ON-GRADE \$4.61 per square foot**



**CRAWL SPACE \$5.13 per square foot**



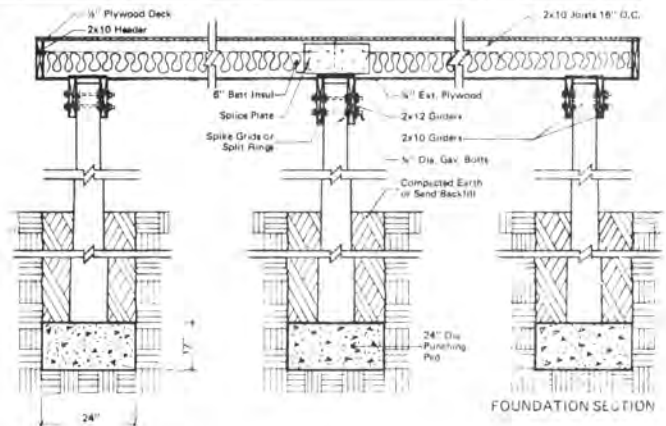
**BASEMENT \$11.01 per square foot**

Figure 5.1. Conventional Foundations (Estimates are spring 1983.)

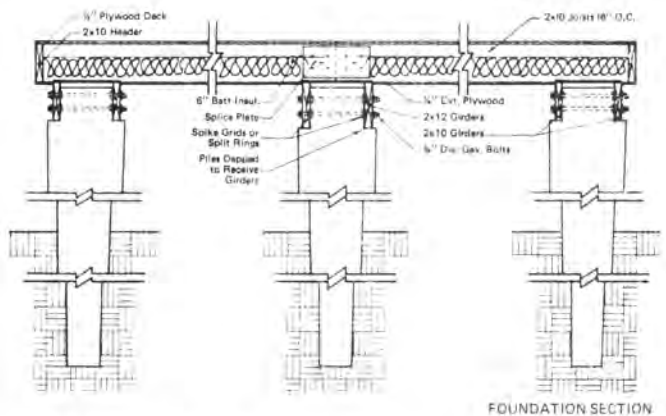
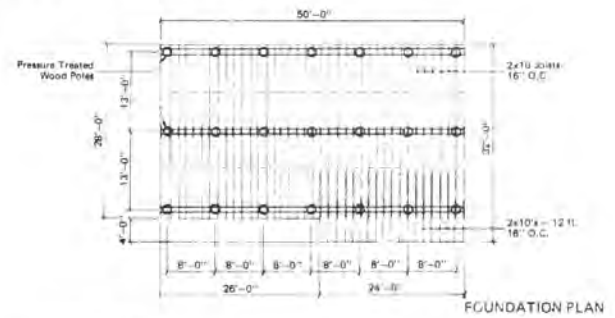
## COST COMPARISON APPROACH

The costs of post, pile, and pier foundations are compared here to each other and to the costs of conventional slab, crawl space, and basement foundations. Cost data and estimating forms are provided for roughly estimating one's particular foundation costs.

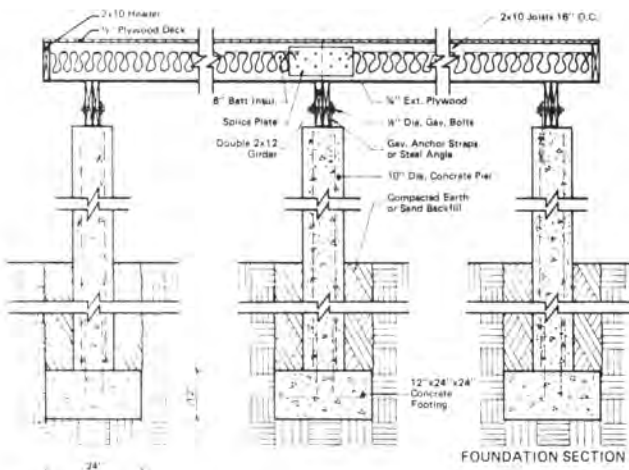
1. *Slab-on-grade, crawl space, and basement foundations* were selected as three of the most common types of residential foundations, and detailed drawings of them were prepared (Figure 5.1). Detailed drawings were also prepared for the three most typical elevation foundation types. These are post, pile, and pier foundations (Figure 5.2). (Regarding use of earth fill, see below.)



WOOD POST \$6.96 per square foot



WOOD PILE \$6.58 per square foot



CONCRETE PIER \$7.08 per square foot

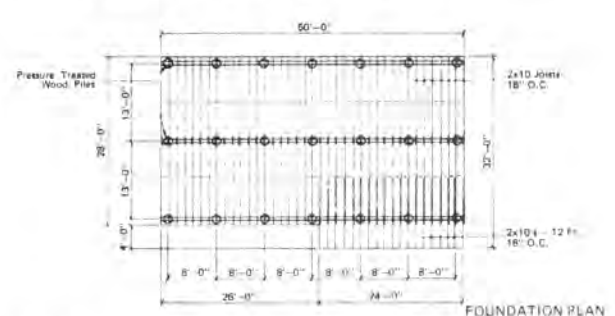
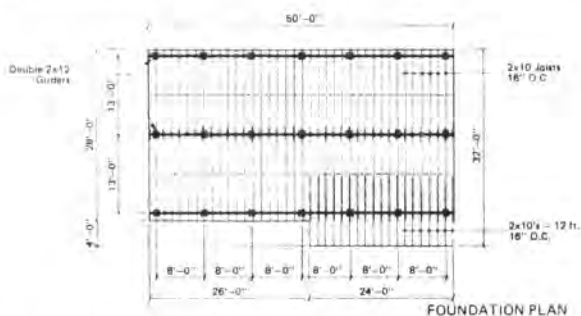


Figure 5.2. Elevated Foundations (Estimates are spring 1983.)

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**Conventional Foundations**

|               |                     |
|---------------|---------------------|
| Slab-on-Grade | \$4.61 per sq. ft.  |
| Crawl Space   | \$5.13 per sq. ft.  |
| Basement      | \$11.01 per sq. ft. |

**Elevated Foundations**

|               |                    |
|---------------|--------------------|
| Wood Post     | \$6.96 per sq. ft. |
| Wood Pile     | \$6.58 per sq. ft. |
| Concrete Pier | \$7.08 per sq. ft. |

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Estimates—Spring 1983

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2. The estimates are summarized in Figure 5.3. They are based on the foundation and deck of a 1,500-square-foot house, 28'x50', with a small offset. The total cost of this house is approximately \$60,000, excluding land. All estimates were based on FHA construction practices.
3. Using data from this cost sampling, the average cost of each conventional foundation type is compared to the average cost of each elevated foundation type. This comparison is done in two ways: first, each foundation as a percentage of the cost of the *entire* house (conventional foundations were established as base 100) and, second the dollar increase in the cost of the foundation above.

Figure 5.3. Foundation Cost Estimates

|                                       | Elevated Foundations | Conventional Foundations |              |          |
|---------------------------------------|----------------------|--------------------------|--------------|----------|
|                                       |                      | Slab on Grade            | Crawl Spaces | Basement |
| % Increase of Total House Cost        | Wood Post            | +5.9                     | +4.6         | -10.1    |
|                                       | Wood Pile            | +4.9                     | +3.6         | -11.1    |
|                                       | Concrete Pier        | +6.2                     | +4.9         | -9.8     |
| Dollar Increase, Foundation Cost Only | Wood Post            | \$3,525                  | \$2,745      | -\$6,075 |
|                                       | Wood Pile            | \$2,955                  | \$2,175      | -\$6,645 |
|                                       | Concrete Pier        | \$3,707                  | \$2,925      | -\$5,895 |

Figure 5.4 Cost Differentials, Conventional Vs. Elevated Foundations, for House Costing \$60,000, Excluding Land.



4. Figure 5.5 graphically compares the cost of constructing the different types of foundations at various elevations. Note that increasing the elevation increases costs at a substantial rate only in the case of the fill option (which is based on the availability of usable fill material on the site).

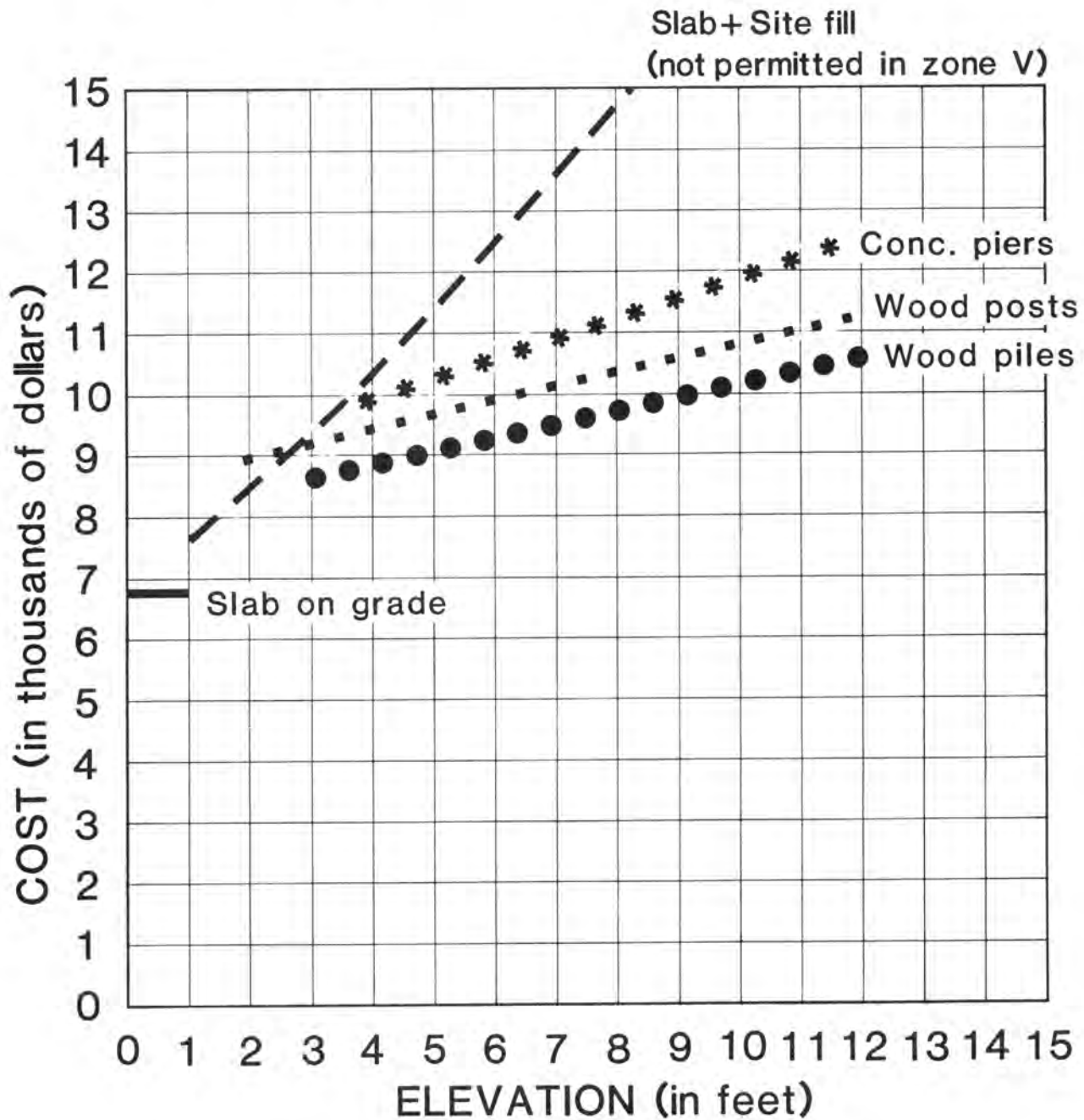


Figure 5.5. Relative Costs of Foundations Elevated to Different Heights

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## **Fill**

Fill can often be used in A Zones to elevate conventional foundations such as slab-on-grade. The cost of this approach varies widely, depending on the availability, quality, and unit cost of fill as well as the height and compaction necessary. Local building officials or soils engineers should be consulted to evaluate local conditions.

## **COST COMPARISON CAVEATS**

The comparative cost data given above do not take into account a number of factors that can affect either basic construction costs or long-term insurance costs.

### **Insurance Costs**

Insurance rates under the NFIP vary greatly depending on the elevation of a building and other features related to flood safety. Differences in these rates can overshadow the construction cost differentials discussed in this chapter, and should be considered carefully in making design decisions.

### **Design Assumptions**

Each house elevated on piles, posts, and piers was assumed to have 21 foundation elements. In addition, each element was assumed to be an average length that included the length below grade and the length between grade and the structure. These lengths are 16 feet for piles, 14 feet for posts, and 15 feet for piers. In practice, both the number and length of foundation elements will vary depending on soil conditions, expected flood levels, etc.

### **Earthquakes**

Constructing elevated foundations in earthquake areas may require additional structural expenditures that should be noted in cost estimates. Local building officials or a structural engineer should be consulted to evaluate local conditions.

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## **Stairs and Utilities**

Elevating a residence may result in increased cost for stairs and for utilities that must be elevated above grade. These costs were not considered in the estimates presented here since they vary with height of elevation, cost assignment, i.e., who pays for installation of utilities, and elevation method.

## **Regional Cost Variations**

The cost data presented above are based on national averages, and do not take into account regional cost variations.

## **Cost Inflation**

Building costs are difficult to predict because of the tendency for the cost of basic construction commodities—lumber, concrete, and steel—to fluctuate and to vary relative to each other. The costs here are estimated using data for the spring of 1983.

## **Non-Cost Considerations**

Cost is not the only determinant for selecting the material and method for elevating. Market acceptance (buyers and banks), architectural design integration, climatic conditions, site conditions, and anticipated flood hazards should also be considered.

## **ESTIMATING FORMS**

The forms on the following pages can be used for making cost estimates for conventional and elevated foundations.

## SLAB-ON-GRADE

ESTIMATING FORM  
TO DETERMINE LOCAL COSTS

Compute the following and enter:

\_\_\_\_\_ *Square Footage of Floor Area*  
 \_\_\_\_\_ *Lineal Footage of Perimeter*  
 \_\_\_\_\_ *Square Footage of Foundation Wall*

Enter you costs (combine labor and material) and extend:

*Layout house on lot* \_\_\_\_\_ = \$ \_\_\_\_\_

*Trench for footing* \_\_\_\_\_ x \_\_\_\_\_ LF = \$ \_\_\_\_\_

*Place footings* \_\_\_\_\_ x \_\_\_\_\_ LF = \$ \_\_\_\_\_

*Lay-up or form & pour  
foundation wall* \_\_\_\_\_ x \_\_\_\_\_ SF = \$ \_\_\_\_\_

*Fill & grade for slab* \_\_\_\_\_ x \_\_\_\_\_ SF = \$ \_\_\_\_\_

*Place vapor barrier, wire  
mesh & insulation* \_\_\_\_\_ x \_\_\_\_\_ SF = \$ \_\_\_\_\_

*Place & finish slab* \_\_\_\_\_ x \_\_\_\_\_ SF = \$ \_\_\_\_\_

*Grand Total* \_\_\_\_\_ \$ \_\_\_\_\_

## CRAWL SPACE

ESTIMATING FORM  
TO DETERMINE LOCAL COSTS

Compute the following and enter:

\_\_\_\_\_ *Square Footage of Floor Area*  
 \_\_\_\_\_ *Lineal Footage of Perimeter*  
 \_\_\_\_\_ *Square Footage of Foundation Wall*  
 \_\_\_\_\_ *Number of Piers*

Enter your costs (combine labor and material) and extend:

|  |               |                       |
|--|---------------|-----------------------|
| <i>Layout house on lot</i>                         |               | = \$ _____            |
| <i>Trench for footing</i>                          | _____ x _____ | <i>LF</i> = \$ _____  |
| <i>Place footings</i>                              | _____ x _____ | <i>LF</i> = \$ _____  |
| <i>Lay-up or form and pour<br/>foundation wall</i> | _____ x _____ | <i>SF</i> = \$ _____  |
| <i>Place pier footings</i>                         | _____ x _____ | <i>Ea.</i> = \$ _____ |
| <i>Lay-up or form and<br/>pour piers</i>           | _____ x _____ | <i>Ea.</i> = \$ _____ |
| <i>Backfill</i>                                    | _____ x _____ | <i>CY</i> = \$ _____  |
| <i>Floor Girder</i>                                | _____ x _____ | <i>LF</i> = \$ _____  |
| <i>Floor Framing</i>                               | _____ x _____ | <i>SF</i> = \$ _____  |
| <i>Insulation &amp; sealer</i>                     | _____ x _____ | <i>SF</i> = \$ _____  |
| <i>Subfloor</i>                                    | _____ x _____ | <i>SF</i> = \$ _____  |
| <i>Place floor slab</i>                            | _____ x _____ | <i>SF</i> = \$ _____  |
| <br><i>Grand Total</i>                             |               | <br>\$ _____          |

# BASEMENT

# ESTIMATING FORM TO DETERMINE LOCAL COSTS

Compute the following and enter:

\_\_\_\_\_ Square Footage of Floor Area  
 \_\_\_\_\_ Lineal Footage of Perimeter  
 \_\_\_\_\_ Square Footage of Basement Wall Area  
 \_\_\_\_\_ Number of Basement Support Columns

Enter your costs (combine labor and materials) and extend:

|  |               |     |            |
|--|---------------|-----|------------|
| Layout house on lot                      |               |     | = \$ _____ |
| Excavation & spoil removal               | _____ x _____ | SF  | = \$ _____ |
| Place footings                           | _____ x _____ | LF  | = \$ _____ |
| Place pier footings                      | _____ x _____ | Ea. | = \$ _____ |
| Lay-up or form & pour<br>foundation wall | _____ x _____ | SF  | = \$ _____ |
| Parge wall                               | _____ x _____ | SF  | = \$ _____ |
| Set drain tile                           | _____ x _____ | LF  | = \$ _____ |
| Backfill                                 | _____ x _____ | CY  | = \$ _____ |
| Place vapor barrier<br>and wire mesh     | _____ x _____ | SF  | = \$ _____ |
| Place and finish<br>floor slab           | _____ x _____ | SF  | = \$ _____ |
| Place girder                             | _____ x _____ | LF  | = \$ _____ |
| Frame Floor                              | _____ x _____ | SF  | = \$ _____ |
| Place subfloor                           | _____ x _____ | SF  | = \$ _____ |

Grand Total \$ \_\_\_\_\_



## WOOD POST

ESTIMATING FORM  
TO DETERMINE LOCAL COSTS

Compute the following and enter:

\_\_\_\_\_ *Square Footage of Floor Area*  
\_\_\_\_\_ *Lineal Footage of Girders*  
\_\_\_\_\_ *Number of Posts*

Enter your costs (combine labor and material) and extend:

*Layout house on lot* \_\_\_\_\_ = \$ \_\_\_\_\_

*Auger or dig post holes  
and remove spoil* \_\_\_\_\_ x \_\_\_\_\_ Qty = \$ \_\_\_\_\_

*Place concrete punching  
pad* \_\_\_\_\_ x \_\_\_\_\_ Qty = \$ \_\_\_\_\_

*Place poles* \_\_\_\_\_ x \_\_\_\_\_ Qty = \$ \_\_\_\_\_

*Backfill poles and plumb* \_\_\_\_\_ x \_\_\_\_\_ Qty = \$ \_\_\_\_\_

*Set girder* \_\_\_\_\_ x \_\_\_\_\_ LF = \$ \_\_\_\_\_

*Frame floor* \_\_\_\_\_ x \_\_\_\_\_ SF = \$ \_\_\_\_\_

*Place insulation & sealer* \_\_\_\_\_ x \_\_\_\_\_ SF = \$ \_\_\_\_\_

*Place subfloor* \_\_\_\_\_ x \_\_\_\_\_ SF = \$ \_\_\_\_\_

*Grand Total* \_\_\_\_\_ = \$ \_\_\_\_\_

## WOOD PILE

ESTIMATING FORM  
TO DETERMINE LOCAL COSTS

Compute the following and enter:

\_\_\_\_\_ *Square Footage of Floor Area*  
\_\_\_\_\_ *Lineal Footage of Girders*  
\_\_\_\_\_ *Number of Piles*  
\_\_\_\_\_ *Total Lineal Footage of Piles*

Enter your costs (combine labor and material) and extend:

*Layout house on lot* \_\_\_\_\_ = \$ \_\_\_\_\_

*Bring pile-driving equipment to site* \_\_\_\_\_ x \_\_\_\_\_ = \$ \_\_\_\_\_

*Furnish and drive piles* \_\_\_\_\_ x \_\_\_\_\_ *LF* = \$ \_\_\_\_\_

*Set girder* \_\_\_\_\_ x \_\_\_\_\_ *LF* = \$ \_\_\_\_\_

*Frame floor* \_\_\_\_\_ x \_\_\_\_\_ *SF* = \$ \_\_\_\_\_

*Place insulation and sealer* \_\_\_\_\_ x \_\_\_\_\_ *SF* = \$ \_\_\_\_\_

*Place subfloor* \_\_\_\_\_ x \_\_\_\_\_ *SF* = \$ \_\_\_\_\_

*Grand Total* \_\_\_\_\_ \$ \_\_\_\_\_

**CONCRETE PIER****ESTIMATING FORM  
TO DETERMINE LOCAL COSTS**

Compute the following and enter:

\_\_\_\_\_ *Square Footage of Floor Area*  
\_\_\_\_\_ *Lineal Footage of Girder*  
\_\_\_\_\_ *Number of Piers*

Enter you costs (combine labor and material) and extend:

*Layout house on lot* \_\_\_\_\_ = \$ \_\_\_\_\_

*Auger or dig pier holes  
and remove spoil* \_\_\_\_\_ x \_\_\_\_\_ Qty = \$ \_\_\_\_\_

*Place concrete footing* \_\_\_\_\_ x \_\_\_\_\_ Qty = \$ \_\_\_\_\_

*Form & pour piers* \_\_\_\_\_ x \_\_\_\_\_ Qty = \$ \_\_\_\_\_

*Backfill* \_\_\_\_\_ x \_\_\_\_\_ Qty = \$ \_\_\_\_\_

*Set girder* \_\_\_\_\_ x \_\_\_\_\_ LF = \$ \_\_\_\_\_

*Frame floor* \_\_\_\_\_ x \_\_\_\_\_ SF = \$ \_\_\_\_\_

*Place insulation  
and sealer* \_\_\_\_\_ x \_\_\_\_\_ SF = \$ \_\_\_\_\_

*Place subfloor* \_\_\_\_\_ x \_\_\_\_\_ SF = \$ \_\_\_\_\_

*Grand Total* \_\_\_\_\_ \$ \_\_\_\_\_

# RESOURCE MATERIALS

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# Glossary

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## Base Flood Elevation (BFE)

The elevation for which there is a one-percent chance in any given year that flood levels will equal or exceed it (see *Special Flood Hazard Areas*). The BFE is determined by statistical analysis of stream-flow records for the watershed and rainfall and runoff characteristics in the general region of the watershed.

## Coastal High Hazard Area

The portion of a coastal floodplain that is subject to high velocity waters caused by tropical storms, hurricanes, northeasters, or tsunamis. Labeled V Zones on Flood Insurance Rate Maps, these areas experience breaking waves of three feet or more.

## Debris Impact Loads

Loads induced on a structure by solid objects carried by flood water. Debris can include trees, lumber, displaced sections of structures, tanks, runaway boats, and chunks of ice. Debris impact loads are difficult to predict accurately, yet reasonable allowances must be made for them in the design of potentially affected structures.

## Encroachment

Any physical object placed in a floodplain that hinders the passage of water or otherwise affects flood flows.

## Existing Construction

Those structures already existing or on which construction or substantial improvement was started prior to the effective date of a community's floodplain management regulations.

## Flood or Flooding

A general and temporary condition of partial or complete inundation of normally dry land areas. Flooding results from the overflow of inland or tidal waters or the unusual and rapid accumulation of surface water runoff from any source.

## Flood Insurance Rate Map (FIRM)

An official map of a community, issued or approved by the Federal Emergency Management Agency, that delineates both the special hazard areas and the risk premium zones applicable to the community. Zones are as follows:

**Zone A (unnumbered)** - special flood hazard area inundated by the 100-year flood; determined by approximate methods with no base flood elevation shown.

**Zones A1–A30** - special flood hazard area inundated by the 100-year flood; determined by detailed methods with base flood elevations shown.

**Zone B** - area between the limits of the 100-year flood and the 500-year flood, or certain areas subject to 100-year flooding with average depths less than 1 foot, or areas protected by levees from the base flood.

**Zone C** - area of minimal flooding; located outside the limits of the 500-year flood.

**Zone V (unnumbered)** - area subject to wave action, without base flood elevation shown.

**Zones V1–V30** - special flood hazard area of 100-year coastal flooding with velocity (wave action); base flood elevations shown.

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## **Floodplain**

Any normally dry land area that is susceptible to being inundated by water from any natural source. This area is usually low land adjacent to a river, stream, watercourse, ocean, or lake.

## **Floodplain Management**

The operation of a program of corrective and preventive measures for reducing flood damage, including but not limited to flood control projects, floodplain land-use regulations, flood-proofing of buildings, and emergency preparedness plans.

## **Floodway**

The channel of a river or watercourse and the adjacent land areas that must be reserved to discharge the one-percent-probability flood without cumulatively increasing the water surface elevation more than a designated height, generally one foot.

## **Hydrology**

The science of the behavior of water in the atmosphere, on the earth's surface, and underground.

## **Hydrodynamic Loads**

As flood water flows around a structure it imposes loads on the structure. These loads consist of frontal impact by the mass of moving water against the structure, drag effect along the sides of the structure, and eddies or negative pressure on the structure's downstream side.

## **Hydrostatic Loads**

Those loads or pressures resulting from the static mass of water at any point of flood water contact with a structure. They are equal in all directions and always act perpendicular to the surface on which they are applied. Hydrostatic loads can act vertically on structural members such as

floors, decks, and roofs, and can act laterally on upright structural members such as walls, piers, and foundations.

## **Mean Sea Level**

The average height of the sea for all stages of the tide, usually determined from hourly height observations over a nineteen-year period on an open coast or in adjacent waters having free access to the sea.

## **New Construction**

Structures on which construction or substantial improvement was started after the effective date of a community's floodplain management regulations.

## **One-Hundred Year Flood**

(See *Special Flood Hazard Areas*).

## **Permeability**

The property of soil or rock that allows passage of water through it.

## **Regulatory Floodway**

Any floodway referenced in a floodplain ordinance for the purpose of applying floodway regulations.

## **Special Flood Hazard Areas**

Areas in a community that have been identified as susceptible to a one-percent or greater chance of flooding in any given year. A one-percent probability flood is also known as the 100-year flood or the base flood.

## **Stillwater Elevations**

The elevation that the surface of the water would assume if all wave action were absent.



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### Storm Surge

A rise above normal water level on the open coast due to the action of wind stress and atmospheric pressure on reduction on the water surface.

### Substantial Improvement

Any repair, reconstruction, or improvement of a structure, the cost of which equals or exceeds 50 percent of the market value of the structure either (a) before the improvement is started or (b) if the structure has been damaged, and is being restored, before the damage occurred.

### Watershed

An area from which water drains to a single point; in a natural basin, the watershed is the area contributing flow to a given place or stream.

### Wave Height

The vertical distance between a wave crest and the preceding trough.

### Wave Crest Elevation

The elevation of the 100-year storm surge plus wave height.



# Sources of Design Information

## Regulatory Information

| Information Required   | Purpose or Implications of Data  | Possible Forms of Data   | Potential Sources of Data  |
|--|--|--|--|
| <ul style="list-style-type: none"> <li>National Flood Insurance Program (NFIP)</li> </ul>                      | <ul style="list-style-type: none"> <li>Requires local communities to implement floodplain regulations.</li> <li>Sets minimum standards for floodplain regulations.</li> <li>Prohibits federal funding for projects in violation of floodplain regulations.</li> <li>Prohibits federal loan guarantees for projects in violation of floodplain regulations.</li> <li>Establishes flood insurance rate differentials for properties in flood-prone areas.</li> </ul> | <ul style="list-style-type: none"> <li>Program regulations</li> <li>Insurance rate information and tables</li> <li>Flood Insurance Studies</li> <li>Flood Maps</li> <li>Section 1362 Guidelines</li> </ul> | <ul style="list-style-type: none"> <li>Federal Insurance Administration</li> <li>Federal Emergency Management Agency</li> <li>State Floodplain Management Coordinating Agency</li> <li>Local Government Planning Agency</li> </ul>                           |
| <ul style="list-style-type: none"> <li>Local Government Planning Programs</li> </ul>                           | <ul style="list-style-type: none"> <li>Implements floodplain regulations</li> <li>Determines local floodplain regulations based on NFIP guidelines (includes zoning and subdivision regulations, performance standards, Planned Unit Development ordinances, building codes, etc.)</li> <li>Note: Local regulations can be set at a higher standard than NFIP minimum standards, depending on local needs and circumstances.</li> </ul>                            | <ul style="list-style-type: none"> <li>Planning and Zoning Ordinances</li> <li>Zoning Maps</li> <li>Building Codes</li> </ul>  | <ul style="list-style-type: none"> <li>Local Government Planning Agency</li> <li>Local Government Engineer</li> <li>Building Code Officials</li> </ul>   |
| <ul style="list-style-type: none"> <li>State Floodplain and Coastal Zone Programs</li> </ul>                   | <ul style="list-style-type: none"> <li>Provides statewide floodplain development regulations and guidelines.</li> <li>Regulates development in coastal zones.</li> <li>Coordinates implementation of NFIP in local jurisdictions and in areas where multiple state agencies have an interest in flooding.</li> <li>Clearinghouse for Floodplain Management Information.</li> </ul>   | <ul style="list-style-type: none"> <li>State program regulations</li> <li>State development guidelines</li> </ul>  | <ul style="list-style-type: none"> <li>State Floodplain Management Coordinating Agency</li> <li>State Office of Coastal Zone Management</li> <li>State Office of Natural or Water Resources</li> </ul>   |
| <ul style="list-style-type: none"> <li>Regional Planning Restrictions or Guidelines</li> </ul>                 | <ul style="list-style-type: none"> <li>Can provide additional regulations and guidelines for regional jurisdictions.</li> <li>Coordinates activities of different agencies within the region.</li> <li>Source of information and, in some cases, technical assistance.</li> </ul>  | <ul style="list-style-type: none"> <li>Program regulations</li> <li>Development guidelines</li> </ul>  | <ul style="list-style-type: none"> <li>Regional Authorities (e.g., Tennessee Valley Authority, Appalachian Regional Commission, etc.)</li> <li>Regional Planning Commissions</li> <li>River Basin Commissions</li> </ul>                                     |
| <ul style="list-style-type: none"> <li>Federal Agency Requirements and Guidelines (other than NFIP)</li> </ul> | <ul style="list-style-type: none"> <li>May include regulations relating to development in flood-prone areas (e.g., Corps of Engineers permits for development on navigable rivers).</li> <li>May involve federal funding, the use of which is restricted in flood-prone areas.</li> <li>Projects may require federal approval for development in flood-prone areas (e.g., Environmental Impact Statements).</li> </ul>   | <ul style="list-style-type: none"> <li>Program regulations</li> </ul>  | <ul style="list-style-type: none"> <li>U.S. Army Corps of Engineers</li> <li>Environmental Protection Agency</li> <li>Federal Emergency Management Agency</li> <li>State Floodplain Management Coordinating Agency</li> <li>Local Planning Agency</li> </ul> |

## Hydrologic Data

| Information Required  | Purpose or Implications of Data  | Possible Forms of Data  | Potential Sources of Information  |
|---|--|---|---|
| <ul style="list-style-type: none"> <li>Flood Hazard Boundaries</li> </ul> | <ul style="list-style-type: none"> <li>Determines where floodplain regulations, insurance, and federal financing restrictions apply.</li> <li>Determines specific flood hazard zones.</li> <li>Determines variable flood insurance rate zones.</li> </ul>  | <ul style="list-style-type: none"> <li>Flood Hazard Boundary Maps</li> <li>Flood Insurance Rate Maps</li> <li>Flood Boundary and Floodway Maps</li> <li>Hydrologic Atlases</li> <li>Local Zoning Maps</li> <li>Flood Insurance Studies</li> </ul> | <ul style="list-style-type: none"> <li>Local Government Planning Agency</li> <li>Local Government Municipal Engineer</li> <li>State Floodplain Coordinating Agency</li> </ul> |
| <ul style="list-style-type: none"> <li>Flood Depths</li> </ul>            | <ul style="list-style-type: none"> <li>Indicates elevations at which flood damage is likely to occur.</li> <li>Determines appropriate building elevations for meeting floodplain regulations and flood insurance restrictions and rates.</li> <li>Indicates hydrostatic loads in flood-prone areas.</li> </ul> | <ul style="list-style-type: none"> <li>Flood Elevations</li> <li>Water Surface Profiles</li> <li>Stream and Coast Cross-sections</li> <li>Flood Insurance Studies</li> </ul>  | <ul style="list-style-type: none"> <li>State Office of Natural Resources</li> <li>Federal Insurance Administration</li> <li>Federal Emergency Management Agency</li> </ul>    |
| <ul style="list-style-type: none"> <li>Flood Water Velocity</li> </ul>    | <ul style="list-style-type: none"> <li>Determines hydrodynamic loads in flood-prone areas.</li> <li>Determines debris-impact loads in flood-prone areas.</li> <li>Indicates potential for erosion and slope deterioration.</li> </ul>  | <ul style="list-style-type: none"> <li>Floodplain Technical Studies</li> <li>Hydrologic Studies</li> <li>Flood Insurance Studies</li> </ul>   | <ul style="list-style-type: none"> <li>U.S. Army Corps of Engineers</li> <li>U.S. Geologic Survey</li> </ul>  |

|  |  |  |   |
|--|--|--|---|
| • Warning Time   | <ul style="list-style-type: none"> <li>Indicates importance of emergency evacuation as part of the design program</li> <li>Influences design of floodproofing techniques such as flood shields</li> <li>Influences design of drainage systems</li> <li>Influences design of wet floodproofing techniques</li> </ul>                | <ul style="list-style-type: none"> <li>Hydrographs</li> <li>Floodplain Technical Studies</li> <li>Historical Records</li> <li>Flood Insurance Studies</li> </ul> | <ul style="list-style-type: none"> <li>Regional Authorities               <ul style="list-style-type: none"> <li>Tennessee Valley Authority</li> <li>Appalachian Regional Commission</li> <li>River Basin Commissions</li> </ul> </li> <li>Hydrologic Engineering Consultants</li> <li>Surveys by Professional Staff</li> <li>U.S. Department of the Interior Water and Power Resources Service (operates west of the Mississippi River)</li> </ul> |
| • Duration of Flooding   | <ul style="list-style-type: none"> <li>Affects seepage into buildings and saturation of soils and building materials</li> <li>Affects the length of time facilities might be inaccessible or inoperable</li> <li>Affects building design relative to orientation, configuration, and choice of floodproofing techniques</li> </ul> | <ul style="list-style-type: none"> <li>Floodplain Technical Studies</li> <li>Historical Records</li> <li>Flood Insurance Studies</li> </ul>                      |   |
| • Frequency of Flooding  | <ul style="list-style-type: none"> <li>Influences site choice</li> <li>Affects choice of floodproofing techniques, especially those that require installation before every flood</li> <li>Indicates need for special access</li> </ul>   | <ul style="list-style-type: none"> <li>Floodplain Technical Studies</li> <li>Historical Records</li> </ul>   |   |
| • Climate and Weather  | <ul style="list-style-type: none"> <li>Indicates frequency and type of precipitation and, in turn, the type and magnitude of flooding that is likely</li> </ul>  | <ul style="list-style-type: none"> <li>Weather Service Records</li> <li>Historical Records</li> </ul>  |   |
| • Ground Water Level   | <ul style="list-style-type: none"> <li>Influences potential water pressure on footings, foundations, and floors</li> <li>Affects site design techniques for controlling water runoff</li> </ul>  | <ul style="list-style-type: none"> <li>Geologic Surveys</li> <li>Soil Analysis Reports</li> </ul>  |   |
| • Structural Flood Control Measures (e.g., dams, levees, channel improvements) | <ul style="list-style-type: none"> <li>Existing measures can affect site if the limits of the flood control device are exceeded</li> <li>Proposed measures can, when implemented, alter basic flood data</li> </ul>  | <ul style="list-style-type: none"> <li>Feasibility Studies</li> <li>Design Specifications</li> <li>Probability Reports</li> </ul>                                |   |

Hydrologic Data

| Information Required     | Purpose or Implications of Data   | Possible Forms of Data  | Potential Sources of Information  |
|--------------------------|---|---|---|
| • Physiographic Features | <ul style="list-style-type: none"> <li>Affects location and magnitude of flooding on the site</li> <li>Identifies areas of the site that should be avoided or protected</li> <li>Affects orientation, distribution, and density of built elements on the site</li> <li>Identifies physical constraints and advantages for site development</li> </ul>                               | <ul style="list-style-type: none"> <li>Topographic Maps</li> <li>Floodplain Technical Studies</li> <li>Site Surveys</li> </ul>              | <ul style="list-style-type: none"> <li>Local Government Planning Agency</li> <li>Local Government Municipal Engineer</li> <li>State Floodplain Coordinating Agency</li> <li>State Office for Natural Resources</li> <li>Soil Conservation Service, U.S. Department of Agriculture</li> <li>U.S. Geologic Survey</li> <li>Regional Authorities</li> <li>Hydrologic and Civil Engineering Consultants</li> <li>Surveys by Professional Staff</li> <li>U.S. Department of the Interior Water and Power Resources Service (operates west of the Mississippi River)</li> </ul> |
| • Topography             | <ul style="list-style-type: none"> <li>Influences siting of buildings</li> <li>Indicates erosion potential</li> <li>Indicates need for, and feasibility of using, fill material on the site</li> <li>Indicates appropriate site design techniques for controlling water runoff</li> </ul>   | <ul style="list-style-type: none"> <li>Topographic Maps</li> <li>Floodplain Technical Studies</li> <li>Site Surveys</li> </ul>              |   |
| • Soil Characteristics   | <ul style="list-style-type: none"> <li>Soil porosity influences the rate of water runoff and flooding potential</li> <li>Determines the feasibility and design specifications for use of fill material to elevate buildings, the use of backfill around foundations, and construction of earth berms</li> <li>Indicates required depth for footings, pilings, or columns</li> </ul> | <ul style="list-style-type: none"> <li>Soil Maps</li> <li>Soil Analysis Reports</li> <li>Site Surveys</li> </ul>                            |   |
| • Slope Stability        | <ul style="list-style-type: none"> <li>Affects choice of building sites, the use of fill material, and the design of foundations, footings, and pilings</li> <li>Influences erosion</li> <li>Indicates the need for terracing or ground cover to protect slopes</li> </ul>  | <ul style="list-style-type: none"> <li>Analysis of combined effects of topography and soil characteristics</li> <li>Site Surveys</li> </ul> |   |
| • Vegetation             | <ul style="list-style-type: none"> <li>Aids in control of water runoff and thus can be a factor in reducing flooding levels</li> </ul>  | <ul style="list-style-type: none"> <li>Site Surveys</li> </ul>  |   |
| • Water Storage          | <ul style="list-style-type: none"> <li>Aids in control of water runoff and thus can be a factor in reducing flooding levels</li> <li>Recharges ground water supplies</li> </ul>   | <ul style="list-style-type: none"> <li>Geologic, soil, and hydrologic surveys</li> <li>Site Surveys</li> </ul>                              |   |

Site Characteristics

# FEMA Regional Offices

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The Federal Emergency Management Agency (FEMA) was created in 1978 to provide a single point of accountability for all federal activities related to disaster mitigation and emergency preparedness and response. It was established as an independent agency in the executive branch to consolidate a variety of existing agencies and offices performing related functions. The Federal Insurance Administration (FIA), formerly a part of the Department of Housing and Urban Development, is only responsible for administering the National Flood Insurance Program. This responsibility includes assisting state and local governments in the implementation of flood-plain management programs and providing information on flooding to communities and individuals. Regional offices are the primary means by which FEMA's programs are carried out at the state and local level.



## Region I

Connecticut, Maine,  
Massachusetts, New Hampshire,  
Rhode Island &  
Vermont

J.W. MacCormack Post  
Office Building, Room 442  
Boston, Massachusetts 02109  
(617) 223-9540

## Region II

New Jersey, New York,  
Puerto Rico & Virgin Islands

26 Federal Plaza  
Rm. 1349  
New York, New York 10278  
(212) 264-8980

## Region III

Delaware, District of  
Columbia, Maryland,  
Pennsylvania, Virginia &  
West Virginia

Liberty Square Building  
105 South Seventh Street  
Philadelphia, Pennsylvania  
19106  
(215) 597-9416

## Region IV

Alabama, Florida, Georgia,  
Kentucky, Mississippi,  
North Carolina, South  
Carolina & Tennessee

1375 Peachtree Street, N.W.  
Suite 700  
Atlanta, Georgia 31792  
(404) 347-2400

|                   |   |                    |   |
|-------------------|---|--------------------|---|
| <b>Region V</b>   | Illinois, Indiana, Michigan,<br>Minnesota, Ohio &<br>Wisconsin<br><br>300 South Wacker Drive<br>24th Floor<br>Chicago, Illinois 60606<br>(312) 353-8661       | <b>Region VIII</b> | Colorado, Montana, North<br>Dakota, South Dakota, Utah<br>& Wyoming<br><br>Federal Regional Center<br>Building 710, Box 25267<br>Denver, Colorado 80225<br>(303) 235-4811 |
| <b>Region VI</b>  | Arkansas, Louisiana, New<br>Mexico, Oklahoma & Texas<br><br>Federal Regional Center<br>Rm. 206<br>800 North Loop 288<br>Denton, Texas 76201<br>(817) 387-5811 | <b>Region IX</b>   | Arizona, California, Hawaii<br>& Nevada<br><br>Building 105<br>Presidio of San Francisco<br>San Francisco, California<br>94129<br>(415) 556-8794                          |
| <b>Region VII</b> | Iowa, Kansas, Missouri &<br>Nebraska<br><br>911 Walnut Street<br>Room 300<br>Kansas City, Missouri 64106<br>(816) 374-5912                                    | <b>Region X</b>    | Alaska, Idaho, Oregon &<br>Washington<br><br>Federal Regional Center<br>130 228th Street, S.W.<br>Bothell, Washington 98011<br>(206) 481-8800                             |



Federal Emergency Management Agency  
Regional Offices and Boundaries

# State Coordinating Offices for the NFIP

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Each of the states, in cooperation with the Federal Emergency Management Agency, has designated a specific agency to coordinate implementation of the National Flood Insurance Program. This agency provides a link between federal, state, and local levels of government and between different state agencies with flood-related responsibilities. The designated agency will typically be a department responsible for natural resources, emergency services, or physical development, and is a focal point for information relating to flood insurance and floodplain management. It can be an important source of physical data, information on community eligibility for flood insurance, relevant state regulations, references to other agencies, and, in some instances, technical assistance. The authority of each state's coordinating agency varies, and can best be determined through direct contact.

**Alabama** Department of Economics  
and Community Affairs  
State Planning Division  
P.O. Box 2939  
3465 Norman Bridge Road  
Montgomery, Alabama 36105  
(205) 284-8735

**Alaska** Department of Community  
& Regional Affairs  
Division of Municipal  
and Regional Affairs  
949 East 36 Avenue  
Suite 400  
Anchorage, Alaska 99508  
(907) 561-8586

**Arizona** Department of Water  
Resources  
Flood Control Branch  
99 E. Virginia 2nd Floor  
Phoenix, Arizona 85004  
(602) 255-1566

**Arkansas** Soil & Water  
Conservation Commission  
#1 Capitol Mall  
Suite 2D  
Little Rock, Arkansas 72201  
(501) 371-1611

**California** Department of Water  
Resources  
P.O. Box 388  
Sacramento, California 95802  
(916) 445-6249

**Colorado** Colorado Water  
Conservation Board  
State Centennial Building,  
Room 823  
1313 Sherman Street  
Denver, Colorado 80202  
(303) 866-3441

**Connecticut** Dept. of Environmental  
Protection  
165 Capitol Avenue  
Hartford, Connecticut 06106  
(203) 566-7245

**Delaware** Dept. of Natural &  
Environmental Control  
Division of Soil & Water  
Conservation  
Edward Tatnall Building  
P.O. Box 1401  
Dover, Delaware 19901  
(302) 736-4411

**District of  
Columbia** Department of Consumer  
Regulatory Affairs  
614 H Street, N.W.  
Washington, D.C. 20001  
(202) 727-7577



|                 |   |                      |   |
|-----------------|---|----------------------|---|
| <b>Florida</b>  | Department of Community Affairs<br>Div. of Resource Planning and Management<br>2571 Executive Ctr. Circle East<br>Tallahassee, Florida 32301<br>(904) 488-9210                          | <b>Iowa</b>          | Iowa Natural Resources Council<br>Wallace State Office Building<br>Des Moines, Iowa 50319<br>(515) 281-5029   |
| <b>Georgia</b>  | Georgia Department of Natural Resources,<br>Environmental Protection Division<br>19 Martin Luther King, Jr. Dr., S.W., Room 400<br>Atlanta, Georgia 30334<br>(404) 656-3214             | <b>Kansas</b>        | Kansas State Board of Agriculture<br>Division of Water Resources<br>109 Southwest Ninth Street<br>Topeka, Kansas 66612<br>(913) 296-3717              |
| <b>Guam</b>     | Office of Civil Defense<br>Post Office Box 2877<br>Agana, Guam 96910<br>011-671-477-9841  | <b>Kentucky</b>      | Department of Natural Resources<br>Division of Water<br>18 Reilly Road<br>Fort Boone Plaza<br>Frankfort, Kentucky 40601<br>(502) 564-3410             |
| <b>Hawaii</b>   | Hawaii Board of Land and Natural Resources<br>P.O. Box 373<br>Honolulu, Hawaii 96809<br>(808) 548-7539  | <b>Louisiana</b>     | Louisiana Department of Urban & Community Affairs<br>P.O. Box 44455, Capitol Station<br>Baton Rouge, Louisiana 70804<br>(504) 925-3730                |
| <b>Idaho</b>    | Department of Water Resources<br>State House<br>Boise, Idaho 83720<br>(208) 334-4470  | <b>Maine</b>         | Bureau of Civil Emergency Preparedness<br>State House<br>187 State Street<br>Augusta, Maine 04330<br>(207) 289-3154                                   |
| <b>Illinois</b> | Illinois Department of Transportation<br>Division of Water Resources<br>Local Flood Plain Programs<br>300 North State Street,<br>Room 1010<br>Chicago, Illinois 60610<br>(312) 793-3864 | <b>Maryland</b>      | Maryland Water Resources Administration<br>Flood Management Section<br>Tawes State Office Building D-2<br>Annapolis, Maryland 21401<br>(301) 269-3826 |
| <b>Indiana</b>  | Department of Natural Resources<br>608 State Office Building<br>Indianapolis, Indiana 46204<br>(317) 232-4160   | <b>Massachusetts</b> | Massachusetts Water Resources Commission<br>State Office Building<br>100 Cambridge Street<br>Boston, Massachusetts 02202<br>(617) 727-3267            |

**Michigan** Michigan Department of  
Natural Resources  
Water Management Division  
P.O. Box 30028  
Lansing, Michigan 48909  
(517) 373-3930

**Minnesota** Minnesota Department of  
Natural Resources  
Division of Waters  
444 LaFayette Road  
St. Paul Minnesota 55101  
(612) 296-9226

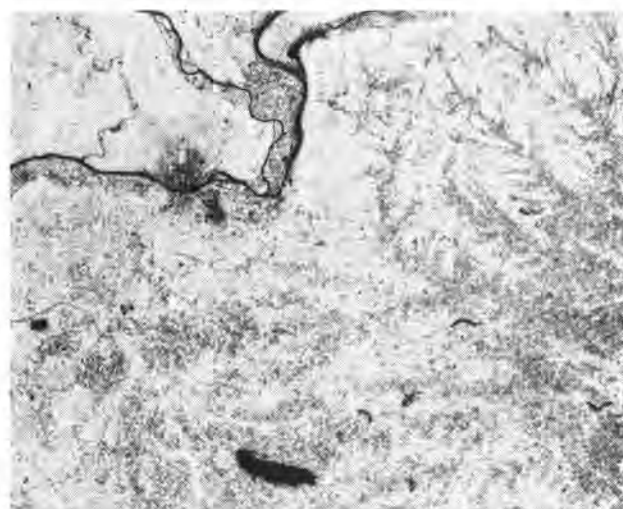
**Mississippi** Mississippi Research &  
Development Center  
3825 Ridgewood Road  
Jackson, Mississippi 39211  
(601) 982-6376

**Missouri** Department of Natural  
Resources  
1101 R. Southwest Blvd.  
P.O. Box 1368  
Jefferson City, Missouri  
65102  
(314) 751-4932

**Montana** Department of Natural  
Resources & Conservation  
32 South Ewing Street  
Helena, Montana 59601  
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**Nebraska** Nebraska Natural Resources  
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Lincoln, Nebraska 68509  
(402) 471-2081

**Nevada** Division of Emergency  
Management  
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Carson City, Nevada 89710  
(702) 885-4240



**New Hampshire** New Hampshire Office of  
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2½ Beacon Street  
Concord, NH 03301  
(603) 271-2231

**New Jersey** New Jersey Department of  
Environmental Protection  
Division of Water Resources  
P.O. Box CN 029  
Trenton, New Jersey 08625  
(609) 292-2296

**New Mexico** State Engineer  
Bataan Memorial Bldg.  
Santa Fe, New Mexico  
97501  
(505) 827-6140

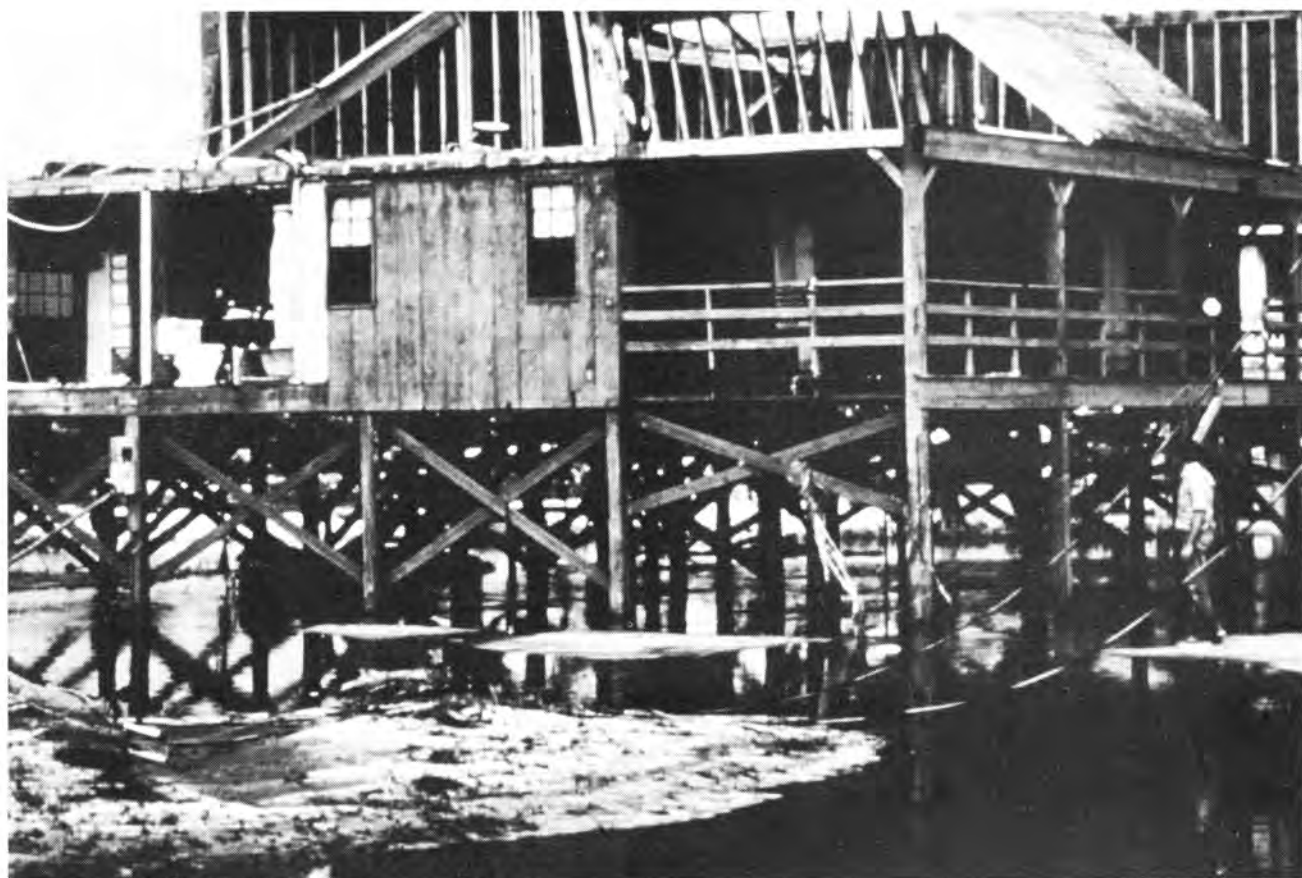
**New York** New York Department of  
Environmental  
Conservation  
Flood Protection Bureau  
50 Wolf Road-Room 422  
Albany, New York 12233  
(518) 457-3157

**North Carolina** North Carolina Department  
of Natural Resources &  
Community Development  
Division of Community  
Assistance  
512 North Salisbury Street  
P.O. Box 27687  
Raleigh, North Carolina  
27611  
(919) 733-2850



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|---------------------|---|-----------------------|---|
| <b>North Dakota</b> | State Water Commission<br>900 E. Boulevard<br>Bismarck, North Dakota<br>58501<br>(701) 224-2750                                   | <b>Puerto Rico</b>    | Puerto Rico Planning Board<br>P.O. Box 4119, Minillas<br>Station<br>D-Diego Avenue<br>Santurce, Puerto Rico 00940<br>(809) 726-7110   |
| <b>Ohio</b>         | Ohio Department of Natural<br>Resources<br>Flood Plain Planning Unit<br>Fountain Square<br>Columbus, Ohio 43224<br>(614) 265-6755 | <b>Rhode Island</b>   | Rhode Island Office of State<br>Planning<br>Statewide Planning Program<br>265 Melrose Street<br>Providence, RI 02907<br>(401) 277-2656  |
| <b>Oklahoma</b>     | Oklahoma Water Resources<br>Board<br>12th Floor Northeast<br>10th & Stonewall<br>Oklahoma City, OK 73105<br>(405) 271-2533        | <b>South Carolina</b> | South Carolina Water<br>Resources Commission<br>3830 Forest Drive<br>P.O. Box 4440<br>Columbia, SC 29240<br>(803) 758-2514  |
| <b>Oregon</b>       | Department of Land<br>Conservation and<br>Development<br>1175 Court Street, N.E.<br>Salem, Oregon 97310<br>(503) 378-2332         | <b>South Dakota</b>   | Department of Military and<br>Veterans Affairs<br>Division of Emergency and<br>Disaster<br>State Capitol<br>Pierre, South Dakota 57501<br>(605) 773-3231  |
| <b>Pennsylvania</b> | Department of Community<br>Affairs<br>551 Forum Building,<br>Room 317<br>Harrisburg, PA 17120<br>(717) 787-7400                   | <b>Tennessee</b>      | Department of Economic<br>and Community<br>Development<br>Division of Local Planning<br>1800 James K. Polk<br>Office Building<br>505 Deaderick Street<br>Nashville, Tennessee 37219<br>(615) 741-2211 |
|                     |   | <b>Texas</b>          | Texas Dept. of Water<br>Resources<br>P.O. Box 13087, Capitol<br>Station<br>1700 North Congress<br>Avenue<br>Austin, Texas 78711<br>(512) 475-2171   |
|                     |   | <b>Utah</b>           | Office of Comprehensive<br>Emergency Management<br>1543 Sunnyside Avenue<br>Salt Lake City, Utah 84108<br>(801) 533-5271  |

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|-----------------------|--|----------------------|--|
| <b>Vermont</b>        | Environmental Conservation Agency<br>Division of Water Resources<br>State Office Building<br>Montpelier, Vermont 05602<br>(802) 828-2761 | <b>West Virginia</b> | West Virginia Office of Emergency Services<br>Room EB-80<br>Capitol Building<br>Charleston, WV 25305<br>(304) 348-3831                     |
| <b>Virgin Islands</b> | Disaster Preparedness Office<br>Box 1208<br>St. Thomas, VI 00801<br>(809) 774-6555   | <b>Wisconsin</b>     | Department of Natural Resources<br>Flood Plain-Shoreline Management Section<br>P.O. Box 7921<br>Madison, Wisconsin 53707<br>(608) 266-1926 |
| <b>Virginia</b>       | Virginia State Water Control Board<br>P.O. Box 11143<br>Richmond, Virginia 23230<br>(804) 257-0075                                       | <b>Wyoming</b>       | Wyoming Disaster and Civil Defense Agency<br>P.O. Box 1709<br>Cheyenne, Wyoming 82003<br>(307) 777-7566                                    |
| <b>Washington</b>     | Department of Ecology<br>Mail Stop PV11<br>Olympia, Washington 98504<br>(206) 459-6288   |                      |  |



# Performance Criteria

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The following performance requirements and criteria identify a range of considerations that should be addressed during the design of residential structures for flood hazard areas. These performance criteria do not represent the entire range of items applicable to each requirement. Instead, a selective number of criteria have been presented.

The performance requirements and criteria are applicable to all structural materials and all construction methods used in flood hazard areas. Traditional or conventional construction solutions, as well as innovative techniques, are acceptable so long as the performance requirements and criteria are satisfied.

## DEFINITIONS

Terms important to proper interpretation of the performance requirements and criteria are defined as follows:

### Applicable Codes

The system of legal regulations adopted by a community setting forth standards for the construction, addition, modification, and repair of buildings and other structures for the purpose of protecting the health, safety and general welfare of the public.

### Community

Any state or political subdivision thereof with authority to adopt and enforce floodplain management regulations for areas within its jurisdiction.

### Design Flood (Base Flood)

The design flood is the base or 100-year flood used for purposes of compliance with the National Flood Insurance Program (NFIP).

In coastal high hazard zones the 100-year flood includes wave height above the stillwater level.

## Design Loads

The design load is the minimum loading condition that the building should be designed to resist. Some loading conditions most likely will be defined in the applicable codes while other load conditions (e.g., flood impact loads) will have to be determined. The following loads constitute the design load and should be considered as minimum loading conditions as defined in Criterion A.1 (see below):

### *Dead Load (D)*

The weight of all permanent construction. The dead load includes a) the weight of the structure itself, b) the weight of all materials of construction incorporated into the building that are to be permanently supported by the structure, including built-in partitions, c) the weight of permanent equipment, and d) forces due to prestressing.

### *Gravity Live Load (L)*

Gravity live loads result from both the occupancy (floor) and the environment (roof) of the building, as stipulated in the applicable code. These include, where applicable, loads caused by soil and hydrostatic pressures.

### *Wind Loads (W)*

Wind loads stipulated in the applicable code.

### *Restraint Loads (R)*

Loads, forces, and effects due to contraction or expansion resulting from temperature changes, shrinkage, moisture changes, creep in component materials, movement due to differential settlement or combinations thereof.



## Flood Loads (F)

Loads caused by the design flood, which include:

- Flood-induced dimensional changes such as swelling of wood or heave of expansive foundation soils
- Water loads as defined in Section 602.0 of the Corps of Engineers' publication, *Flood-Proofing Regulations*
- Soil loads as defined in Section 604.0 of the Corps of Engineers' publication, *Flood-Proofing Regulations*

Sections of 602.0 and 604.0 of *Flood-Proofing Regulations* (EP 116S-2-314, Office of the Chief of Engineers, U.S. Army, June 1972), are reproduced below:

### SECTION 602.0 WATER LOADS

#### Sec. 602.1 Types

Water loads, as defined herein, are loads or pressures on surfaces of the buildings and structures caused and induced by the presence of flood waters. These loads are of two basic types: hydrostatic and hydrodynamic.

#### Sec. 602.2 Hydrostatic Loads

Hydrostatic loads are those caused by water either above or below the ground surface, free or confined, which is either stagnant or moves at very low velocities, or up to five (5) feet per second. These loads are equal to the product of the water pressure times the surface area on which the pressure acts. The pressure at any point is equal to the product of the unit weight of water (62.5 pounds per cubic foot) multiplied by the height of water above the point or by the height to which confined water would rise if free to do so. Hydrostatic pressures at any point are equal in all directions and always act perpendicular to the surface on which they are applied. For the purpose of these Regulations, hydrostatic loads are subdivided into the following types:

##### Sec. 602.2.1 Vertical Loads

These are loads acting vertically downward on horizontal or inclined surfaces of buildings or structures, such as roofs, decks or floors, and walls, caused by the weight of flood waters above them.

##### Sec. 602.2.2 Lateral Loads

Lateral hydrostatic loads are those which act in a horizontal direction, against vertical or inclined surfaces, both above and below the ground surface and tend to cause lateral displacement and overturning of the building, structure, or parts thereof.

##### Sec. 602.2.3 Uplift

Uplift loads are those which act in a vertically upward direction on the underside of horizontal or sloping surfaces of buildings or structures, such as basement slabs, footings, floors, decks, roofs and overhangs. Hydrostatic loads acting on inclined, rounded or irregular surfaces may be resolved into vertical or uplift loads and lateral loads based on the geometry of the surfaces and the distribution of hydrostatic pressures.

### Sec. 602.3 Hydrodynamic Loads

Hydrodynamic loads . . . are those induced on buildings or structures by the flow of flood water moving at moderate or high velocity around the buildings or structures or parts thereof, above ground level. Such loads may occur below the ground level when openings or conduits exist which allow free flow of flood waters. Hydrodynamic loads are basically of the lateral type and relate to direct impact loads by the moving mass of water, and to drag forces as the water flows around the obstruction. Where application of hydrodynamic loads is required, the loads shall be computed or estimated by recognized and authoritative methods. Methods for evaluating water velocities and related dynamic effects are beyond the scope of these Regulations, but shall be subject to review and approval by the Building Official.

#### Sec. 602.3.1 Conversion to Equivalent Hydrostatic Loads

For cases when water velocities do not exceed 10 feet per second, dynamic effects of the moving water may be converted into equivalent hydrostatic loads by increasing the depth of water to the RFD [use the level of the base or design flood], by an amount  $dh$ , on the headwater side and above the ground level only, equal to:

$$dh = \frac{aV^2}{2g}, \text{ where}$$

$V$  is the average velocity of the water in feet per second;  
 $g$  is the acceleration of gravity, 32.2 feet per second;  
 $a$  is the coefficient of drag or shape factor (The value of  $a$ , unless otherwise evaluated, shall not be less than 1.25)



The equivalent surcharge depth,  $dh$ , shall be added to the depth measured between the design level and the RFD and the resultant pressures applied to, and uniformly distributed across, the vertical projected area of the building or structure which is perpendicular to the flow. Surfaces parallel to the flow or surfaces wetted by the tail-water shall be considered subject to hydrostatic pressures for depths to the RFD only.

#### Sec. 602.4 Intensity of Loads

##### Sec 602.4.1 Vertical Loads

Full intensity of hydrostatic pressure caused by a depth of water between the design elevation(s) and the RFD applied over all surfaces involved, both above and below ground.

##### Sec. 602.4.2 Lateral Loads

Full intensity of hydrostatic pressure caused by a depth of water between the design elevation(s) and the RFD applied over all surfaces involved, both above and below ground level, except that for surfaces exposed to free water, the design depth shall be increased by one foot.

##### Sec. 602.4.3 Uplift

Full intensity of hydrostatic pressures caused by a depth of water between the design level and the RFD acting on all surfaces involved . . . .

##### Sec. 602.4.4 Hydrodynamic Loads

Hydrodynamic loads, regardless of method of evaluation, shall be applied at full intensity over all above ground surfaces between the ground level and the RFD.

#### Sec. 602.5 Applicability

Hydrostatic loads shall be used in the design of buildings and structures exposed to water loads from stagnant flood waters, for conditions when water velocities do not exceed five (5) feet per second, and for buildings and structures or parts thereof not exposed or subject to flowing water. For buildings and structures, or parts thereof, which are exposed and subject to flowing water having velocities greater than five (5) feet per second, hydrostatic and hydrodynamic loads shall apply.



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## SECTION 604.0 SOIL LOADS

### Sec. 604.1 Applicability

Full consideration shall be given in the design of buildings, structures and parts thereof, to the loads or pressures resulting from the presence of soils against or over the structure. Loads or pressures shall be computed in accordance with accepted engineering practice, giving full consideration to the effects that the presence of flood water, above or within the soil, has on loads and pressures. When expansive soils are present, the Building Official may require that special provisions be made in foundation and wall design and construction to safeguard against damage due to this expansiveness. He may require a special investigation and report to provide these design and construction criteria.

### *Flood Impact Loads (FI)*

The loads caused by the design flood as defined in Section 603.0, "Impact Loads," and Section 605.0, "Hurricane and Tidal Wave Loads," of the Corps of Engineers' publication, *Flood-Proofing Regulations*. In the case of Section 605.0, where no specific guidance is provided, design loads shall be recommended by a professional engineer. (Also refer to FIA-7, *Design and Construction Manual for Residential Buildings in Coastal High Hazard Areas*, cited in this manual's preface.)

Section 603.0 of *Flood-Proofing Regulations* is reproduced below:

## SECTION 603.0 IMPACT LOADS

### Sec. 603.1 Types

Impact loads are those which result from floating debris, ice and any floatable object or mass carried by flood waters striking against buildings and structures or parts thereof. These loads are of three basic types: normal, special and extreme.

#### Sec. 603.1.1 Normal Impact Loads

Normal impact loads are those which relate to isolated occurrences of logs, ice blocks or floatable objects of normally encountered sizes striking buildings or parts thereof.

#### Sec. 603.1.2 Special Impact Loads

Special impact loads are those which relate to large conglomerates of floatable objects, such as broken up ice floats and accumulation of floating debris, either striking or resting against a building, structure, or parts thereof.

#### Sec. 603.1.3 Extreme Impact Loads

Extreme impact loads are those which relate to large floatable objects and masses such as runaway barges or collapsed buildings and structures, striking the building, structure or component under consideration.

### Sec. 603.2 Applicability

Impact loads should be considered in the design of buildings, structures and parts thereof as stipulated below:

#### Sec. 603.2.1 Normal Impact Loads

A concentrated load acting horizontally at the RFD or at any point below it, equal to the impact force, produced by a 1,000-pound mass traveling at the velocity of the flood water and acting on a one (1) square foot surface of the structure.

#### Sec. 603.2.2 Special Impact Loads

Where special impact loads are likely to occur, such loads shall be considered in the design of buildings, structures, or parts thereof. Unless a rational and detailed analysis is made and submitted for approval by the Building Official, the intensity of load shall be taken as 100 pounds per foot acting horizontally over a one-foot wide horizontal strip at the RFD [use the level of the base or design flood], or at any level below it. Where natural or artificial barriers exist which would effectively prevent these special impact loads from occurring, the loads may be ignored in the design.

#### Sec. 603.2.3 Extreme Impact Loads

It is considered impractical to design buildings having adequate strength for resisting extreme impact loads. Accordingly, except for special cases when exposure to these loads is highly probable and the resulting damages are extremely severe, no allowances for these loads need be made in the design.

### Flood or Flooding

- A general and temporary condition of partial or complete inundation of normally dry land areas from:

- the overflow of inland or tidal waters
  - the unusual and rapid accumulation or runoff of surface waters from any source
  - mudslides (i.e., mudflows) which are proximately caused or precipitated by accumulations of water on or under the ground.
- The collapse or subsidence of land along the shore of a lake or other body of water as a result of erosion or undermining caused by waves or currents of water exceeding anticipated cyclical levels or suddenly caused by an unusually high water level in a natural body of water, accompanied by a severe storm, or by an unanticipated force of nature, such as a flash flood or an abnormal tidal surge, or by some similarly unusual and unforeseeable event which results in flooding as defined above.

## PERFORMANCE REQUIREMENTS AND CRITERIA FOR RESIDENTIAL STRUCTURES IN FLOOD HAZARD AREAS

### PERFORMANCE REQUIREMENT A

The building, its contiguous structure(s), and its service systems shall be designed to withstand the design flood without causing unacceptable risks to its occupants or to adjacent property owners.

The building complies with Performance Requirement A if the following conditions are satisfied:

#### Criterion A.1: Strength

The building is designed to resist the following loads, acting simultaneously:

- 1.1 D, L, R, and F
- 1.2 D, L, R, F, and Fl
- 1.3 D, L, R, W, F, and Fl
- 1.4 D, R, and F

#### 1.5 D, R, W, F, and Fl

Where the working stress method of design is used the following provisions apply:

- 2.1 In load combinations 1.1 through 1.5 all loads are applied as listed or as required by the applicable codes for the same load combinations with loads F and Fl.
- 2.2 Allowable (working) stresses cannot be exceeded for loading conditions 1.1 and 1.4. For all other loading conditions the allowable stresses can be increased by the amount permitted in applicable codes for design against load combinations including wind or earthquake load.

Where ultimate-load design is used (such as instances where the American Concrete Institute, *Building Code Requirements for Reinforced Concrete* [ACI 318, ACI, Detroit, current edition], is applicable) load factors are applied as recommended in the applicable standard, and F will be combined with L, or factored as if it were a live load for loading conditions 1.1 and 1.4. For all other loading conditions loads F + Fl will be combined with W, or considered to be equivalent to a wind load.

#### Test

Structural analysis and/or physical simulation.

#### Commentary

The criterion provides a suitable margin of safety against structural collapse when the building is subjected to the base flood. The intent of the criterion is that the margin of safety for these buildings, when subjected to the base flood, be no less than the margin required for other buildings not subjected to flooding. It is assumed that loads F may act on the building over a long period of time, while loads Fl are short-term loads. Thus the margin of safety against load combinations containing Fl need not exceed that provided against wind or seismic loads.

The combined load of earthquakes and floods is not considered here because of the low probability of a flood and an earthquake occurring simultaneously. Where tsunami flooding is the base flood, earthquake loading should perhaps be considered concurrently.

#### **Criterion A.2: Stability and Flotation**

There shall be a factor of safety of 1.5 against overturning, sliding, and flotation under the following load:

$$D + W + R + F + FI$$

#### **Test**

Structural analysis and/or physical simulation.

#### **Commentary**

This criterion provides a suitable margin of safety against sliding and overturning. The most critical load combination is being considered. Tie-down devices can be used to achieve structural stability, provided it can be demonstrated that deterioration of these devices during the service life of the building or by flood conditions will not cause the factor of safety to fall below its stipulated value.

#### **Criterion A.3: Provision Against Debris and Scour**

Unless it can be demonstrated that the flood waters will be stagnant, or that there will be no floating debris during the design flood, the following provisions apply:

- 1.1 Building on stilts shall comply with Section 612.2.3 of the Corps of Engineers' publication, *Flood-Proofing Regulations*. This section is reproduced below.

#### **Sec. 612.2.3 Building on "Stilts"**

The building may be constructed above the RFD [use the level of the base or design flood] by supporting it on "stilts" or other columnar type members, such as columns, piers, and in certain cases, walls. Clear spacing of support members, measured perpendicular to the general

direction of flood flow shall not be less than eight (8) feet apart at the closest point. The "stilts" shall, as far as practicable, be compact and free from unnecessary appendages which would tend to trap or restrict free passage of debris during a flood. Solid walls, or walled in columns are permissible if oriented with the longest dimension of the member parallel to the flow. "Stilts" shall be of a type that causes the least obstruction to the flow and the least potential for trapping floating debris. Foundation supports for the "stilts" may be of any approved type capable of resisting all applied loads, such as spread footings, mats, piles and similar types. In all cases, the effect of submergence of the soil and additional flood water related loads shall be recognized. The potential of surface scour around the stilts shall be recognized and protective measures provided, as required.

- 1.2 For flow velocities in excess of 5 feet per second the hydrodynamic loads in F shall be assumed to act over the entire width of the building, perpendicular to the direction of flow, and reasonable vertical clearance shall be provided for the passage of debris. The depth of all foundation elements shall allow for the potential effect of scour.

#### **Test**

Structural analysis and/or physical simulation. Evaluation of data and documentation for design, tests, and installation; evaluation of plans and specifications.

#### **Commentary**

Criterion A.3 is designed to prevent structural collapse caused by the accumulation of floating debris or the undermining of foundation elements as a result of scour. Part of the provision is designed to avoid debris accumulation. The other part provides adequate strength to resist the effects of the formation of a barrier over the entire width of the building. Buildings are exempt if it can be demonstrated that no debris will accumulate and no scour will occur.



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#### Criterion A.4: Disruption of Service Systems

The service systems shall be designed to resist the loads stipulated in Criterion A.1 with safety margins as stipulated in A.1 against disruptions which may endanger human lives.

##### Test

Engineering analysis and/or physical simulation. Evaluation of data and documentation for design, tests, and installation; evaluation of plans and specifications.

##### Commentary

This criterion only applies to disruption which may cause fatal accidents, such as rupture of gas lines. Lesser load levels are stipulated in B.1 for disruptions which constitute a health hazard.

#### Criterion A.5: Execution of Rescue Operations

The building is designed to permit the execution of rescue operations.

During the duration and at heights of the design flood the building shall:

- 1.1 Allow the safe evacuation of the occupants out of the building
- 1.2 Allow the safe transfer of occupants from the building to rescue vehicles
- 1.3 Provide means of access or adjacency for rescue vehicles.

##### Test

Evaluation of data and documentation for design, tests, and installation; evaluation of plans and specifications.

##### Commentary

Criterion A.5 is designed to prevent the entrapment of building occupants by rising water levels. Part of the provision is designed to provide means to evacuate the building (e.g., windows, roof trap door). The other parts provide for the accommodation and execution of rescue operations (e.g., by boat, helicopter).



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## PERFORMANCE REQUIREMENT B

The building, its contiguous structure(s), and its service systems shall be designed to withstand the design flood without causing unacceptable health hazards to its occupants.

The building complies with Performance Requirement B if the following conditions are satisfied:

### Criterion B.1: Disruption of Utility Connections

Building utility connections shall be designed to resist the following loads:

At loading conditions:

1.1  $D + L + R + W + F + Fl$

1.2  $D + W + R + F + Fl$

The building utility connections should not sustain:

- 2.1 Permanently disrupted and/or broken attachment with their fixtures and/or supporting structural elements
- 2.2 Leakage or escape of effluent that could contaminate drinking water
- 2.3 Rupture of electrical service that could cause electrocution and/or fire.

### Test

Evaluation of data and documentation for design, tests, and installations; evaluation of plans and specifications. Inspection and/or testing of built elements when deemed essential. Determination of conformance to generally accepted codes, standards and engineering and trade practices, where applicable.

### Commentary

This criterion applies to all utility connections subject to the forces of the design flood. Utility connections which are designed to disconnect

during the design flood without the release of deleterious substances are exempt from provisions 1.1 and 1.2.

### Criterion B.2: Provision Against Drinking Water Contamination

There will be no contamination of drinking water with sewer effluent or flood water.

Criterion B.2 and Performance Requirement B are deemed satisfied if the following provisions are met.

- 1.1 Approved backflow preventers or devices are installed on main water service lines, at water wells and/or at suitable building locations to protect the system from backflow or back siphonage of flood waters or other contaminants in the event of a line break or temporary disconnection.

Devices are installed at accessible locations and maintained in good working order.

- 1.2 Sanitary sewer and storm drainage system connections are provided with approved backflow preventers or devices installed at each discharge point.
- 1.3 No storm or flood waters are drained into systems designed for sewage only, and vice versa.

### Test

Evaluation of data and documentation for design, tests, and installation; evaluation of plans and specifications.

### Commentary

Criterion B.2 is designed to prevent contamination of drinking water with sewer effluent or flood waters. Also, the criterion is designed to prevent damage to fixtures and interior finishes (e.g., flooring, wall surfaces) from backflow or back siphonage of flood waters.

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**Criterion B.3: Provision Against Contamination of Potable Water Wells**

Private potable water wells shall not be contaminated by toxic substances or impurities caused by the design flood.

Criterion B.3 is deemed satisfied if the following provisions are satisfied.

- 1.1 Private potable well water is not supplied from a water table located less than 25 feet below grade, nor from any deeper supply which may be polluted by contamination entering fissure or crevice formations.
- 1.2 Each well is provided with a watertight casing to a distance of at least 25 feet below the ground surface that extends at least one foot above the well platform.

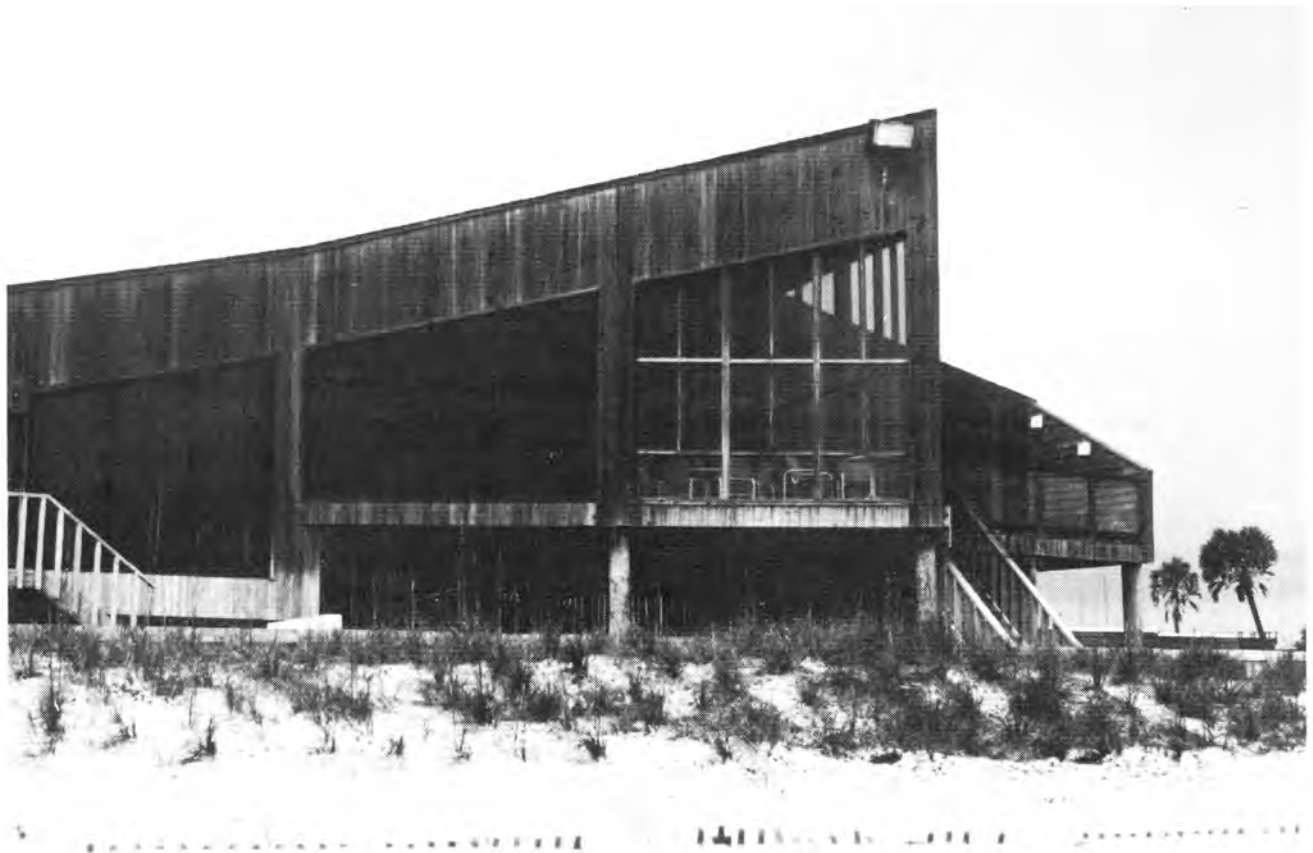
**Test**

Evaluation of data and documentation for design, tests, and installation; evaluation of plans and specifications.

Geological analysis of site.

**Commentary**

Criterion B.3 is designed to prevent the contamination of water wells used as a source for potable water. Part of the provision provides against the contamination of the water supply source. The other part provides against the contamination of the water removal system. In any case, local health codes should be consulted.





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## PERFORMANCE REQUIREMENT C

The building, its contiguous structure(s), and its service systems shall be designed to withstand the design flood without sustaining damage of unacceptable magnitude.

The building complies with Performance Requirement C if the following conditions are satisfied:

### Criterion C.1: Provision Against Permanent Damage

Under loading conditions 1.1 through 1.3 the building as a whole, or any element thereof, shall not suffer permanent damage which would require replacement or major repair, or which would extensively impair its intended function.

1.1  $D + L + R + W + F + FI$

1.2  $D + W + R + F + FI$

1.3  $D + L + R + F + FI$

The criterion is deemed satisfied if stress and deflection limits under loading conditions 1.1 through 1.3 do not exceed those stipulated in applicable codes, or if it can be demonstrated that deflections caused by load combinations 1.1 through 1.3 can be accommodated by suitable detail and adequate flexibility of elements.

### Test

Evaluation of data and documentation for design, tests, and installation; evaluation of plans and specifications. Inspection and/or testing of built elements when deemed essential. Determination of conformance to generally accepted standards and engineering and trade practices, where applicable.

### Commentary

This criterion assures that the design flood will not cause excessive damage. Effects of swelling caused by increased moisture or inundation must be included in  $F$ .

### Criterion C.2: Provision Against Unnecessary Damage

All living areas, major utilities, furnaces, and air-conditioning units shall not be submerged by the design flood.

1.1 Living areas shall be considered habitable areas that provide for the essential needs of people: living, sleeping, dining, cooking and sanitation.

Recreation areas, libraries, and other specialty areas are to be considered habitable areas and therefore should not be submerged by the design flood.

1.2 The electrical system complies with Criterion C.2 if the following conditions are satisfied:

1.2.1 All portions of the electrical system installed below the design flood level are suitable for continuous submergence in water. Only submersible type splices are used and conduits located below the design flood level are self draining if subject to flooding.

1.2.2 Lighting panels, distribution panels, and all other stationary electrical equipment are located above the design flood.

1.3 The mechanical system complies with Criterion C.2 if the following conditions are satisfied:

1.3.1 Heating, air-conditioning, and ventilating are installed above the design flood.

1.3.2 All duct work for warm air heating systems located below the design flood level is provided with emergency openings for drainage of ducts after a flood condition.

1.4 The plumbing system complies with Criterion C.2 if the following conditions are satisfied:

1.4.1 Tanks, softeners and heaters are installed above the design flood.

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1.4.2 Plumbing below the design flood level will not suffer loss of stability or loss of tightness that will permit leakage or physical damage to fixtures and joints and connections that will permanently impair functioning.

1.4.3 Utility connections designed to disconnect during the design flood are easily reconnected. (See Criterion B.1.)

#### Commentary

Criterion C.2 is designed to prevent unnecessary damage of living areas, major utilities, furnaces, and air-conditioning units by the design flood. Part of the provision is designed to elevate living areas and equipment above the design flood. Other parts are designed to prevent the damage of utilities and mechanical/electrical connections below the design flood.

#### Test

Evaluation of data and documentation for design, tests, and installation; evaluation of plans and specifications.



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