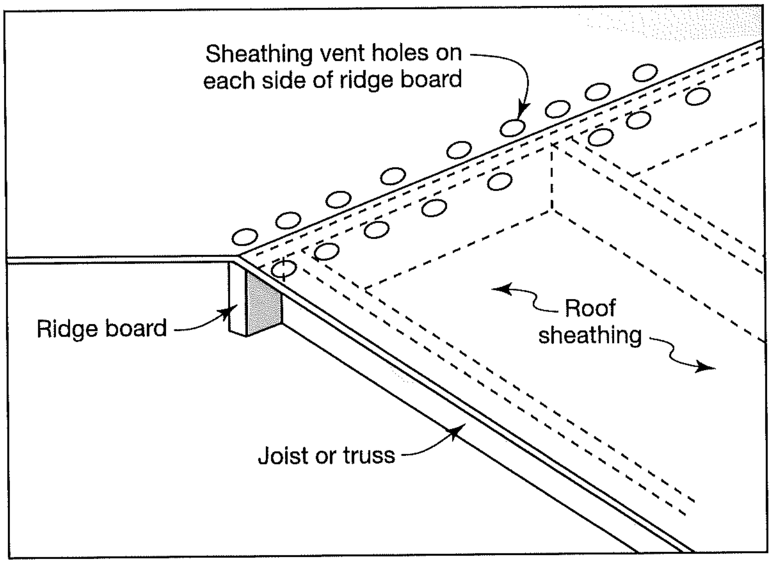


Figure 11-56.
Holes drilled in roof sheathing for ventilation and roof diaphragm action is maintained (sheathing nails not shown)

2. Install two ridge boards separated by an air space of at least 3 inches, with solid blocking between the ridge boards at each rafter or truss. Stop the sheathing at the ridge board and fully nail the sheathing as required. The ridge vent must be wide enough to cover the 3-inch gap between the ridge boards. The ridge board and blocking must be nailed to resist the calculated shear force.

For new construction, the designer should detail the ridge vent installation with the proper consideration for the load transfer requirement. Where high-diaphragm loads may occur, a design professional should be consulted regarding the amount of sheathing that can be removed or other methods of providing ventilation while still transferring lateral loads. The need to meet these requirements may become a significant problem in large or complex residential buildings where numerous ventilation openings are required. In these instances, ridge vents may need to be augmented with other ventilating devices (e.g., off-ridge vents or gable end vents).

Many ridge vent products are not very wide. When these products are used, it may be difficult to provide sufficiently large openings through the sheathing and maintain diaphragm integrity if holes are drilled through the sheathing. Manufacturers' literature often illustrates large openings at the ridge with little or no consideration for the transfer of lateral loads.

NOTE

When continuous ridge vents are used, it is not possible to continue the underlayment across the ridge. Hence, if wind-driven rain is able to drive through the vent or if the ridge vent blows off, water will leak into the house. It is likely that the ridge vent test standard referenced in Fact Sheet 7.5 *in FEMA P-499* is inadequate. One option is to avoid vent water infiltration issues by designing an unventilated attic (where appropriate, as discussed in Fact Sheet 7.5). The other option is to specify a vent that has passed the referenced test method and attach the vent with closely spaced screws (with spacing a function of the design wind speed).

11.7 Additional Environmental Considerations

In addition to water intrusion and possible resulting decay, sun (heat and ultraviolet [UV] radiation) and wind-driven rain must also be considered in selecting materials to be used in coastal buildings. The coastal environment is extremely harsh, and materials should be selected that not only provide protection from the harsh elements but also require minimal maintenance.

11.7.1 Sun

Buildings at or near the coast are typically exposed to extremes of sun, which produces high heat and UV radiation. This exposure has the following effects:

- The sun bleaches out many colors
- Heat and UV shorten the life of many organic materials
- Heat dries out lubricants such as those contained in door and window operating mechanisms

To overcome these problems:

- Use materials that are heat/UV-resistant
- Shield heat/UV susceptible materials with other materials
- Perform periodic maintenance and repair (refer to Chapter 14)

11.7.2 Wind-Driven Rain

Wind-driven rain is primarily a problem for the building envelope. High winds can carry water droplets into the smallest openings and up, into, and behind flashings, vents, and drip edges. When buildings are constructed to provide what is considered to be complete protection from the effects of natural hazards, any small "hole" in the building envelope becomes an area of weakness into which sufficiently high wind can drive a large amount of rain.

11.8 References

AAMA (American Architectural Manufacturers Association). 2008. *Standard/Specification for Windows, Doors, and Unit Skylights.* AAMA/WDMA/CSA 101/I.S.2/A440-08.

AAMA. 2008. *Voluntary Specification for Field Testing of Newly Installed Fenestration Products.* AAMA 502-08.

AAMA. 2009. *Voluntary Specification for Rating the Severe Wind-Driven Rain Resistance of Windows, Doors, and Unit Skylights.* AAMA 520-09.

AAMA. *Fenestration Anchorage Guidelines.* AAMA TIR-A14.

AAMA. *Voluntary Guideline for Engineering Analysis of Window and Sliding Glass Door Anchorage Systems.* AAMA 2501.

ANSI/SPRI (American National Standards Institute / Single-Ply Roofing Industry). 2003. *Wind Design Standard for Edge Systems Used with Low Slope Roofing Systems.* ANSI/SPRI ES-1.

ANSI/SPRI. 2010. *Structural Design Standard for Gutter Systems Used with Low-Slope Roofs.* ANSI/SPRI GD-1.

ASCE (American Society of Civil Engineers). 2005. *Minimum Design Loads for Buildings and Other Structures.* ASCE Standard ASCE 7-05.

ASCE. 2010. *Minimum Design Loads for Buildings and Other Structures.* ASCE Standard ASCE 7-10.

ASTM. *Standard Practice for Determining Resistance of Solar Collector Covers to Hail by Impact with Propelled Ice Balls.* ASTM E822.

ASTM. *Standard Specification for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Windborne Debris in Hurricanes.* ASTM E1996.

ASTM. *Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls, by Uniform or Cyclic Static Air Pressure Difference.* ASTM E1105.

ASTM. *Standard Test Method for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials.* ASTM E1886.

ASTM. *Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights, and Curtain Walls by Uniform Static Air Pressure Difference.* ASTM E330.

ASTM. *Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights, and Curtain Walls by Cyclic Air Pressure Differential.* ASTM E1233.

ASTM. *Standard Test Method for Wind Resistance of Asphalt Shingles (Uplift Force/Uplift Resistance Method).* ASTM D7158.

DASMA (Door & Access Systems Manufacturers Association International). 2005. *Standard Method for Testing Sectional Garage Doors and Rolling Doors: Determination of Structural Performance Under Missile Impact and Cyclic Wind Pressure.* ANSI/DASMA 115. Available at http://www.dasma.com. Accessed January 2011.

DASMA. 2005. *Standard Method For Testing Sectional Garage Doors and Rolling Doors: Determination of Structural Performance Under Uniform Static Air Pressure Difference.* ANSI/DASMA 108. Available at http://www.dasma.com. Accessed January 2011.

DASMA. 2010. *Connecting Garage Door Jambs to Building Framing.* Technical Data Sheet #161. Available at http://www.dasma.com/PubTechData.asp. Accessed January 2011.

FEMA (Federal Emergency Management Agency). 1992. *Building Performance: Hurricane Andrew in Florida – Observations, Recommendations, and Technical Guidance.* FEMA FIA 22.

FEMA. 1993. *Building Performance: Hurricane Iniki in Hawaii – Observations, Recommendations, and Technical Guidance.* FEMA FIA 23.

FEMA. 1998. *Typhoon Paka: Observations and Recommendations on Building Performance and Electrical Power Distribution System, Guam, U.S.A.* FEMA-1193-DR-GU.

FEMA. 1999. *Building Performance Assessment Team (BPAT) Report – Hurricane Georges in Puerto Rico, Observations, Recommendations, and Technical Guidance.* FEMA 339.

FEMA. 2005a. *Mitigation Assessment Team Report: Hurricane Charley in Florida.* FEMA 488.

FEMA. 2005b. *Hurricane Ivan in Alabama and Florida: Observations, Recommendations and Technical Guidance.* FEMA 489.

FEMA. 2006. *Hurricane Katrina in the Gulf Coast.* FEMA 549.

FEMA. 2008. *Home Builder's Guide to Construction in Wildfire Zones.* FEMA P-737.

FEMA. 2009. *Hurricane Ike in Texas and Louisiana.* FEMA P-757.

FEMA. 2010a. *Design Guide for Improving School Safety in Earthquakes, Floods and High Winds.* FEMA P-424.

FEMA. 2010b. *Home Builder's Guide to Coastal Construction Technical Fact Sheet Series.* FEMA P-499.

Fernandez, G., F. Masters, and K. Gurley. 2010. "Performance of Hurricane Shutters under Impact by Roof Tiles," *Engineering Structures* Vol. 32, Issue 10, pp. 3384–3393.

FMA/AAMA (Fenestration Manufacturers Association/American Architectural Manufacturers Association). 2007. *Standard Practice for the Installation of Windows with Flanges or Mounting Fins in Wood Frame Construction.* FMA/AAMA 100-07.

FMA/AAMA. 2009. *Standard Practice for the Installation of Windows with Frontal Flanges for Surface Barrier Masonry Construction for Extreme Wind/Water Conditions.* FMA/AAMA 200-09.

FRSA/TRI (Florida Roofing, Sheet Metal and Air Conditioning Contractors Association, Inc./The Roofing Institute). 2001. *Concrete and Clay Roof Tile Installation Manual. Third Edition.*

FRSA/TRI. 2005. *Concrete and Clay Roof Tile Installation Manual. Fourth Edition.*

ICC (International Code Council). 2008. *2007 Florida Building Code: Building.*

ICC. 2009a. *International Building Code* (2009 IBC). Country Club Hills, IL: ICC.

ICC. 2009b. *International Residential Code* (2009 IRC). Country Club Hills, IL: ICC.

ICBO (International Council of Building Officials). *Uniform Building Code.*

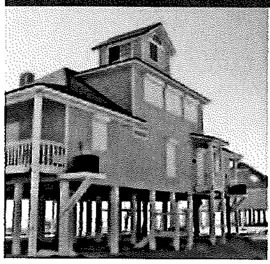
Lopez, C., F.J. Masters, and S. Bolton. 2011. "Water Penetration Resistance of Residential Window and Wall Systems Subjected to Steady and Unsteady Wind Loading," *Building and Environment* 46, Issue 7, pp. 1329–1342.

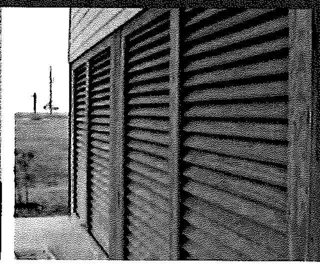
McDonald, J.R. and T.L. Smith. 1990. *Performance of Roofing Systems in Hurricane Hugo.* Institute for Disaster Research, Texas Tech University.

NRCA (National Roofing Contractors Association). 2011. *The NRCA Roofing Manual.*

Salzano, C.T., F.J. Masters, and J.D. Katsaros. 2010. "Water Penetration Resistance of Residential Window Installation Options for Hurricane-prone Areas," *Building and Environment* 45, Issue 6, pp. 1373–1388.

Smith, T.L. 1994. "Causes of Roof Covering Damage and Failure Modes: Insights Provided by Hurricane Andrew," *Proceedings of the Hurricanes of 1992*, ASCE.




Installing Mechanical Equipment and Utilities

This chapter provides guidance on design considerations for elevators, exterior-mounted and interior mechanical equipment, and utilities (electric, telephone, and cable TV systems and water and wastewater systems). Protecting mechanical equipment and utilities is a key component of successful building performance during and after a disaster event.

CROSS REFERENCE

For resources that augment the guidance and other information in this Manual, see the Residential Coastal Construction Web site (http://www.fema.gov/rebuild/mat/fema55.shtm).

12.1 Elevators

Elevators are being installed with increasing frequency in elevated, single-family homes in coastal areas. The elevators are generally smaller than elevators in non-residential buildings but are large enough to provide handicap accessibility and accommodate small household furniture and equipment.

Small (low-rise) residential elevators that are added as part of a post-construction retrofit are usually installed in a shaft independent of an outside wall. Residential elevators designed as part of new construction can be installed in a shaft in the interior of the structure. In either case, the elevator shaft must have a landing, which is usually at the ground level, and a cab platform near the top. The bottom or pit of an elevator with a landing at the lower level is almost always below the BFE.

Appendix H in NFIP Technical Bulletin 4, *Elevator Installation for Buildings Located in Special Flood Hazard Areas in Accordance with the National Flood Insurance Program* (FEMA 2010a), discusses the installation of elevator systems and equipment in the floodplain. As explained in the bulletin, elevator shafts and enclosures that extend below the BFE in coastal areas must be designed to resist hydrostatic, hydrodynamic, and wave forces as well as erosion and scour, but are not required to include hydrostatic openings or breakaway walls. In addition, elevator accessory equipment should be installed above the BFE, replaced with flood damage-resistant elements, or treated with flood damage-resistant paint or coatings to minimize flood damage.

For safety reasons, commercial and large (high-rise) elevators are designed with "fire recall" circuitry that sends the elevator to a designated floor during a fire so emergency services personnel can use the elevators. However, during flooding, this feature may expose the cab directly to floodwaters. Therefore, for elevators in coastal buildings, the elevator must be equipped with a float switch that sends the elevator cab to a level above the BFE. In addition, the design professional must ensure that the elevator stops at a level above the BFE when the power is lost. This can be accomplished by installing an emergency generator or a battery descent feature that is integrated into the float switch, as described in NFIP Technical Bulletin 4.

Finally, although elevators and elevator equipment are permitted for building access and may be covered by flood insurance, their presence, location, and size can affect flood insurance premiums. For buildings in Zone V, the NFIP considers an elevator enclosure a building enclosure or an obstruction, which may be subject to an insurance rate loading depending on:

- Square footage of the enclosure
- Value of the elevator equipment
- Location of the elevator equipment in relation to the BFE

12.2 Exterior-Mounted Mechanical Equipment

Exterior-mounted mechanical equipment can include exhaust fans, vent hoods, air conditioning units, duct work, pool motors, and well pumps. High winds, flooding, and seismic events are the natural hazards that can cause the greatest damage to exterior-mounted mechanical equipment.

12.2.1 High Winds

Equipment is typically damaged because it is not anchored or the anchorage is inadequate. Damage may also be caused by inadequate equipment strength or corrosion. Relatively light exhaust fans and vent hoods are commonly blown away during high winds. Air conditioning condensers, which are heavier than fans and vent hoods, can also be blown off of buildings.

Considering the small size of most exhaust fans, vent hoods, and air-conditioning units used on residential buildings, the following prescriptive attachment recommendations should be sufficient for most residences:

- For curb-mounted units, #14 screws with gasketed washers
- For curbs with sides smaller than 12 inches, one screw at each side of the curb

- For curbs between 12 and 24 inches, two screws per side
- For curbs between 24 and 36 inches, three screws per side
- For buildings within 3,000 feet of the ocean, stainless steel screws
- For units that have flanges attached directly to the roof, #14 pan-head screws, a minimum of two screws per side, and a maximum spacing of 12 inches o.c.
- Air conditioning condenser units, 1/2-inch bolts at the four corners of base of each unit

If the equipment is more than 30 inches above the curb, the attachment design should be based on calculated wind loads. ASCE 7-10 contains provisions for determining the horizontal and lateral force and the vertical uplift force on rooftop equipment for buildings with a mean roof height less than or equal to 60 feet. The lateral force is based on the vertical area of the equipment as projected on a vertical plane normal to the direction of the wind. The uplift force is based on the horizontal area of the equipment as projected on a horizontal plane above the equipment and parallel to the direction of the wind.

Until equipment manufacturers produce more wind-resistant equipment, job-site strengthening of vent hoods is recommended. One approach is to use 1/8-inch-diameter stainless steel cables. Two or four cables are recommended, depending on design wind conditions. Alternatively, additional heavy straps can be screwed to the hood and curb.

To avoid corrosion problems in equipment within 3,000 feet of the ocean shoreline (including sounds and backbays), nonferrous metal, such as aluminum, stainless steel, or steel with minimum G-90 hot-dip galvanized coating, is recommended for the equipment, equipment stands, and equipment anchors. Stainless steel fasteners are also recommended. See Section 11.6 for guidance regarding attic vents.

12.2.2 Flooding

Flood damage to mechanical equipment is typically caused by the failure to elevate equipment sufficiently, as shown in Figure 12-1. Figure 12-2 shows proper elevation of an air-conditioning condenser in a flood-prone area.

Exterior-mounted mechanical equipment in one- to four-family buildings is normally limited to the following:

- Air-conditioning condensers
- Ductwork (air supply and return)
- Exhaust fans
- Pool filter motors
- Submersible well pumps

Floodwaters can separate mechanical equipment from the supports and sever the connection to mechanical or electric

CROSS REFERENCE

For additional information, see FEMA 348, *Protecting Building Utilities From Flood Damage – Principles and Practices for the Design and Construction of Flood-Resistant Building Utility Systems* (FEMA 1999), and Fact Sheet 8.3, *Homebuilder's Guide to Coastal Construction,* in FEMA P-499 (FEMA 2010b).

Figure 12-1.
Condenser damaged as a result of insufficient elevation, Hurricane Georges (U.S. Gulf Coast, 1998)

Figure 12-2.
Proper elevation of an air-conditioning condenser in a floodprone area; additional anchorage is recommended

systems. Mechanical equipment can also be damaged or destroyed when inundated by floodwaters, especially saltwater. Although a short period of inundation may not destroy some types of mechanical equipment, any inundation of electric equipment causes, at a minimum, significant damage to wiring and other elements.

NOTE

Although the 2012 IBC and 2012 IRC specify that flood damage-resistant materials be used below the BFE, in this Manual, flood damage-resistant materials are recommended below the DFE.

Minimizing flood damage to mechanical equipment requires elevating it above the DFE. Because of the uncertainty of wave heights and the probability of wave run-up, the designer should consider additional elevation above the DFE for this equipment.

In Zone V, mechanical equipment must be installed either on a cantilevered platform supported by the first floor framing system or on an open foundation. A cantilevered platform is recommended. However, if the platform is not cantilevered, it is strongly recommended that the size of the elements, depth, and structural integrity of the open foundation that is used to support mechanical equipment be the same as the primary building foundation. Although smaller diameter piles could be used because the platform load is minimal, the smaller piles are more susceptible to being broken by floodborne debris, as shown in Figure 12-3.

In Zone A, mechanical equipment must be elevated to the DFE on open or closed foundations or otherwise protected from floodwaters entering or accumulating in the equipment elements. For buildings constructed over crawlspaces, the ductwork of some heating, ventilation, and air-conditioning systems are routed through the crawlspace. The ductwork must be installed above the DFE or be made watertight in order to minimize flood damage. Many ductwork systems today are constructed with insulated board, which is destroyed by flood inundation.

Figure 12-3.
Small piles supporting a platform broken by floodborne debris

12.2.3 Seismic Events

Residential mechanical equipment is normally fairly light. Therefore, with some care in the design of the attachment of the equipment for resistance to shear and overturning forces, these units should perform well during seismic events. Because air-conditioning units that are mounted on elevated platforms experience higher accelerations than ground-mounted units, extra attention should be given to attaching these units in areas that are prone to large ground accelerations.

12.3 Interior Mechanical Equipment

Interior mechanical equipment includes but is not limited to furnaces, boilers, water heaters, and distribution ductwork. High winds normally do not affect interior mechanical equipment. Floodwaters, however, can cause significant damage to furnaces, boilers, water heaters, and distribution ductwork. Floodwaters can extinguish gas-powered flames, short circuit the equipment's electric system, and inundate equipment and ductwork with sediment.

The following methods of reducing flood damage to interior equipment are recommended:

- Elevate the equipment and the ductwork above the DFE by hanging the equipment from the existing first floor or placing it in the attic or another location above the DFE.
- In areas other than Zone V (where enclosure of utilities below the BFE is not recommended), build a waterproof enclosure around the equipment, allowing access for maintenance and replacement of equipment parts.

12.4 Electric Utility, Telephone, and Cable TV Systems

Electric utilities serving residential buildings in coastal areas are frequently placed in harsh and corrosive environments. Such environments increase maintenance and shorten the lifespan of the equipment. Common electric elements of utilities in residential buildings that might be exposed to severe wind or flood events, which increase maintenance and shorten the lifespan further, are electric meters, electric service laterals and service drops from the utility company, electric panelboards, electric feeders, branch circuit wiring, receptacles, lights, security system wiring and equipment, and telephone and cable television wiring and equipment.

The primary method of protecting elements from flooding is to elevate them above the DFE, but elevation is not always possible. Floodplain management requirements and other code requirements sometimes conflict. One conflict that is difficult to fully resolve is the location of the electric meter. Figure 12-4 shows a bank of meters and electric feeds that failed during Hurricane Opal.

Utility companies typically require electric meters to be mounted where they can be easily read for billing purposes; meters are usually centered approximately 5 feet above grade. They are normally required by utility regulations to be no higher than eye level. However, this height is often below the DFE for coastal homes, and the placement therefore conflicts with floodplain management requirements that meters be installed above the DFE. Since meter sockets typically extend 12 inches below the center of the meter, design floods

Figure 12-4.
Electric service meters and feeders that were destroyed by floodwaters during Hurricane Opal (1995)

that produce 4 feet of flooding can cause water to enter the meter socket and disrupt the electric service. When a meter is below the flood level, electric service can be exposed to floodborne debris, wave action, and flood forces. Figure 12-5 shows an electric meter that is easily accessible by the utility company but is above the DFE.

Since many utility companies no longer manually read meters, there may be flexibility in meter socket mounting, preferably above the design flood. The use of automatic meter reading ("smart meters") by electric utility companies is increasing. The designer should consult the utility to determine whether smart meters can be placed higher than meters that must be read manually.

Similar situations often exist with other electrical devices. For example, switches for controlling access and egress lighting and security sensors occasionally need to be placed below the DFE. The following methods are recommended when necessary to reduce the potential for damage to electric wiring and equipment and to facilitate recovery from a flood event:

- **Wiring methods.** Use conduit instead of cable. Placing insulated conductors in conduits allows flood-damaged wiring to be removed and replaced. The conduit, after being cleaned and dried, can typically be reused. In saltwater environments, non-metallic conduits should be used.

- **Routing and installation.** Install main electric feeders on piles or other vertical structural elements to help protect them from floating debris forces. Since flood damage is often more extensive on the seaward side of a building, routing feeders on the landward side of the structural elements of the building can further reduce the potential for damage. Do not install wiring or devices on breakaway walls. Figure 12-5 is an illustration of recommended installation techniques for electric lines, plumbing, and other utility elements.

- **Design approach.** Install the minimum number of electric devices below the DFE that will provide compliance with the electric code. Feed the branch circuit devices from wiring above the DFE to minimize the risk of flood inundation.

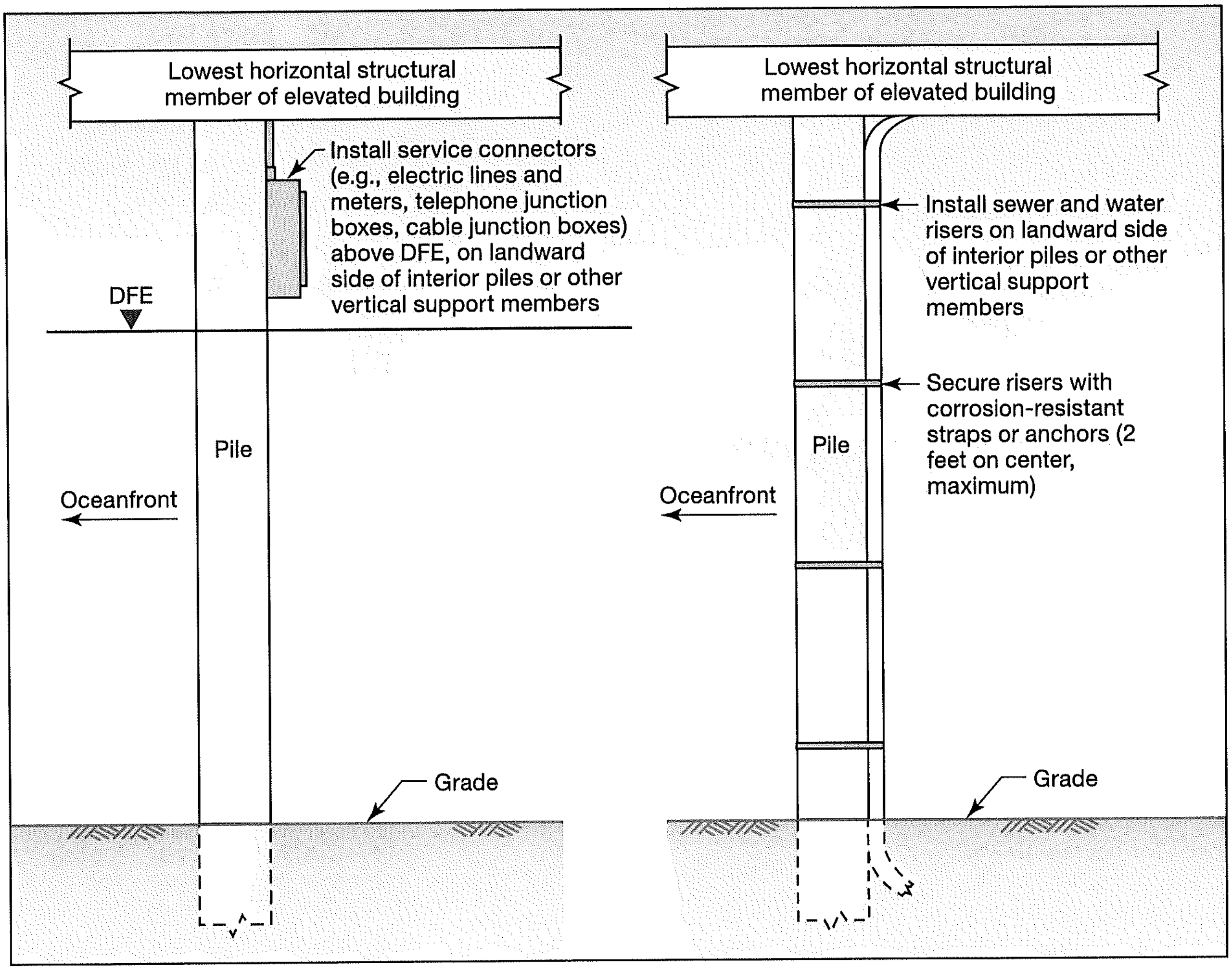


Figure 12-5.
Recommended installation techniques for electric and plumbing lines and utility elements

- **Service style.** Feed the building from underground service laterals instead of overhead electric service drops. When overhead services are needed, avoid penetrating the roof with the service mast to reduce the potential for roof damage and resulting water infiltration. Figure 12-6 illustrates the vulnerability of roof damage and resulting water infiltration when an electric service mast penetrates a roof.

- **Panel location.** Install branch circuit and service panelboards above the DFE. If required to meet utility National Electrical Code requirements, provide a separate service disconnect remote to the panel.

Fact Sheet 8.3, *Protecting Utilities,* in FEMA P-499 contains other recommendations for reducing the vulnerability of utilities that supply buildings.

Direct wind damage to exterior-mounted electric utility equipment (see Figure 12-6) is infrequent in part because of the small size of most equipment (e.g., disconnect switches, conduit). Exceptions are satellite dishes, photovoltaic panels, and electric service penetrations through the roof. Satellite dish and photovoltaic panel failures are typically caused by the design professional's failure to perform wind load calculations and provide for adequate anchorage.

Figure 12-6. Damage caused by dropped overhead service, Hurricane Marilyn (U.S. Virgin Islands, 1995)

12.4.1 Emergency Power

Because a severe wind event often interrupts electric service, designers and homeowners need to make a decision about the need for backup power.

Emergency power can be provided by permanently installed onsite generators or by temporary generators brought to the site after the event. For permanently installed units, the following is recommended:

CROSS REFERENCE

For guidance on determining the proper size of an emergency generator, see Section VI-D of FEMA 259, *Engineering Principles and Practices for Retrofitting Flood Prone Residential Buildings* (FEMA 2001).

- Locate the generator above the DFE.
- If located on the exterior of the building, place the unit to prevent engine exhaust fumes from being drawn into doors, windows, or any air intake louvers into the building. If located on the inside of the building, provide ventilation for combustion air and cooling air and provision for adequately discharging exhaust fumes.
- Locate the fuel source above the DFE and store an amount of fuel adequate for the length of time the generator is expected to operate.
- Install the generator where its noise and vibration will cause the least disruption.
- Determine the expected load (e.g., heat, refrigeration, lights, sump pumps, sewer ejector pumps). Non-fuel-fired heating systems and most cooling systems require large generators. Capacity considerations may limit the generator to providing only freeze protection and localized cooling.
- Install manual or automatic transfer switches that prevent backfeeding power from the generator into the utility's distribution system. Backfeeding power from generators into the utility's distribution system

can kill or injure workers attempting to repair damaged electrical lines.

- Provide an "emergency load" subpanel to supply critical circuits. Do not rely on extension cords. Supply the emergency panel from the load side of a manual or automatic transfer switch.

WARNING

Do not "backfeed" emergency power through the service panel. Utility workers can be killed!

- Determine whether operation of the generator will be manual or automatic. Manual operation is simpler and less expensive. However, a manual transfer switch requires human intervention. Owners should not avoid or delay evacuation to tend to an emergency power source.

- Size the generator, transfer switches, and interconnecting wiring for the expected load. The generator should be large enough to operate all continuous loads and have ample reserve capacity to start the largest motor load while maintaining adequate frequency and voltage control and maintaining power quality.

12.5 Water and Wastewater Systems

Water and wastewater systems include wells, septic systems, sanitary systems, municipal water connections, and fire sprinkler systems.

12.5.1 Wells

For protection of well systems from a severe event (primarily a flood), the design must include a consideration of the following, at a minimum:

- Floodwaters that enter aquifers or saturate the soil can contaminate the water supply. FEMA P-348, *Principles and Practices for Flood-Resistant Building Utilities* (FEMA 1999), recommends installing a watertight encasement that extends from at least 25 feet below grade to at least 1 foot above grade.

- Non-submersible well pumps must be above the DFE.

- If water is to be available following a disaster, an alternative power source must be provided.

- The water supply line riser must be protected from hydrodynamic and floodborne debris impact damage; the supply line must be on the landward side of a pile or other vertical structural member or inside an enclosure designed to withstand the forces from the event (see Figure 12-5).

- Backflow valves must be installed to prevent floodwaters from flowing into the water supply when water pressure in the supply system is lost.

12.5.2 Septic Systems

WARNING

In some areas, high groundwater levels may preclude the installation of septic tanks below the level of expected erosion and scour.

Leach fields and septic tanks, and the pipes that connect them, are highly susceptible to erosion and scour, particularly in Coastal A Zone and Zone V with velocity flow risks. The best way to protect leach fields and other onsite sewage management elements is to locate them outside the floodplain.

If septic systems cannot be located outside the floodplain, the design of septic systems for protection from severe events must include a consideration of the following, at a minimum:

- If the septic tank is dislodged from its position in the ground, the piping will be disconnected, releasing sewage into floodwaters. Also, the tank could damage the nearest structure. Therefore, bury the system below the expected depth of erosion and scour, if possible, and ensure the tank is anchored to prevent a buoyancy failure.

- The sewage riser lines and septic tank risers must be protected from water and debris flow damage; risers should be on the landward side of a pile or other vertical structural member or inside an enclosure designed to withstand the forces from the event (see Figure 12-5).

If leach fields, pipes, and tanks cannot be located outside the floodplain, one possible way to protect them is to bury them below the expected scour depth. However, many local health codes or ordinances restrict or even prohibit the placement of septic elements in the floodplain. In these cases, alternate sewage management systems must be used.

Because leach fields rely on soil to absorb moisture, saturated soil conditions can render leach fields inoperable. This problem and its potential mitigating measures depend on complex geotechnical considerations. Therefore, a geotechnical engineer and/or a qualified sewer designer should be consulted for the design and installation of leach fields.

12.5.3 Sanitary Systems

To protect sanitary systems from a severe event, the design must include a consideration of the following, at a minimum:

- Sanitary riser lines must be protected from water and debris flow damage; risers should be on the landward side of a pile or other vertical structural member or inside an enclosure designed to withstand the forces from the event (see Figure 12-5).

- When the line breaks at the connection of the building line and main sewer line, raw sewage can flow back out of the line, contaminating the soil near the building. A check valve in the line may help prevent this problem.

12.5.4 Municipal Water Connections

If water risers are severed during a coastal event, damage to the water supply system can include waste from flooded sewer or septic systems intruding into the water system, sediment filling some portion of the pipes, and breaks in the pipes at multiple locations. Protecting municipal water connections is accomplished primarily by protecting the water riser that enters the building from damage by debris. See Section 12.5.1 for more information.

12.5.5 Fire Sprinkler Systems

Protecting the fire sprinkler system is similar to protecting the other systems discussed in Section 12.5. The primary issue is to locate the sprinkler riser such that the location provides shielding from damage. In addition, there must be consideration to the location of shutoff valves and other elements so that if an unprotected portion of the fire water supply line is damaged, the damage is not unnecessarily added to the damage caused by the natural hazard event.

12.6 References

ASCE (American Society of Civil Engineers). 2010. *Minimum Design Loads for Buildings and Other Structures.* ASCE Standard ASCE 7-10.

FEMA (Federal Emergency Management Agency). 1999. *Principles and Practices for Flood-Resistant Building Utilities.* FEMA P-348.

FEMA. 2001. *Engineering Principles and Practices for Retrofitting Flood Prone Residential Buildings.* FEMA 259.

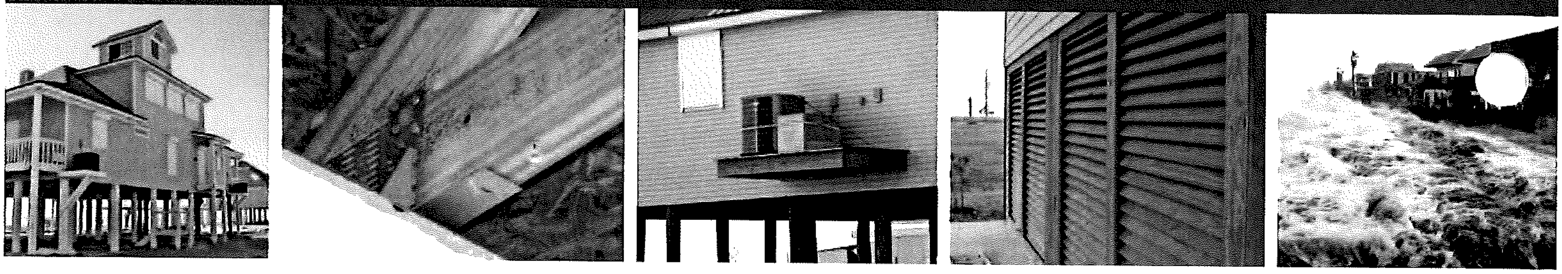
FEMA. 2010a. *Elevator Installation for Buildings Located in Special Flood Hazard Areas in Accordance with the National Flood Insurance Program.* FEMA NFIP Technical Bulletin 4.

FEMA. 2010b. *Homebuilder's Guide to Coastal Construction.* FEMA P-499.

FEMA. 2010c. *National Flood Insurance Program Flood Insurance Manual.*

ICC (International Code Council). 2011a. *International Building Code.* 2012 IBC. Country Club Hills, IL: ICC.

ICC. 2011b. *International Residential Code for One-and Two-Family Dwellings.* 2012 IRC. Country Club Hills, IL: ICC.



Constructing the Building

This chapter provides guidance on constructing residential buildings in coastal areas, which presents challenges that are usually not present in more inland locations (risk of high winds and coastal flooding and a corrosive environment) and other challenges such as the need to elevate the building.

Considerations related to these challenges include the need to:

- Perform more detailed inspections of connection details than those performed in noncoastal areas to ensure the details can withstand the additional hazards found in coastal areas
- Include with the survey staking the building within property line setbacks and at or above the design flood elevation (DFE) (see Section 4.5 for additional coastal survey regulatory requirements)
- Ensure that all elements of the building will be able to withstand the forces associated with high winds, coastal flooding, or other hazards required of the design
- Ensure that the building envelope is constructed to minimize and withstand the intrusion of air and moisture during high-wind events (see Section 11.3.1.4)
- Provide durable exterior construction that can withstand a moist and sometimes salt-laden environment
- Protect utilities, which may include placing them at or above the DFE

CROSS REFERENCE

For resources that augment the guidance and other information in this Manual, see the Residential Coastal Construction Web site (http://www.fema.gov/rebuild/mat/fema55.shtm).

Constructing coastal residential buildings on elevated pile foundations present the following additional challenges:

- The difficulty of constructing a driven pile foundation to accepted construction plan tolerances
- The difficulty of constructing a building on an elevated post-and-beam foundation, which is more difficult than building on a continuous wall foundation

This chapter discusses the construction aspects of the above challenges and other aspects of the coastal construction process, including the construction items that are likely to require the most attention from the builder in order for the design intent to be achieved.

Although much of the discussion in this chapter is related to constructing the building to meet the architect's and engineer's design intent for existing and future conditions (such as erosion and sea-level rise), durability of the building elements is also important. Wood decay, termite infestation, metal corrosion, and concrete and masonry deterioration can weaken a building significantly, making it hazardous to occupy under any conditions and more likely to fail in a severe natural hazard event.

Builders may find that the permitting and inspection procedures in coastal areas are more involved than those in inland areas. Not only must all Federal, State, and local Coastal Zone Management and other regulatory requirements be met, the design plans and specifications may need to be sealed by a design professional. Building permit submittals must often include detailed drawings and other types of information for all elements of the wind-resisting load path, including sheathing material, sheathing nailing, strap and tiedown descriptions, bolted connections, and pile description and placement. The placement of utilities at or above the DFE, breakaway walls, and flood equalization openings must be clearly shown. Site inspections are likely to focus on the approved plans, and building officials may be less tolerant of deviations from these approved construction documents than those in noncoastal areas. Inspection points are also discussed.

13.1 Foundation Construction

Constructing a foundation in a coastal environment includes designing the layout, selecting the foundation type, selecting the foundation material with consideration for durability, and installing the foundation. Although pile foundations are the most common foundation type in Zone V and should be used in Coastal A Zones, shallow foundations, both masonry and concrete, may be acceptable elsewhere. Whether masonry, concrete, wood, or steel, all coastal foundation materials must be designed and installed to withstand the likelihood of high winds, moisture, and salt-laden air. See Chapter 10 for guidance on the design of coastal foundations.

13.1.1 Layout

Surveying and staking must be done accurately in order to establish the building setback locations, the DFE, and the house plan and support locations. Figure 13-1 is a site layout with pile locations, batter boards, and setbacks and is intended to show the constraints a builder may face when laying out a pile-supported structure on a narrow coastal lot. There may be conflicts between what the contractor would like to do to prepare the site and what the environmental controls dictate can be done on the site. For example, leveling the site, especially altering dunes, and removing existing vegetation may be restricted. Furthermore, these

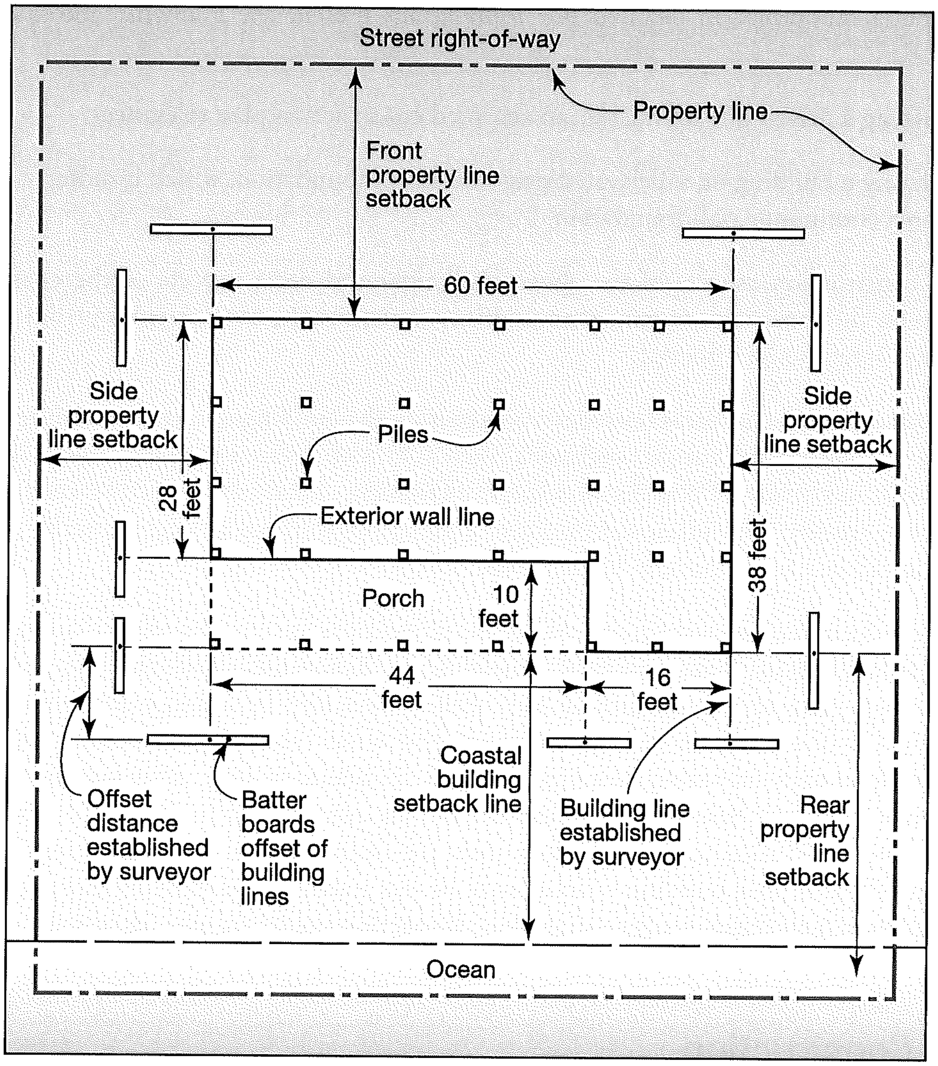


Figure 13-1.
Site layout

restrictions may limit access by pile drivers and other heavy equipment. Similarly, masonry and concrete foundations may require concrete pumping because of limited access to the traditional concrete mix truck and chute.

In an elevated building with a pile foundation, the layout of the horizontal girders and beams should anticipate the fact that the final plan locations of the tops of the piles will likely not be precise. Irregularities in the piles and soil often prevent the piles from being driven perfectly plumb. The use of thick shims or overnotching for alignment at bolted pile-girder connections may have a significant adverse effect on the connection capacity and should be avoided.

Figure 13-2 shows the typical process of pile notching; the use of a chain saw for this process can lead to inaccuracies at this early stage of construction. Figure 13-3 shows a wood pile that is overnotched. Figure 13-4 shows a pile that has been properly notched to support the floor girder and cut so plenty of wood remains at the top of the pile.

Figure 13-2.
Typical pile notching process
SOURCE: PATTY MCDANIEL, USED WITH PERMISSION

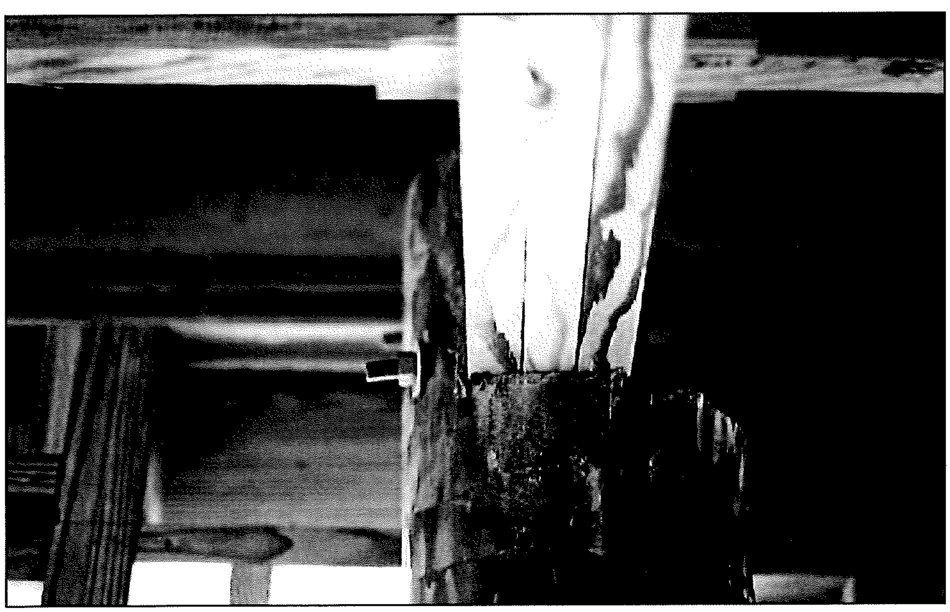


Figure 13-3.
Improper overnotched wood pile
SOURCE: PATTY MCDANIEL, USED WITH PERMISSION

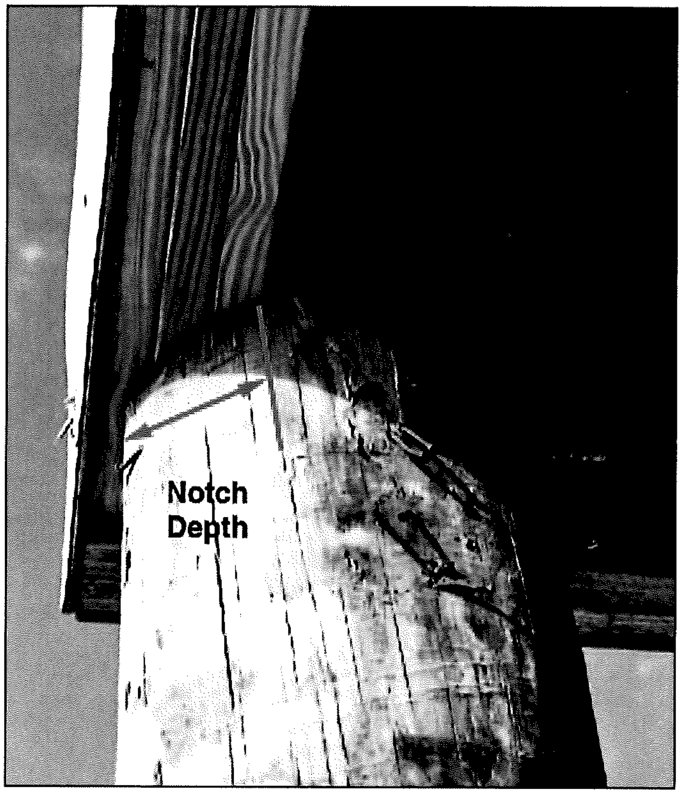


Figure 13-4.
Properly notched pile; outer member of this three-member beam supported by the through-bolt rather than the beam seat

A rule of thumb regarding notching is to notch no more than 50 percent of the pile cross section, but in no case should notching be in excess of that specified by the design professional. Section 13.2 presents information concerning the reinforcement of overnotched and misaligned piles.

The primary floor girders spanning between pile or foundation supports should be oriented parallel to the primary flow of potential floodwater and wave action if possible. This orientation (normally at right angles to the shoreline) allows the lowest horizontal structural member perpendicular to flow to be the floor joists. Thus, in an extreme flood, the girders are not likely be subjected to the full force of the floodwater and debris along their more exposed surfaces.

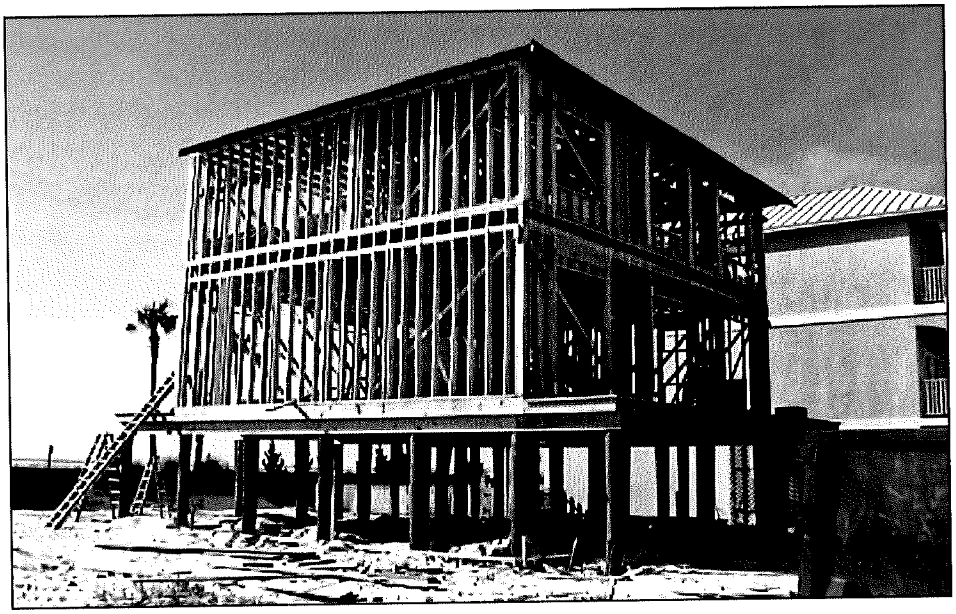
The entire structure is built on the first floor, and it is therefore imperative that the first floor be level and square. The "squaring" process normally involves taking diagonal measurements across the outer corners and shifting either or both sides until the diagonal measurements are the same, at which point the building is square. An alternative is to take the measurements of a "3-4-5" triangle and shift the floor framing until the "3-4-5" triangular measurement is achieved.

13.1.2 Pile Foundations

Pile foundations are the most common foundation type in Zone V coastal buildings and should also be used in Coastal A Zones where scour and erosion conditions along with potentially destructive wave forces make it inadvisable to construct buildings on shallow foundations.

In many coastal areas, the most common type of pile foundation is the elevated wood pile foundation in which the tops of the piles extend above grade to about the level of the DFE (see Figure 13-5).

Figure 13-5.
Typical wood pile foundation



Horizontal framing girders connected to the tops of the piles form a platform on which the house is built. Appendix B of ICC 600-2008 contains some girder designs for use with foundations discussed in FEMA P-550, *Recommended Residential Construction for the Gulf Coast* (FEMA 2006). In addition, the 2012 IRC contains prescriptive designs of girder and header spans. Furthermore, Fact Sheet 3.2, *Pile Installation*, in FEMA P-499 (FEMA 2011) presents basic information about pile design and installation, including pile types, sizes and lengths, layout, installation methods, bracing, and capacities. For more information on pile-to-beam connections, see Fact Sheet 3.3, *Wood Pile-to-Beam Connections*, in FEMA P-499, which presents basic construction guidance for various construction methods. The discussion in this section is focused on the construction of an elevated wood pile foundation.

Precautions should be taken in handling and storing pressure-preservative-treated round or square wood piles. They should not be dragged along the ground or dropped. They should be stored well-supported on skids so that there is air space beneath the piles and the piles are not in standing water. Additional direction and precautions for pile handling, storage, and construction are found in Section 10.5 of this Manual and AWPA Standard M4-91.

The effectiveness of pile foundations and the pile load capacity is related directly to the method of installation. The best method is to use a pile driver, which uses leads to hold the pile in position while a single- or double-acting diesel- or air-powered hammer drives the pile into the ground. Pile driving is often used with auguring to increase pile embedment. Augurs are used to drill the first several feet into the soil, and the piles are then driven to refusal. Auguring has the added benefit of improving pile alignment.

WARNING

The amount of long-term and storm-induced erosion expected to occur at the site (see Section 3.5 in Volume I of this Manual) must be determined before any assumptions about soils are made or analyses of the soils are conducted. Only the soils that will remain after erosion can be relied on to support the foundation members.

The pile driver method is cost-effective in a development when a number of houses are constructed at one time but may be expensive for a single building. The drop hammer method is a lower cost alternative and is considered a type of pile driving, as discussed in Section 10.5.4. A drop hammer consists of a heavy weight that is raised by a cable attached to a power-driven winch and then dropped onto the end of the pile.

A less desirable but frequently used method of inserting piles into sandy soil is "jetting." Jetting involves forcing a high-pressure stream of water through a pipe advanced along the side of 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. Unfortunately, jetting loosens the soil around the pile and the soil below the tip, resulting in a lower load capacity.

CROSS REFERENCE

See Section 10.5.4 for a discussion of pile capacities for various installation methods.

Holes for piles may be excavated by an auger if the soil is sufficiently clayey or silty. In addition, some sands may contain enough clay or silt to permit augering. This method can be used by itself or in conjunction with pile driving. If the hole is full-sized, the pile is dropped in and the void backfilled. Alternatively, an undersized hole can be excavated and a pile driven into it. When the soil conditions are appropriate, the hole stays open long enough to drop or drive in a pile. In general, piles dropped or driven into augered holes may not have as much capacity as those driven without augering.

If precast concrete piles or steel piles are used, only a regular pile driver with leads and a single- or double-acting hammer should be used. For any pile driving, the building jurisdiction or the engineer-of-record will probably require that a driving log be kept for each pile. The log will show the number of inches per blow as the driving progresses—a factor used in determining the pile capacity, as shown in Equation 13-1. As noted in Section 10.3, the two primary determinants of pile capacity are the depth of embedment in the soil and the soil properties.

Piles must be able to resist vertical loads (both uplift and gravity) and lateral loads. Sections 8.5 and 8.10 contain guidance on determining pile loads. It is common practice to estimate the ultimate vertical load bearing capacity of a single pile on the basis of the driving resistance. Several equations are available for making such estimates. However, the results are not always reliable and may over-predict or under-predict the capacity, so the equations should be used with caution. One method of testing the recommended capacity based on an equation is to load test at least one pile at each location of known soil variation.

The designer should also keep in mind that constructing a pile foundation appropriately for the loads it must resist in the coastal environment may drastically reduce future costs by helping to avoid premature failure. Many factors in addition to vertical and lateral loads must be taken into account in the coastal environment. For example, erosion and scour can add stress on the foundation members and change the capacity to which the piles should be designed. The complex and costly repairs to the home shown in Figure 10-2 could have been avoided if all forces and the reduced pile capacity resulting from erosion and scour had been considered in the pile foundation design.

Equation 13.1 can be used to determine pile capacity for drop hammer pile drivers. Equations for other pile driver configurations are provided in U.S. Department of the Navy Design Manual 7.2, *Foundation and Earth Structures Design* (USDN 1982).

EQUATION 13.1. PILE DRIVING RESISTANCE FOR DROP HAMMER PILE DRIVERS

$$Q_{all} = \frac{2WH}{(S+1)}$$

where:

Q_{all} = allowable pile capacity (in lb)

W = weight of the striking parts of the hammer (in lb)

H = effective height of the fall (in ft)

S = average net penetration, given as in. per blow for the last 6 in. of driving

Lateral and uplift load capacity of piles varies greatly with the soils present at the site. Pile foundation designs should be based on actual soil borings at the site (see Section 10.3.3.2). Variation in the final locations of the pile tops can complicate subsequent construction of floor beams and bracing. The problem is worsened by piles with considerable warp, non-uniform soil conditions, and material buried below the surface of the ground such as logs, gravel bars, and abandoned foundations. Builders should inquire about subsurface conditions at the site of a proposed building before committing to the type of pile or the installation method (see Section 10.3.3). A thorough investigation of site conditions can help prevent costly installation errors.

The soils investigation should determine the following:

- Type of foundations that have been installed in the area in the past
- Type of soil that might be expected (based on past soil borings and soil surveys)
- Whether the proposed site has been used for any other purpose and if so, the likelihood of buried materials present on the site

Scour and erosion both reduce pile capacities and erosion can increase flood loads on a pile. Scour and erosion must be considered in a properly designed pile foundation. Additional guidance on the effects of scour and erosion on piles is provided in Section 8.5.11 and Section 10.5.5.

13.1.3 Masonry Foundation Construction

The combination of high winds and moist and sometimes salt-laden air can have a damaging effect on masonry construction by forcing moisture into the smallest cracks or openings in the masonry joints. The entry of moisture into reinforced masonry construction can lead to corrosion of the reinforcement and subsequent cracking and spalling if proper protection of the reinforcement is not provided, as required by TMS 402/ACI 530/ASCE 5 and TMS 602/ACI 530.1/ASCE 6. Moisture resistance

WARNING

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

is highly influenced by the quality of the materials and the quality of the masonry construction at the site. Masonry material selection is discussed in Section 9.4 of this Manual.

The quality of masonry construction depends on many considerations. Masonry units and packaged mortar and grout materials should be stored off the ground and covered. Mortar and grouts must be carefully batched and mixed. As the masonry units are placed, head and bed joints must be well mortared and tooled. The 2012 IRC provides grouting requirements. Masonry work in progress must be well protected.

Moisture penetration or retention must be carefully controlled where masonry construction adjoins other materials. As in any construction of the building envelope in the coastal environment, flashing at masonry must be continuous, durable, and of sufficient height and extent to impede the penetration of expected wind-driven precipitation. For more information on moisture barrier systems, see Fact Sheet 1.9, *Moisture Barrier Systems*, in FEMA P-499. Because most residential buildings with masonry foundations have other materials (e.g., wood, concrete, steel, vinyl) attached to the foundation, allowance must be made for shrinkage of materials as they dry out and for differential movement between the materials. Expansion and contraction joints must be placed so that the materials can move easily against each other.

NOTE

Tooled concave joints and V-joints provide the best moisture resistance.

Masonry is used for piers, columns, and foundation walls. As explained in Section 10.2.1, the National Flood Insurance Program (NFIP) regulations require open foundations (e.g., piles, piers, posts, columns) for buildings constructed in Zone V. Buildings in Zone A may be constructed on any foundation system. However, because of the history of observed damage in Coastal A Zone and the magnitude of the flood and wind forces that can occur in these areas, this Manual recommends that only open foundation systems be constructed in Coastal A Zones. Figure 13-6 shows an open masonry foundation with only two rows of piers. It is unlikely that this foundation system could resist the overturning caused by the forces described in Chapter 8 and shown in Example 8-10. Fact Sheet 3.4, *Reinforced Masonry Pier Construction*, in FEMA P-499 provides recommendations on pier construction best practices. Fact Sheet 4.2, *Masonry Details*, in FEMA P-499 provides details on masonry wall-to-foundation connections.

Reinforced masonry has much more strength and ductility than unreinforced masonry for resisting large wind, water, and earthquake forces. This Manual recommends that permanent masonry foundation construction in and near coastal flood hazard areas (both Zone A and Zone V) be fully or partially reinforced and grouted solid regardless of the purpose of the construction and the design loads. Grout should be in conformance with the requirements of the 2012 IBC. Knockouts should be placed at the bottom of fully grouted cells to ensure that the grout completely fills the cells from top to bottom. Knockouts are required only for walls (or piers) exceeding 5 feet in height.

NOTE

In areas not subject to earthquake hazards, breakaway walls below elevated buildings may be constructed using unreinforced and ungrouted masonry.

For CMUs, shrinkage cracking can be minimized by using Type I moisture-controlled units and keeping them dry in transit and on the job. Usually, for optimum crack control, Type S mortar should be used for below-grade applications and Type N mortar for above-grade applications. The 2012 IBC specifies grout proportions by volume for masonry construction.

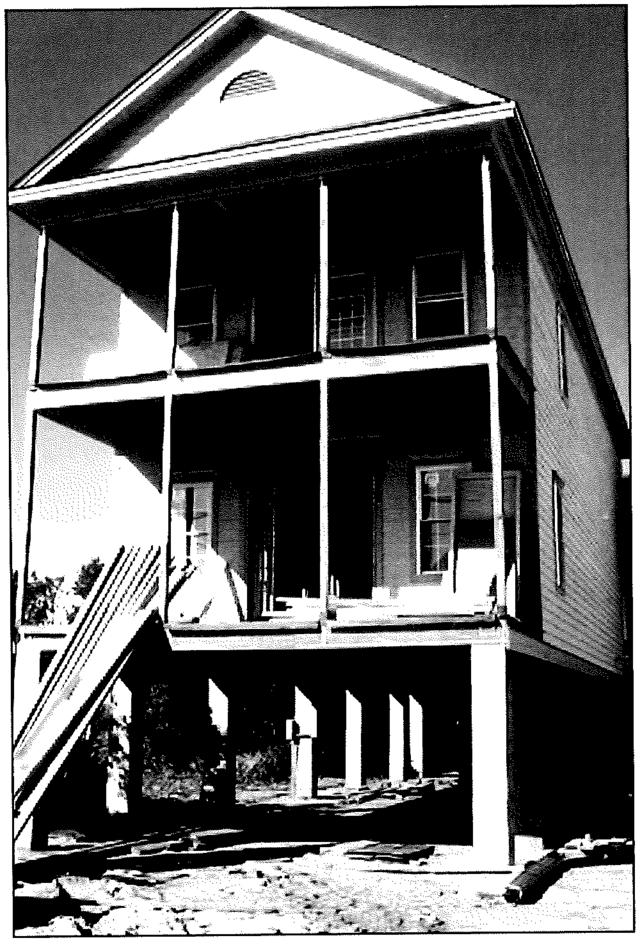


Figure 13-6.
Open masonry foundation

13.1.4 Concrete Foundation Construction

Concrete foundation or superstructure elements in coastal construction almost always require steel reinforcement. Figure 13-7 shows a concrete foundation, and Figure 13-8 shows a house being constructed with concrete. Completed cast-in-place exterior concrete elements should generally provide 1-1/2 inches or more of concrete cover over the reinforcing bars. Minimum cover values vary according to bar size and exposure to earth or weather per ACI 318-08. This thickness of concrete cover serves to protect the reinforcing bars from corrosion, as does an epoxy coating. The bars are also protected by the natural alkalinity of the concrete. However, if saltwater penetrates the concrete cover and reaches the reinforcing steel, the concrete alkalinity will be reduced by the salt chloride and the steel can corrode if it is not otherwise protected. As the corrosion forms, it expands and cracks the concrete, allowing the additional entry of water and further corrosion. Eventually, the corrosion of the reinforcement and the cracking of the concrete weaken the concrete structural element, making it less able to resist loads caused by natural hazards.

During placement, concrete normally requires vibration to eliminate air pockets and voids in the finished surface. The vibration must be sufficient to eliminate the air without separating the concrete or water from the mix.

Figure 13-7.
Concrete foundation

Figure 13-8.
Concrete house

To ensure durability and long life in coastal, saltwater-affected locations, it is especially important to carefully carry out concrete construction in a fashion that promotes durability. "Material Durability in Coastal Environments," available on the Residential Coastal Construction Web site (http://www.fema.gov/rebuild/mat/fema55.html) describes the 2012 IBC requirements for more durable concrete mixes with lower water-cement ratios and higher compressive strengths (5,000 pounds/square inch) to be used in a saltwater environment. The 2012 IBC also requires that additional cover thickness be provided. Proper placement, consolidation, and curing are also essential for durable concrete. The concrete mix water-cement ratio required by 2012 IBC or by the design should not be exceeded by the addition of water at the site.

It is likely that concrete will have to be pumped at many sites because of access limitations or elevation differences between the top of the forms and the concrete mix truck chute. Pumping concrete requires some minor changes in the mix so that the concrete flows smoothly through the pump and hoses. Plasticizers should be used to make the mix pumpable; water should not be used to improve the flow of the mix. Concrete suitable for pumping must generally have a slump of at least 2 inches and a maximum aggregate size of 33 to 40 percent of the pump pipeline diameter. Pumping also increases the temperature of the concrete, thus changing the curing time and characteristics of the concrete depending on the outdoor temperature.

NOTE

ACI 318-08 specifies minimum amounts of concrete cover for various construction applications. Per the Exception to 1904.3 in the 2012 IBC, concrete mixtures for any R occupancies need only comply with the freeze/thaw requirements (as traditionally tabulated in the 2012 IBC and 2012 IRC), not the permeability and corrosion requirements of ACI 318-08.

Freeze protection may be needed, particularly for columns and slabs, if pouring is done in cold temperatures. Concrete placed in cold weather takes longer to cure, and the uncured concrete may freeze, which adversely affects its final strength. Methods of preventing concrete from freezing during curing include:

- Heating adjacent soil before pouring on-grade concrete
- Warming the mix ingredients before batching
- Warming the concrete with heaters after pouring (avoid overheating)
- Placing insulating blankets over and around the forms after pouring
- Selecting a cement mix that will shorten curing time

Like masonry, concrete is used for piers, columns, and walls; the recommendation in Section 13.1.3 regarding open foundations in Coastal A Zones also applies to concrete foundations. In addition, because the environmental impact of salt-laden air and moisture make the damage potential significant for concrete, this Manual recommends that all concrete construction in and near coastal flood hazard areas (both Zone V and Zone A) be constructed with the more durable 5,000-pounds/square inch minimum compressive strength concrete regardless of the purpose of the construction and the design loads.

13.1.5 Wood Foundation Construction

All of the wood used in the foundation piles, girders, beams, and braces must be preservative-treated wood or, when allowed, naturally decay-resistant wood. Section 9.4 discusses materials selection for these wood elements. Piles must be treated with waterborne arsenicals, creosote, or both. Girders and braces may be treated with waterborne arsenicals, pentachlorophenol, or creosote. Certain precautions apply to working with any of these treated wood products, and additional precautions apply for pentachlorophenol- and creosote-treated wood (see Section 13.1.5.1). Additional information is available in Consumer Information Sheets where the products are sold.

Wood foundations are being constructed in some parts of the country as part of a basement or crawlspace. These foundation elements have walls constructed with pressure-preservative-treated plywood and footings constructed with wide pressure- preservative-treated wood boards such as 2x10s or 2x12s. Because the NFIP regulations allow continuous foundation walls (with the required openings) in Coastal A Zones, continuous wood foundations might seem to be acceptable in these areas. However, because of the potential forces from waves less than 2 feet high (as discussed in Section 10.8), a wood foundation supported on a wood footing is not recommended in Coastal A Zones.

When working with treated wood, the following health and safety precautions should be taken:

- Avoid frequent or prolonged inhalation of the sawdust.
- When sawing and boring, wear goggles and a dust mask.
- Use only treated wood that is visibly clean and free of surface residue should be used for patios, decks, and walkways.
- Before eating or drinking, wash all exposed skin areas thoroughly.
- If preservatives or sawdust accumulate on clothes, wash the clothes (separately from other household clothing) before wearing them again.
- Dispose of the cuttings by ordinary trash collection or burial. The cuttings should not be burned in open fires or in stoves, fireplaces, or residential boilers because toxic chemicals may be produced as part of the smoke and ashes. The cuttings may be burned only in commercial or industrial incinerators or boilers in accordance with Federal and State regulations.
- Avoid frequent or prolonged skin contact with pentachlorophenol or creosote-treated wood; when handling it, wear long-sleeved shirts and long pants and use gloves impervious to the chemicals (e.g., vinyl-coated gloves).
- Do not use pentachlorophenol-pressure-treated wood in residential interiors except for laminated beams or for building elements that are in ground contact and are subject to decay or insect infestation and where two coats of an appropriate sealer are applied. Sealers may be applied at the installation site. Urethane, shellac, latex epoxy enamel, and varnish are acceptable sealers.
- Do not use creosote-treated wood in residential interiors. Coal tar pitch and coal tar pitch emulsion are effective sealers for outdoor creosote-treated wood-block flooring. Urethane, epoxy, and shellac are acceptable sealers for all creosote-treated wood.

13.1.6 Foundation Material Durability

Ideally, all of the pile-and-beam foundation framing of a coastal building is protected from rain by the overhead structure, even though all of the exposed materials should be resistant to decay and corrosion. In practice, the overhead structure includes both enclosed spaces (such as the main house) and outside decks. The spaces between the floor boards on an outside deck allow water to pass through and fall on the framing below. A worst case for potential rain and moisture penetration exists when less permeable decks collect water and channel it to fall as a stream onto the framing below. In addition, wind-driven rain and ocean spray penetrates into many small spaces, and protection of the wood in these spaces is therefore important to long-term durability of the structure.

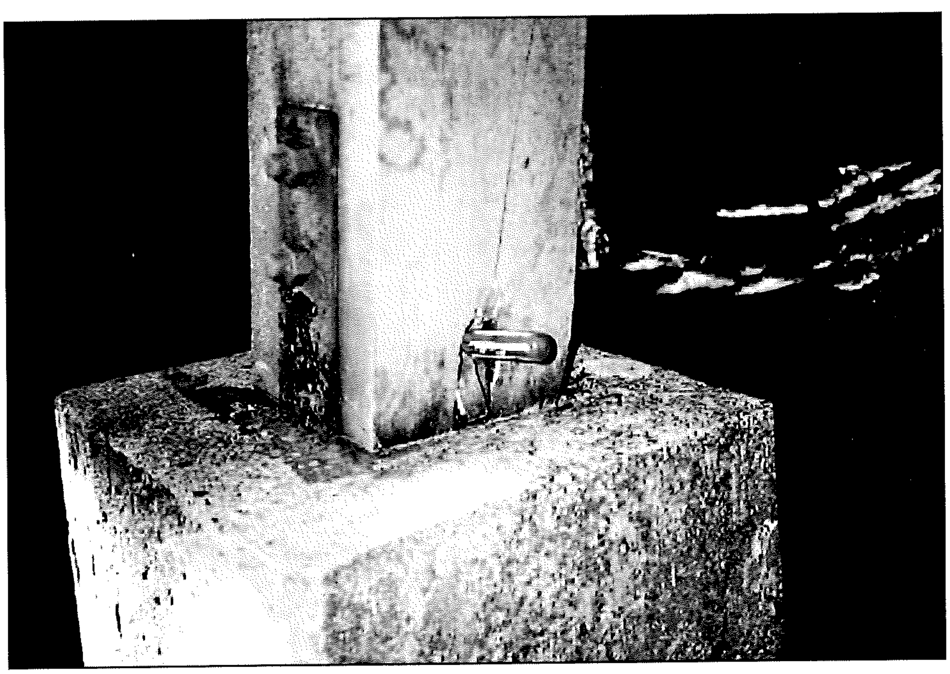
The durability of the exposed wood frame can be improved by detailing it to shed water during wetting and to dry readily afterward. Decay occurs in wetted locations where the moisture content of the exposed, untreated interior core of treated wood elements remains above the fiber saturation point—about 30 percent. The moisture content of seasoned, surface-dry 2x lumber (S-DRY) is less than or equal to 19 percent content when it arrives at the job site, but the moisture content is quickly reduced as the wood dries in the finished building. The moisture content of the large members (i.e., greater than 3 times) is much higher than 19 percent when they arrive at the job site, and the moisture content takes months to drop below 19 percent.

The potential for deterioration is greatest at end grain surfaces. Water is most easily absorbed along the grain, allowing it to penetrate deep into the member where it does not readily dry. Figure 13-9 illustrates deterioration in the end of a post installed on a concrete base. This is a typical place for wood deterioration to occur. Even when the end grain is more exposed to drying, the absorptive nature of the end grain creates an exaggerated shrink/swell cycling, resulting in checks and splits, which in turn allow increased water penetration.

Exposed pile tops present the vulnerable horizontal end grain cut to the weather. Cutting the exposed top of a pile at a slant does not prevent decay and may even channel water into checks. Water enters checks and splits in the top and side surfaces of beams and girders. It can then penetrate into the untreated core and cause decay. These checks and splits occur naturally in large sawn timbers as the wood dries and shrinks over time. They are less common in glue-laminated timbers and built-up sections. It is generally, but not universally, agreed that caulking the checks and splits is unwise because caulking is likely to promote water retention more than keep water out. The best deterrent is to try to keep the water from reaching the checks and splits.

Framing construction that readily collects and retains moisture, such as pile tops, pile-beam connections, and horizontal girder and beam top surfaces, can be covered with flashing or plywood. However, there should always be an air gap between the protected wood and the flashing so that water vapor passing out of the wood is not condensed at the wood surface. For example, a close-fitting cap of sheet metal on a pile top can cause water vapor coming out of the pile top to condense and cause decay. The cap can also funnel water into the end grain penetrations of the vertical fasteners.

Figure 13-9.
Wood decay at the base of a post supported by concrete



When two flat wood surfaces are in contact in a connection, the contact surface tends to retain any water directed to it. The wider the connection's least dimension, the longer the water is retained and the higher the likelihood of decay. Treated wood in this contact surface is more resistant to decay but only at an uncut surface. The least dimension of the contact surface should be as small as possible. When the contact surfaces are for structural bearing, only as much bearing surface as needed should be provided, considering both perpendicular-to-grain and parallel-to-grain bearing design stresses. For example, deck boards on 2x joists have a smaller contact surface least dimension than deck boards on 4x joists. A beam bolted alongside an unnotched round wood pile has a small least dimension of the contact surface. Figure 13-10 illustrates the least-dimension concept.

Poor durability performance has been observed in exposed sistered members. When sistered members must be used in exposed conditions, they should be of ground-contact-rated treated wood, and the top surface should be covered with a self-adhering modified bitumen ("peel and stick") flashing membrane. This material is available in rolls as narrow as 3 inches. The membranes seal around nail penetrations to keep water out. In contrast, sheet-metal flashings over sistered members, when penetrated by nails, can channel water into the space between the members.

Other methods of improving exposed structural frame durability include:

- Using drip cuts to avoid horizontal water movement along the bottom surface of a member. Figure 13-11 shows this type of cut.

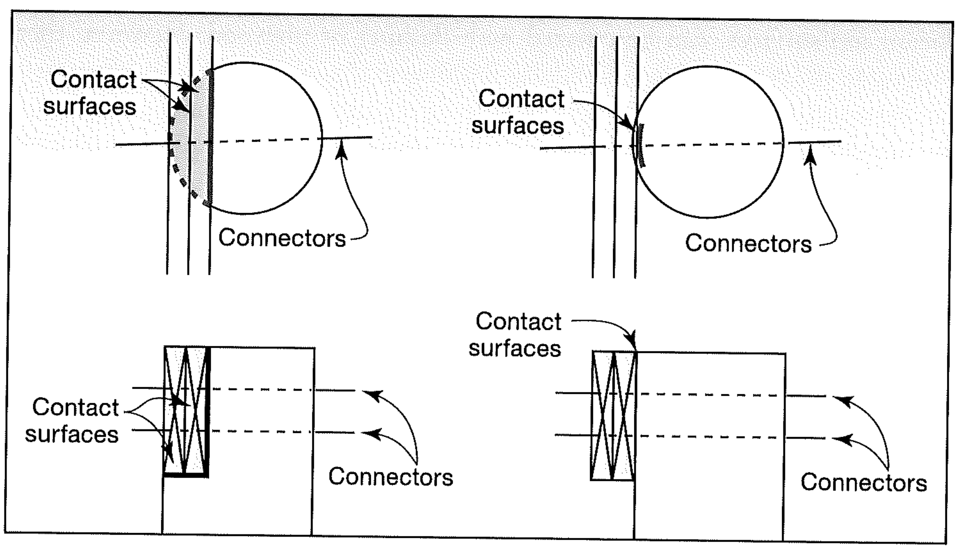


Figure 13-10.
Examples of minimizing the least dimension of wood contact surfaces

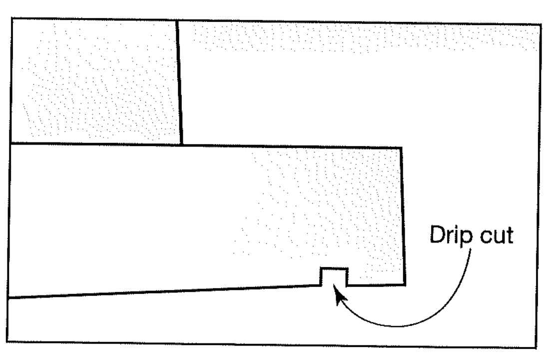


Figure 13-11.
Drip cut to minimize horizontal water movement along the bottom surface of a wood member

- Avoiding assemblies that form "buckets" and retain water adjacent to wood.
- Avoiding designs that result in ledges below a vertical or sloped surface. Ledges collect water quite readily, and the resulting ponding from rain or condensation alternating with solar radiation causes shrink-swell cycling, resulting in checks that allow increased water penetration.
- To the extent possible, minimizing the number of vertical holes in exposed horizontal surfaces from nails, lags, and bolts.
- When possible, avoiding the use of stair stringers that are notched for each stair. Notching exposes the end grain, which is then covered by the stair. As a result, the stair tends to retain moisture at the notch where the bending stress is greatest at the minimum depth section. Figure 13-12 illustrates stair stringer exposure, and Figure 13-13 shows the type of deterioration that can result.

Figure 13-12. Exposure of end grain in stair stringer cuts

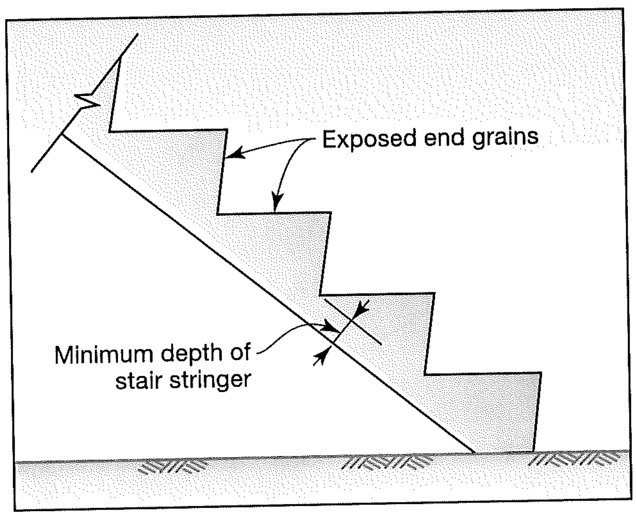
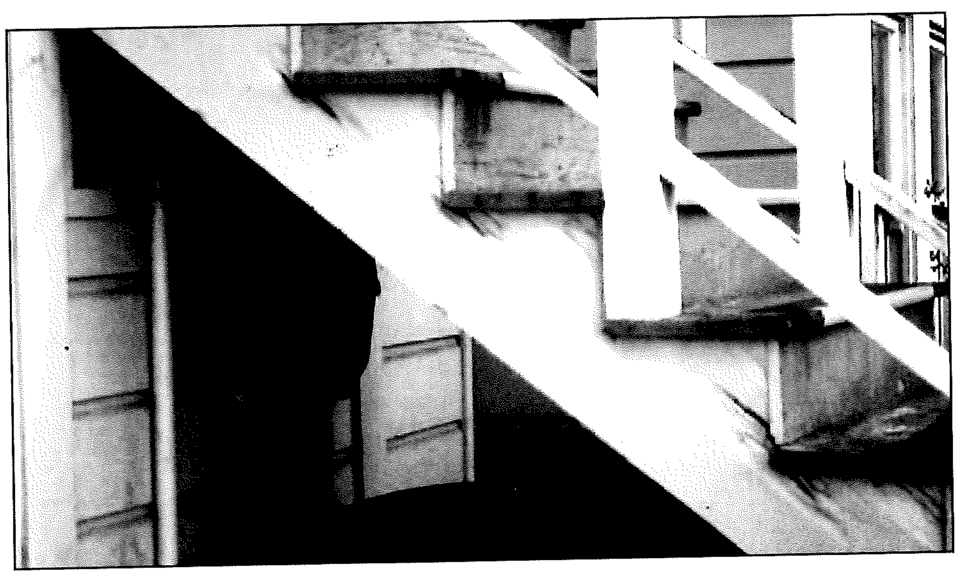


Figure 13-13. Deterioration in a notched stair stringer



- Using the alternative stair stringer installation shown in Figure 13-14 when the stair treads are either nailed onto a cleat or the stringer is routed out so the tread fits into the routed-out area. Even these alternatives allow water retention at end grain surfaces, and these surfaces should therefore be field-treated with wood preservative.

- Caulking joints at wood connections to keep water out. Caulk only the top joints in the connection. Recaulk after the wood has shrunk, which can take up to a year for larger members.

- When structurally possible, considering using spacers or shims to separate contact surfaces. A space of about 1/16-inch discourages water retention by capillary action but can easily fill with dirt and debris. A 1/4- to 1/2-inch space is sufficient to allow water and debris to clear from the interface. This spacing has structural limitations; a bolted connection with an unsupported shim has much less shear capacity than an unspaced connection because of increased bolt bending and unfavorable bearing stress distribution in the wood.

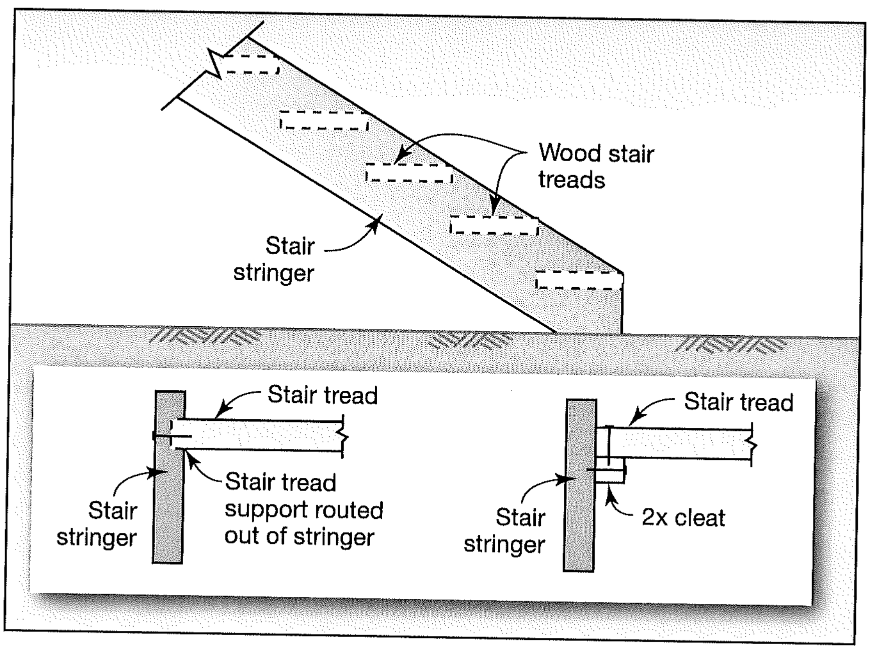


Figure 13-14.
Alternative method of installing stair treads

13.1.7 Field Preservative Treatment

Field cuts and bores of pressure-preservative-treated piles, timbers, and lumber are inevitable in coastal construction. Unfortunately, these cuts expose the inner untreated part of the wood member to possible decay and infestation. Although field preservative treatments are much less effective than pressure-preservative treatment, the decay and infestation potential can be minimized by treating the cuts and bolt holes with field-applied preservative.

13.1.8 Substitutions

During construction, a builder may find that materials called for in the construction plans or specifications are not available or that the delivery time for those materials is too long and will delay the completion of the building. These conflicts require decisions about substituting one type of construction material for another. Because of the high natural hazard forces imposed on buildings near the coast and the effects of the severe year-round environment in coastal areas, substitutions should be made only after approval by a design professional and, if necessary, the local building official.

WARNING

When substitutions are proposed, the design professional's approval should be obtained before the substitution is made. The ramifications of the change must be evaluated, including the effects on the building elements, constructability, and long-term durability. Code and regulatory ramifications should also be considered.

13.1.9 Foundation Inspection Points

If the foundation is not constructed properly, many construction details in the foundation can cause failure during a severe natural hazard event or premature failure because of deterioration caused by the harsh coastal environment. Improperly constructed foundations are frequently covered up, so any deficiency in the load-carrying or distributing capacity of one member is not easily detected until failure occurs. It is therefore very important to inspect the foundation while construction is in progress to ensure that the design is completed as intended. Table 13-1 is a list of suggested critical inspection points for the foundation.

Table 13-1. Foundation and Floor Framing Inspection Points

Inspection Point	Reason
1. **Pile-to-girder connection**	Ensures that pile is not overnotched, that it is field-treated, and that bolts are properly installed with washers and proper end and edge distance
2. **Joist-to-girder connection**	Verifies presence of positive connection with properly nailed, corrosion-resistant connector
3. **Joist blocking**	Ensures that the bottom of the joist is prevented from bending/buckling
4. **Sheathing nailing** – number, spacing, depth	Ensures that sheathing acts as a shear diaphragm
5. **Material storage** – protection from elements prior to installation	Ensures that the wood does not absorb too much moisture prior to installation—exposure promotes checks and splits in wood, warp, and separation in plywood
6. **Joist and beam material** – excessive crown or lateral warping, large splits	Ensures that new floors are installed level and eliminates need to repair large splits in new material

13.1.10 Top Foundation Issues for Builders

The top foundation-related issues for builders are as follows:

- Piles, piers, or columns must be properly aligned.
- Piles, piers, or columns must be driven or placed at the proper elevation to resist failure and must extend below the expected depth of scour and erosion.

- Foundation materials must be damage-resistant to flooding (pressure-treated wood, masonry, or concrete).
- The support at the top of the foundation element must be adequate to properly attach the floor framing system. Notching of a wood foundation element should not exceed the specifications in the construction documents.
- Breakaway walls should not be overnailed to the foundation. They are intended to fail. Utilities and other obstructions should not be installed behind these walls, and the interior faces should not be finished.
- For masonry or concrete foundation elements (except slabs-on-grade), the proper size of reinforcing, proper number of steel bars, and proper concrete cover over the steel should be used.
- Concrete must have the proper mix to meet the specialized demands of the coastal environment.
- Exposed steel in the foundation corrodes; corrosion should be planned for by installing hot-dipped galvanized or stainless steel.
- Areas of pressure-treated wood that have been cut or drilled retain water and decay; these cut areas should be treated in the field.

13.2 Structural Frame

Structural framing includes framing the floors, walls, and roof and installing critical connections between each element.

WARNING

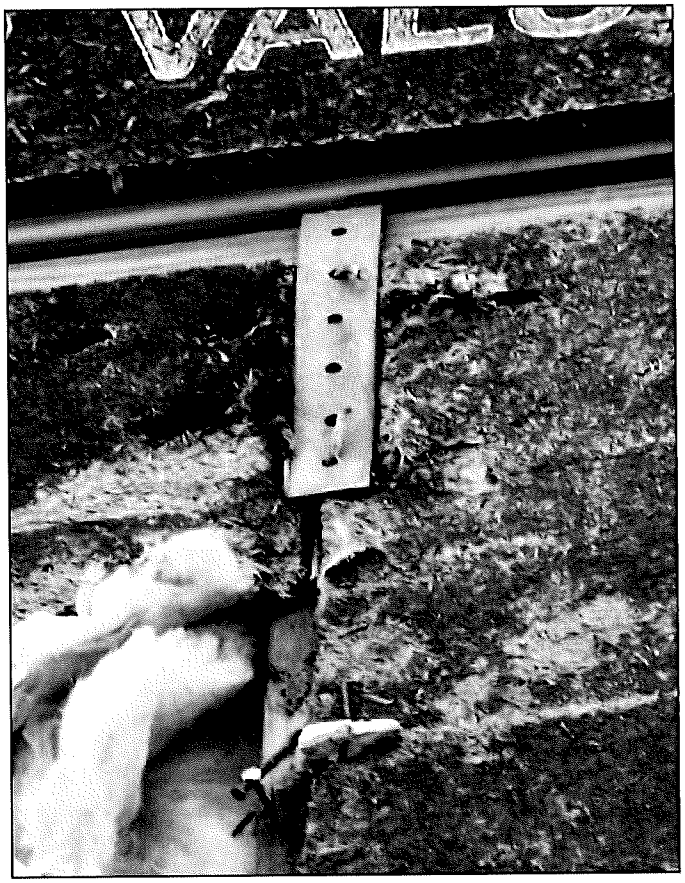
The connections described in this Manual are designed to hold the building together in a design event. Builders should never underestimate the importance of installing connectors according to manufacturers' recommendations. Installing connectors properly is extremely important.

13.2.1 Structural Connections

One of the most critical aspects of building in a coastal area is the method that is used to connect the structural members. A substantial difference usually exists between connections acceptable in inland construction and those required to withstand the natural hazard forces and environmental conditions in coastal areas. Construction in noncoastal, nonseismic areas must normally support only vertical dead and live loads and modest wind loads. In most coastal areas, large forces are applied by wind, velocity flooding, wave impact, and floating debris. The calculated forces along the complete load path usually require that the builder provide considerable lateral and uplift capacity in and between the roof, walls, floors, girders, and piles. Consequently, builders should be sure to use the specified connectors or approved substitutes. Connectors that look alike may not have the same capacity, and a connector designed for gravity loads may have little uplift resistance. Fact Sheet 4.1, *Load Path,* in FEMA P-499 describes load paths and highlights important connections in a typical wind load path.

The nails required for the connection hardware may not be regularly found on the job site. For example, full-diameter 8d to 20d short nails are commonly specified for specific hurricane/seismic connection hardware.

Figure 13-15.
Connector failure caused by insufficient nailing



WARNING

Proper nail selection and installation are critical. Builders should not substitute different nails or nailing patterns without approval from the designer.

For full strength, these connections require that all of the holes in the hardware be nailed with the proper nails. In the aftermath of investigated hurricanes, failed connector straps and other hardware have often been found to have been attached with too few nails, nails of insufficient diameter, or the wrong type of nail. Figure 13-15 shows a connector that failed because of insufficient nailing.

As mentioned previously, connection hardware must be corrosion-resistant. If galvanized connectors are used, additional care must be taken during nailing. When a hammer strikes the connector and nail during installation, some of the galvanizing protection is knocked off. One way to avoid this problem is to use corrosion-resistant connectors that do not depend on a galvanized coating, such as stainless steel or wood (see Section 9.2.3). Only stainless steel nails should be used with stainless steel connectors. An alternative to hand-nailing is to use a pneumatic hammer that "shoots" nails into connector holes.

NOTE

Additional information about pneumatic nail guns can be obtained from the International Staple, Nail and Tool Association, 512 West Burlington Ave., Suite 203, LaGrange, IL 60525-2245. A report prepared by National Evaluation Service, Inc., NER-272, *Power-Driven Staples and Nails for Use in All Types of Building Construction* (NES 1997), presents information about the performance of pneumatic nail guns and includes prescriptive nailing schedules.

All connections between members in a wood-frame building are made with nails, bolts, screws, or a similar fastener. Each fastener is installed by hand. The predominant method of installing nails is by pneumatic nail gun. Many nail guns use nails commonly referred to as "sinkers." Sinkers are slightly smaller in diameter and thus have lower withdrawal and shear capacities than common nails of the same size. Nail penetration is governed by air pressure for pneumatic nailers, and nail penetration is an important quality control issue for builders. Many prescriptive codes have nailing schedules for various building elements such as shearwalls and diaphragms.

Another critical connection is the connection of the floor to the piles. Pile alignment and notching are critical not only to successful floor construction but also to the structural adequacy during a natural hazard event (see Section 13.1.1). Construction problems related to these issues are also inevitable, so solutions to pile misalignment and overnotching must be developed. Figure 13-16 illustrates a method of reinforcing an overnotched pile, including one that is placed on a corner. The most appropriate solution to pile misalignment is to re-drive a pile in the correct location. An alternative is illustrated in Figure 13-17, which shows a method of supporting a beam at a pile that has been driven "outside the layout" of the pile foundation. Figure 13-18

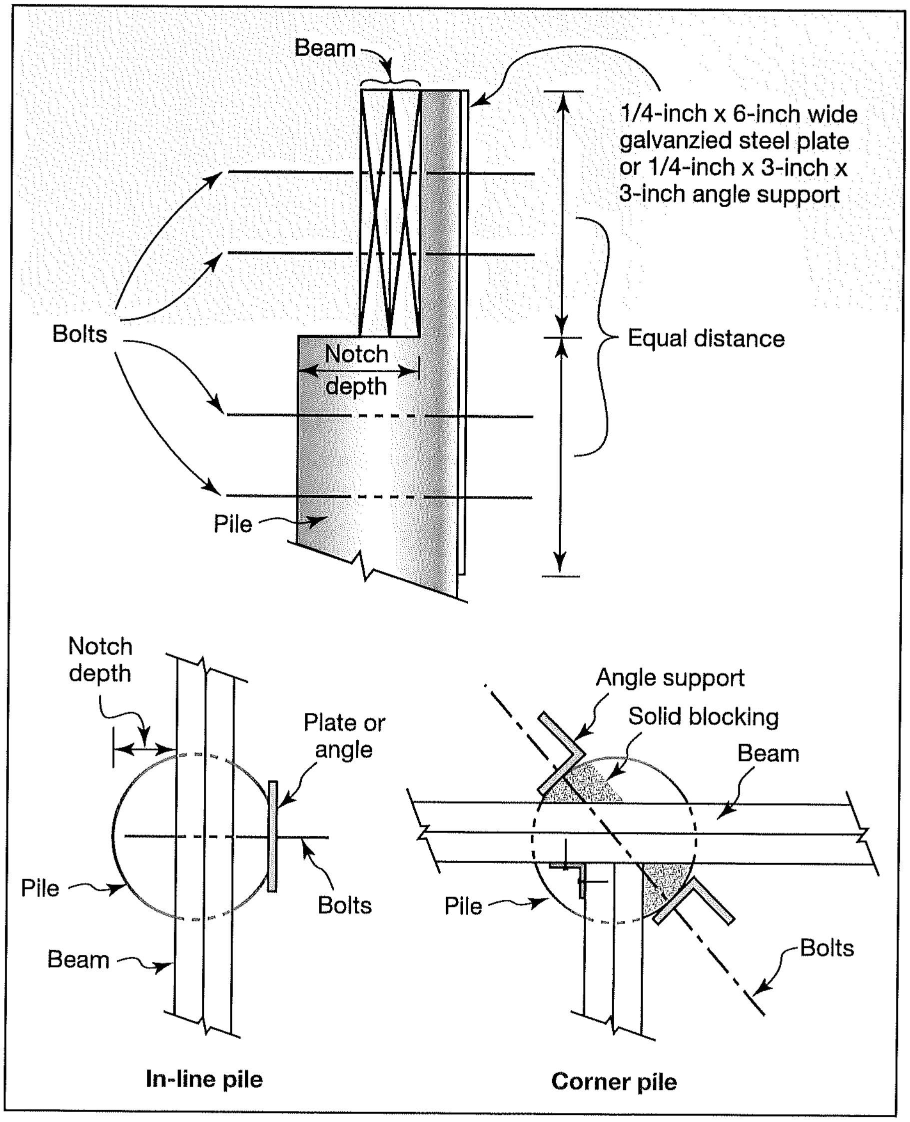


Figure 13-16. Reinforcement of overnotched piles

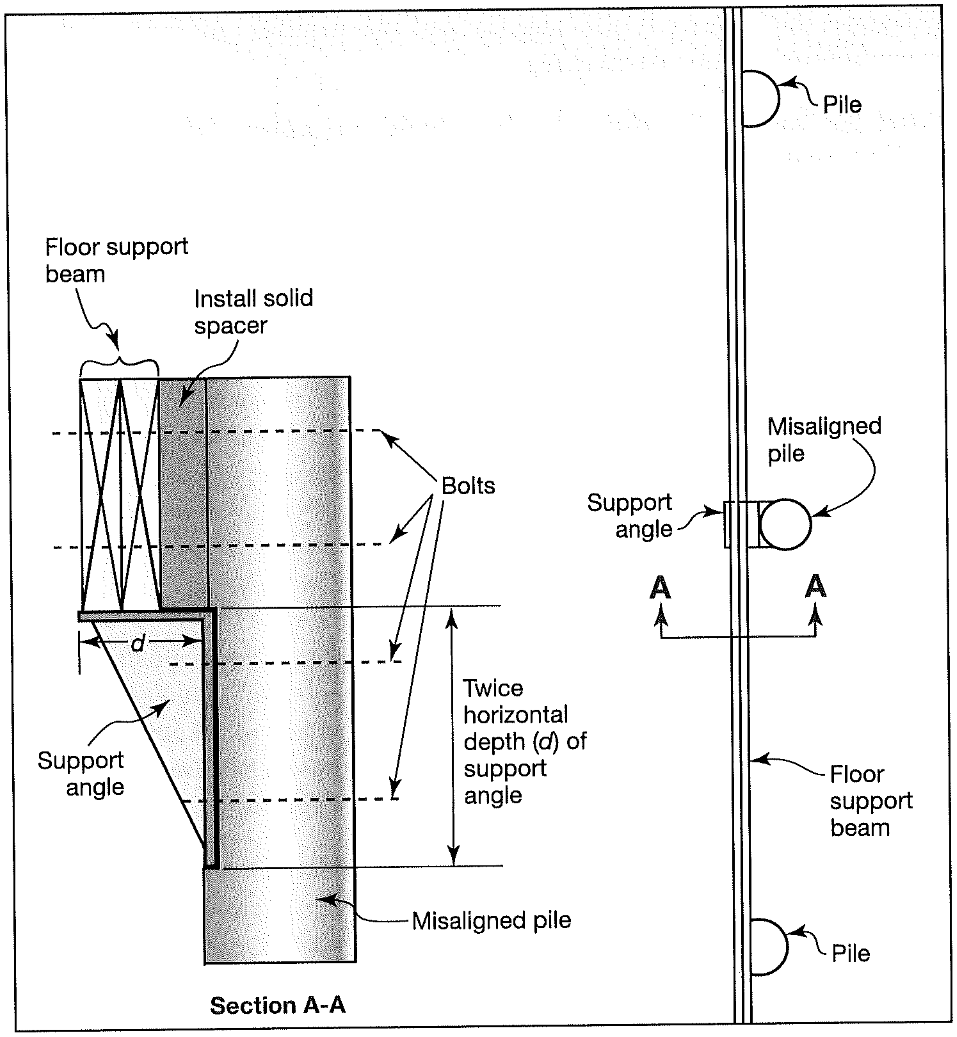


Figure 13-17.
Beam support at misaligned piles

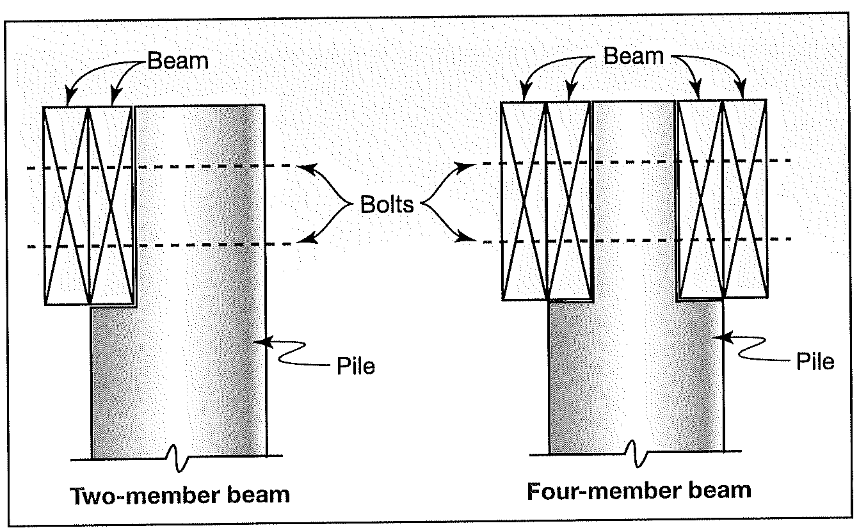


Figure 13-18.
Proper pile notching for two-member and four-member beams

illustrates the proper pile notching for both two-member and four-member beams. See Section 13.1.1 for more information on pile notching.

After the "square" foundation has been built, the primary layout concerns about how the building will perform under loads are confined to other building elements being properly located so that load transfer paths are complete.

13.2.2 Floor Framing

The connection between wood floor joists and the supporting beams and girders is usually a bearing connection for gravity forces with a twist strap tie for uplift forces. Figure 13-19 shows a twist tie connection. This connection is subjected to large uplift forces from high winds. In addition, the undersides of elevated structures, where these connectors are located, are particularly vulnerable to salt spray; the exposed surfaces are not washed by rain, and they stay damp longer because of their sheltered location. Consequently, the twist straps and the nails used to secure them must be hot-dipped galvanized or stainless steel. One way to reduce the corrosion potential for metal connectors located under the building is to cover the connectors with a plywood bottom attached to the undersides of the floor joists. (The bottom half of the joist-to-girder twist straps will still be exposed, however.) This covering will help keep insulation in the floor joist space as well as protect the metal connectors.

CROSS REFERENCE

See NFIP Technical Bulletin 8-96, *Corrosion Protection for Metal Connectors in Coastal Areas* (FEMA 1996).

Because the undersides of Zone V buildings are exposed, the first floor is more vulnerable to uplift wind and wave forces, as well as to the lateral forces of moving water, wave impact, and floating debris. These loads cause compressive and lateral forces in the normally unbraced lower flange of the joist. Solid blocking or 1x3 cross-bridging at 8-foot centers is recommended for at least the first floor joists unless substantial sheathing (at least 1/2-inch thick) has been nailed well to the bottom of these joists. Figure 13-19 also shows solid blocking between floor joists.

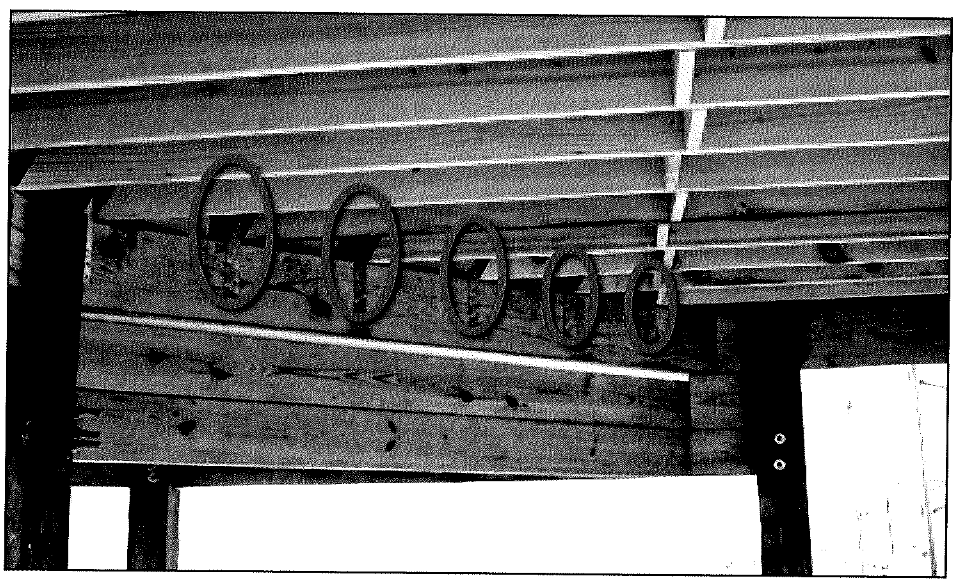


Figure 13-19.
Proper use of metal twist strap ties (circled); solid blocking between floor joists

Floor framing materials other than 2x sawn lumber are becoming popular in many parts of the country. These materials include wood floor trusses and wood I-joists. Depending on the shape of the joist and the manufacturer, the proper installation of these materials may require some additional steps. For instance, some wood I-joists require solid blocking at the end of the joist where it is supported so that the plywood web is not crushed or does not buckle. Figure 13-20 illustrates the use of plywood web I-joists. As shown in the figure, the bottom flanges of the joists are braced with a small metal strip that helps keep the flange from twisting. Solid wood blocking is a corrosion-resistant alternative to the metal braces.

Floor surfaces in high-wind, flood, or seismic hazard areas are required to act as a diaphragm. For the builder, this means that the floor joists and sheathing are an important structural element. Therefore, the following installation features may require added attention:

- Joints in the sheathing should fully bear on top of a joist, not a scabbed-on board used as floor support
- Nailing must be done in accordance with a shear diaphragm plan
- Construction adhesive is important for preventing "squeaky" floors, but the adhesive must not be relied on for shear resistance in the floor

Joints in the sheathing across the joists must be fully blocked with a full-joist-height block. Horizontal floor diaphragms with lower shear capacities can be unblocked if tongue-and-groove sheathing is used.

13.2.2.1 Horizontal Beams and Girders

Girders and beams can be solid sawn timbers, glue-laminated timbers (see Figure 13-20), or built-up sections (see "Material Durability in Coastal Environments" on the Residential Coastal Construction Web site at http://www.fema.gov/rebuild/mat/fema55.html). The girders span between the piles and support the beams and joists. The piles are usually notched to receive the girders. To meet the design intent, girders, beams, and joists must be square and level, girders must be secured to the piles, and beams and joists must be secured to the girders.

Figure 13-20.
Engineered joists used as floor joists with proper metal brace to keep the bottoms of the joists from twisting; engineered wood beam

The layout process involves careful surveying, notching, sawing, and boring. The bottom of the notch provides the bearing surface for downward vertical loads. The bolted connection between the girder and the vertical notch surface provides capacity for uplift loads and stability. Girder splices are made as required at these connections. Splices in multiple-member girders may be made away from the pile but should be engineered so that the splices occur at points of zero bending moment. This concept is illustrated in Figure 13-21.

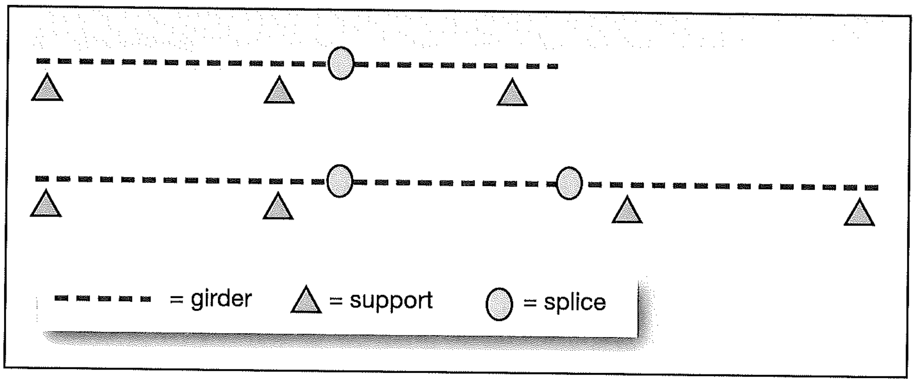


Figure 13-21. Acceptable locations for splices in multiple-member girders

13.2.2.2 Substitution of Floor Framing Materials

The considerations discussed in Section 13.1.8 for substitution of foundation materials also apply to substitutions of floor framing materials.

13.2.2.3 Floor Framing Inspection Points

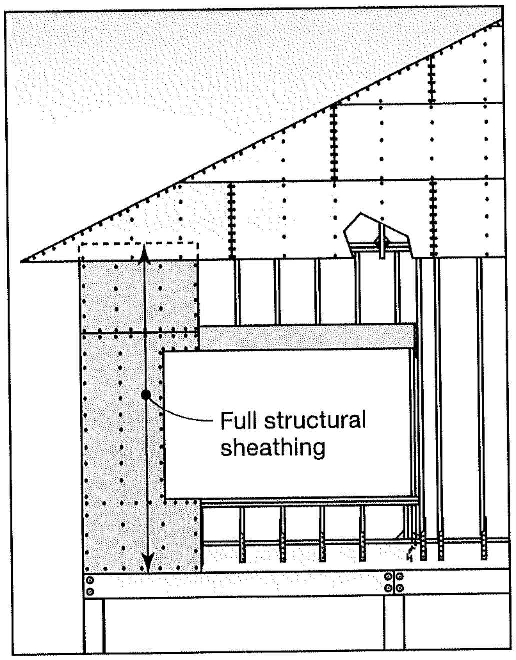
Proper connections between elements of the floor framing help to guarantee that the load path is continuous and the diaphragm action of the floor is intact. If floor framing is not constructed properly, many construction details in the floor framing can become structural inadequacies during a severe natural hazard event or cause premature failure because of deterioration caused by the harsh coastal environment. Table 13-1 is a list of suggested critical inspection points in foundations and a guide for floor framing inspections.

13.2.3 Wall Framing

Exterior walls and designated interior shear walls are an important part of the building's vertical and lateral force-resisting system. All exterior walls must be able to withstand in-plane (i.e., parallel to the wall surface), gravity, and wind uplift tensile forces, and out-of-plane (i.e., normal or perpendicular to the wall surface) wind forces. Exterior and designated interior shear walls must be able to withstand shear and overturning forces transferred through the walls to and from the adjacent roof and floor diaphragms and framing.

The framing of the walls should be of the specified material and fastened in accordance with the design drawings and standard code practice. Exterior wall and designated shear wall sheathing panels must be of the specified material and fastened with accurately placed nails whose size, spacing, and durability are in accordance with the design. Horizontal sheathing joints in shear walls must be solidly blocked in accordance with shear wall capacity tables. Shear transfer can be better accomplished if the sheathing extends the full height from the bottom of the floor joist to the wall top plate (see Figure 13-22), but sheathing this long is often unavailable.

Figure 13-22.
Full-height sheathing to improve transfer of shear



The design drawings may show tiedown connections between large shearwall vertical posts and main girders. Especially in larger, taller buildings, these connections must resist thousands of pounds of overturning forces during high winds. See Section 8.7 for information regarding the magnitude of these forces. The connections must be accomplished with careful layout, boring, and assembly. Shear transfer nailing at the top plates and sills must be in accordance with the design. Proper nailing and attachment of the framing material around openings is very important; see Section 9.2.1 for a discussion of the difficulty of transferring large shear loads when there are large openings in the shearwall.

It is very important that shearwall sheathing (e.g., plywood, oriented strand board [OSB]) with an exterior exposure be finished appropriately with pigmented finishes such as paint, which last longer than unpigmented finishes, or semitransparent penetrating stains. It is also important that these finishes be properly maintained. Salt crystal buildup in surface checks in siding can damage the siding. Damage is typically worse in siding that is sheltered from precipitation because the salt crystals are never washed off with fresh rainwater.

To meet the design intent, walls must:

- Be plumb and square to each other and to the floor
- Be lined up over solid support such as a beam, floor joists, or a perimeter band joist
- Not have any more openings than designated by the plans
- Not have openings located in places other than designated on the plans
- Consist of material expected to resist corrosion and deterioration
- Be properly attached to the floors above and below the wall, including the holddown brackets required to transfer overturning forces

In addition, all portions of walls designed as shearwalls must be covered with sheathing nailed in accordance with either the plans or a specified prescriptive standard.

13.2.3.1 Substitution of Wall Framing Materials

The considerations discussed in Section 13.1.8 for substitution of foundation materials also apply to substitutions of wall framing materials.

13.2.3.2 Wall Framing Inspection Points

Proper connections between elements of the wall framing help to guarantee a continuous load path and the diaphragm action of the walls is intact. If not completed properly, there are many construction details in the floor framing that can become structural inadequacies and fail during a severe natural hazard event or cause premature failure because of deterioration caused by the harsh coastal environment. Table 13-2 is a list of suggested critical inspection points that can be used as a guide for wall framing inspections.

Table 13-2. Wall Inspection Points

Inspection Point	Reason
1. **Wall framing attachment to floors**	Ensures that nails are of sufficient size, type, and number
2. **Size and location of openings**	Ensures performance of shear wall
3. **Wall stud blocking**	Ensures that there is support for edges of sheathing material
4. **Sheathing nailing** – number, spacing, depth of nails	Ensures that sheathing acts as a shear diaphragm
5. **Material storage** – protection from elements prior to installation	Ensures that the wood does not absorb too much moisture prior to installation—exposure promotes checks and splits in wood, warp, and separation in plywood
6. **Stud material** – excessive crown (crook) or lateral warping (bow)	Maintains plumb walls and eliminates eccentricities in vertical loading
7. **Header support over openings**	Ensures that vertical and lateral loads will be transferred along the continuous load path

13.2.4 Roof Framing

Proper roof construction is very important in high-wind and earthquake hazard areas. Reviews of wind damage to coastal buildings reveal that most damage starts with the failure of roof elements. The structural integrity of the roof depends on a complete load path, including the resistance to uplift of porch and roof overhangs, gable end overhangs, roof sheathing nailing, roof framing nailing and strapping, roof member-to-wall strapping, and gable end-wall bracing.

WARNING

The most common roof structure failure is the uplift failure of porch, eave, and gable end overhangs. The next most common is roof sheathing peeling away from the framing. Nailing the sheathing at the leading edge of the roof, the gable edge, and the joints at the hip rafter or ridge is very important, as is securing the roof framing to prevent uplift. This failure point (leading edge of sheathing at gable edge, ridge, and hip) is also the most likely place for progressive failure of the entire structure to begin.

All of this construction must use the specified wood materials, straps, and nails. The appropriate nails must be used in all of the holes in the straps so that the straps develop their full strength. Sheathing nails must be of the specified length, diameter, and head, and the sheathing must be nailed at the correct spacing. In addition, sheathing nails must penetrate the underlying roof framing members and must not be overdriven, which frequently occurs when pneumatic nail guns are used. When prefabricated roof trusses are used, handling precautions must be observed, and the trusses must be laterally braced as specified by the design professional or manufacturer.

Fact Sheets 7.1 through 7.4 in FEMA P-499 discuss roof construction, including sheathing installation, asphalt shingle roofing, and tile roofing.

To meet the design intent, roofs must meet the following requirements:

- Roof trusses and rafters must be properly attached to the walls
- Roof sheathing must be nailed according to either the construction plans or a specified prescriptive standard
- Roofs must consist of materials expected to resist corrosion and deterioration, particularly the connectors

13.2.4.1 Substitution of Roof Framing Materials

The considerations discussed in Section 13.1.8 for substitution of foundation materials also apply to substitutions of roof framing materials.

13.2.4.2 Roof Frame Inspection Points

Proper connections between elements of the roof frame help to guarantee a continuous load path and the diaphragm action of the walls is intact. If not completed properly, there are many construction details in the roof framing that can become structural inadequacies and fail during a severe natural hazard event or cause premature failure because of deterioration caused by the harsh coastal environment. Table 13-3 contains suggestions of critical inspection points as a guide for roof framing inspections.

WARNING

Do not substitute nails, fasteners, or connectors without approval of the designer.

13.2.5 Top Structural Frame Issues for Builders

The top structural frame issues for builders are as follows:

- Connections between structural elements (e.g., roofs to walls) must be made so that the full natural hazard forces are transferred along a continuous load path.
- Care must be taken to nail elements so that the nails are fully embedded.
- Compliance with manufacturers' recommendations on hardware use and load ratings is critically important.

Table 13-3. Roof Frame Inspection Points

Inspection Point	Reason
1. **Roof framing attachment to walls**	Ensures that the sufficient number, size, and type of nails are used in the proper connector
2. **Size and location of openings**	Ensures performance of roof as a diaphragm
3. **"H" clips or roof frame blocking**	Ensures that there is support for edges of the sheathing material
4. **Sheathing nailing** – number, spacing, depth of nails	Ensures that sheathing acts as a shear diaphragm and is able to resist uplift
5. **Material storage** – protection from elements prior to installation	Ensures that the wood does not absorb too much moisture prior to installation—exposure promotes checks and splits in wood, warp, and separation in plywood
6. **Rafter or ceiling joist material** – excessive crown or lateral warping	Maintains level ceilings
7. **Gable-end bracing**	Ensures that bracing conforms to design requirements and specifications

- Only material that is rated and specified for the expected use and environmental conditions should be used.
- Builders should understand that the weakest connections fail first and that it is therefore critical to pay attention to every connection. The concept of continuous load path must be considered for every connection in the structure.
- Exposed steel in the structural frame corrodes even in places such as the attic space. The builder should plan for it by installing hot-dipped galvanized or stainless steel hardware and nails.
- Compliance with suggested nailing schedules for roof, wall, and floor sheathing is very important.

13.3 Building Envelope

The building envelope comprises the exterior doors, windows, skylights, non-load-bearing walls, wall coverings, soffits, roof systems, and attic vents. The floor is also considered a part of the envelope in buildings elevated on open foundations. Building envelope design is discussed in detail in Chapter 11. The key to successful building envelope construction is having a detailed plan that is followed carefully by the builder, as described below.

A suitable design must be provided that is sufficiently specified and detailed to allow the builder to understand the design intent and to give the contractor adequate and clear guidance. Lack of sufficient and clear design guidance regarding the building envelope is common. If necessary, the contractor should seek additional guidance from the design professional or be responsible for providing design services in addition to constructing the building.

The building must be constructed as intended by the design professional (i.e., the builder must follow the drawings and specifications). Examples are:

- Installing flashings, building paper, or air infiltration barriers so that water is shed at laps
- Using the specified type and size of fasteners and spacing them as specified
- Eliminating dissimilar metal contact
- Using materials that are compatible with one another
- Installing elements in a manner that accommodates thermal movements so that buckling or jacking out of fasteners is avoided
- Applying finishes to adequately cleaned, dried, and prepared substrates
- Installing backer rods or bond breaker tape at sealant joints
- Tooling sealant joints

For products or systems specified by performance criteria, the contractor must exercise care in selecting those products or systems and in integrating them into the building envelope. For example, if the design professional specifies a window by requiring that it be capable of resisting a specified wind pressure, the contractor should ensure that the type of window that is being considered can resist the pressure when tested in accordance with the specified test (or a suitable test if a test method is not specified). Furthermore, the contractor needs to ensure that the manufacturer, design professional, or other qualified entity provides guidance on how to attach the window frame to the wall so that the frame can resist the design pressures.

When the selection of accessory items is left to the discretion of the contractor, without prescriptive or performance guidance, the contractor must be aware of and consider special conditions at the site (e.g., termites, unusually severe corrosion, and high earthquake or wind loads) that should influence the selection of the accessory items. For example, instead of using screws in plastic sleeves to anchor elements to a concrete or masonry wall, a contractor can use metal expansion sleeves or steel spikes intended for anchoring to concrete, which should provide a stronger and more reliable connection, or the use of plastic shims at metal doors may be appropriate to avoid termite attack.

Adequate quality control (i.e., inspection by the contractor's personnel) and adequate quality assurance (i.e., inspection by third parties such as the building official, the design professional, or a test lab) must be provided. The amount of quality control/quality assurance depends on the magnitude of the natural hazards being designed for, complexities of the building design, and the type of products or systems being used. For example, installing windows that are very tall and wide and make up the majority of a wall should receive more inspection than isolated, relatively small windows. Inspecting roof coverings and windows is generally more critical than inspecting most wall coverings because of the general susceptibility of roofing and glazing to wind and the resulting damage from water infiltration that commonly occurs when these elements fail.

13.3.1 Substitution of Building Envelope Materials

The considerations discussed in Section 13.1.8 for substitution of foundation materials also apply to substitutions of envelope materials. Proposed substitutions of materials must be thoroughly evaluated and must be approved by the design professional (see Section 13.1.8). The building envelope must be installed in a manner that will not compromise the building's structural integrity. For example, during construction, if a window larger than originally intended is to be installed because of delivery problems or other reasons, the contractor should obtain the design professional's approval prior to installation. The larger window may unacceptably reduce the shear capacity of the wall, or different header or framing connection details may be necessary. Likewise, if a door is to be located in a different position, the design professional should evaluate the change to determine whether it adversely affects the structure.

13.3.2 Building Envelope Inspection Points

Table 13-4 is a list of suggested critical inspection points that can be used as a guide for building envelope inspections. Fact Sheet 6.1, *Window and Door Installation,* in FEMA P-499 discusses proper window and door installation and inspection points.

Table 13-4. Building Envelope Inspection Points

Inspection Point	Reason
1. **Siding attachment** to wall framing	Ensures there are sufficient number, type, and spacing of nails
2. **Attachment of windows and doors** to the wall framing	Ensures there are sufficient number, type, and spacing of either nails or screws
3. **Flashings** around wall and roof openings, roof perimeters, and at changes in building shape	Prevents water penetration into building envelope
4. **Roof covering attachment to sheathing,** including special connection details	Minimizes potential for wind blowoff. In high-seismic-load areas, attention to attachment of heavy roof coverings, such as tile, is needed to avoid displacement of the covering.
5. **Attachments of vents and fans** at roofs and walls	Reduces chance that vents or fans will blow off and allow wind-driven rain into the building

13.3.3 Top Building Envelope Issues for Builders

The top building envelope issues for builders are as follows:

- Many manufacturers do not rate their products in a way that it is easy to determine whether the product will really be adequate for the coastal environment and the expected loads. Suppliers should be required to provide information about product reliability in the coastal environment.
- Wind-driven rain finds a way into a building if there is an open path. Sealing openings and shedding water play significant parts in building a successful coastal home.
- Window and door products are particularly vulnerable to wind-driven rain leakage and air infiltration. These products should be tested and rated for the expected coastal conditions.
- The current high-wind techniques of adding extra roof surface sealing or attachments at the eaves and gable end edges should be used.
- Coastal buildings require more maintenance than inland structures. The maintenance requirement needs to be considered in the selection of materials and the care with which they are installed.

13.4 References

ACI (American Concrete Institute). 2008. *Building Code Requirements for Structural Concrete.* ACI 318-08.

AWPA (American Wood Protection Association). 1991. *Care of Pressure-Treated Wood Products.* AWPA Standard M4-91. Woodstock, MD.

AWPA. 1994. *Standards.* Woodstock, MD.

FEMA (Federal Emergency Management Agency). 1996. *Corrosion Protection for Metal Connectors in Coastal Areas.* NFIP Technical Bulletin 8-96.

FEMA. 2006. *Recommended Residential Construction for the Gulf Coast.* FEMA P-550.

FEMA. 2011. *Home Builder's Guide to Coastal Construction Technical Fact Sheets.* FEMA P-499.

ICC (International Code Council). 2008. *Standard for Residential Construction in High-Wind Regions,* ICC 600-2008. ICC: Country Club Hills, IL.

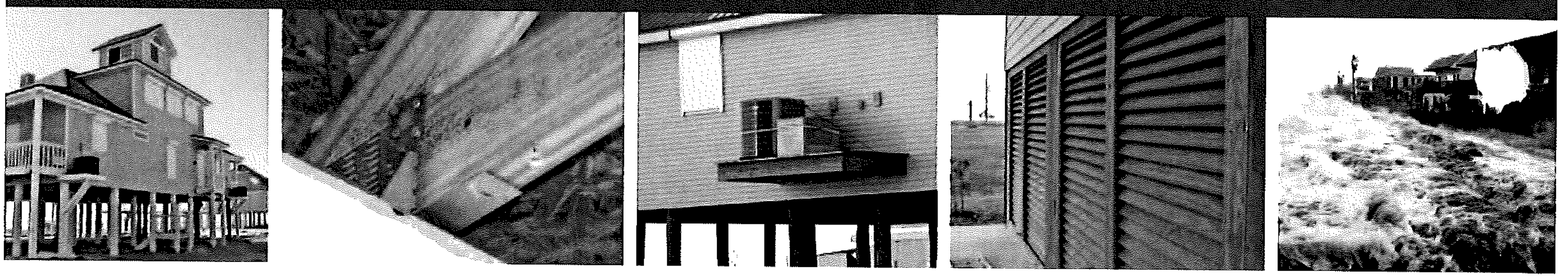
ICC. 2011a. *International Building Code.* 2012 IBC. Country Club Hills, IL: ICC.

ICC. 2011b. *International Residential Code for One-and Two-Family Dwellings.* 2012 IRC. Country Club Hills, IL: ICC.

NES (National Evaluation Service, Inc.). 1997. *Power-Driven Staples and Nails for Use in All Types of Building Construction.* National Evaluation Report NER-272.

TMS (The Masonry Society). 2008. *Building Code Requirements and Specification for Masonry Structures and Commentaries.* TMS 402-08/ACI 530-08/ASCE 5-08 and TMS 602-08/ACI 530.1-08/ ASCE 6-08.

USDN (U.S. Department of the Navy). 1982. *Foundation and Earth Structures Design.* Design Manual 7.2.



Maintaining the Building

This chapter provides guidance on maintaining the building structure and envelope.

CROSS REFERENCE

or resources that augment the guidance and other information in this Manual, see the Residential Coastal Construction Web site (http://www.fema.gov/rebuild/mat/fema55.shtm).

For maximum performance of a building in a coastal area, the building structure and envelope (i.e., exterior doors, windows, skylights, exterior wall coverings, soffits, roof systems, and attic vents) must not be allowed to deteriorate. Significant degradation by corrosion, wood decay, termite attack, or weathering increases the building's vulnerability to damage from natural hazards. Figure 14-1 shows a post that appears on the exterior to be in

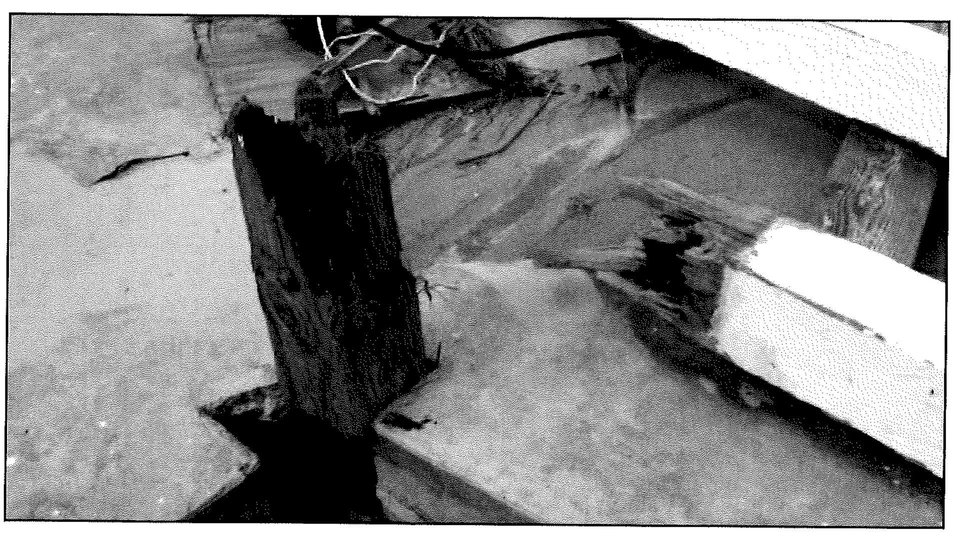


Figure 14-1.
Pile that appears acceptable from the exterior but has interior decay

acceptable condition but is weakened by interior decay, which can be determined only through a detailed inspection. This post failed under the loads imposed by a natural hazard event.

Long-term maintenance and repair demands are influenced directly by decisions about design, materials, and construction methods during building design and construction. Using less durable materials will increase the frequency and cost of required maintenance and repair. The design and detailing of various building systems (e.g., exposed structural, window, or roof systems) also significantly influence maintenance and repair demands.

COST CONSIDERATION

Maintenance and repair costs are related directly to original design decisions, materials selection, and construction methods.

14.1 Effects of Coastal Environment

The coastal environment can cause severe damage to the building structure and envelope. The damage arises primarily from salt-laden moisture, termites, and weathering.

14.1.1 Corrosion

The corrosive effect of salt-laden, wind-driven moisture in coastal areas cannot be overstated. Salt-laden, moist air can corrode exposed metal surfaces and penetrate any opening in the building. The need to protect metal surfaces through effective design and maintenance (see Section 14.2.6 for maintenance of metal connectors) is very important for the long-term life of building elements and the entire building. Stainless steel is recommended because many galvanized (non-heavy-gauge) products and unprotected steel products do not last in the harsh coastal environment.

Corrosion is most likely to attack metal connectors (see Section 14.2.6) that are used to attach the parts of the structure to one another, such as floor joists to beams and connectors used in cross-bracing below the finished lowest floor. Galvanized connectors coated with zinc at the rate of 0.9 ounce per square foot of surface area (designated G-90) can corrode in coastal environments at a rate of 0.1 to 0.3 millimeter/year. At this rate, the zinc protection will be gone in 7 years. A G-185 coated connector, which provides twice as much protection as G-90, can corrode in less than 20 years. More galvanized protection (more ounces of zinc per square foot of surface area to be protected) increases service life.

CROSS REFERENCE

For additional information on corrosion, see Section 9.4.5 in this Manual and FEMA Technical Bulletin 8-96, *Corrosion Protection of Metal Connectors in Coastal Areas for Structures Located in Special Flood Hazard Areas* (FEMA 1996).

Corrosion can also affect fasteners for siding and connectors for attaching exterior-mounted heating, ventilation, and air-conditioning units, electrical boxes, lighting fixtures, and any other item mounted on the exterior of the building. These connectors (nails, bolts, and screws) should be stainless steel or when they must be replaced, replaced with stainless steel. These connectors are small items, and the increased cost of stainless steel is small.

14.1.2 Moisture

There are many sources of exterior moisture from outside the home in the coastal environment. Whenever an object absorbs and retains moisture, the object may decay, mildew, or deteriorate in other ways. Figure 14-2 shows decay behind the connection plate on a beam.

Significant sources of interior moisture, such as kitchens, baths, and clothes dryers, should be vented to the outside in such a way that condensation does not occur on interior or exterior surfaces.

Figure 14-2. Wood decay behind a metal beam connector

Connectors should be designed to shed water to prevent water from accumulating between the connector and the material the connector is attached to. Trapped moisture increases the moisture content of the material and potentially leads to decay. Moisture is most likely to enter at intersections of materials where there is a hole in the building envelope (e.g., window, door) of where two surfaces are joined (e.g., roof to wall intersection). If properly installed, the flashings for the openings and intersections should not require maintenance for many years. However, flashings are frequently not properly installed or installed at all, creating an ongoing moisture intrusion problem.

The potential for wood framing in crawlspaces in low-lying coastal areas to decay is high. Moisture migration into the floor system can be reduced if the floor of the crawlspace is covered with a vapor barrier of at least 6-millimeter polyethylene. Where required by the local building code, wood framing in the crawlspace should be preservative-treated or naturally decay-resistant. The building code may have ventilation requirements.

Many existing crawlspaces are being converted to "conditioned crawlspaces." A moisture barrier is placed on the floor and walls of the crawlspace interior, insulation is added to the floor system (commonly sprayed-on polyurethane foam), and conditioned air is introduced into the space. In order for a conditioned crawlspace to be successful in low-lying coastal areas, moisture control must be nearly perfect so that the moisture content of the floor system does not exceed 20 percent (the minimum water content in wood that promotes mold growth). Conditioned crawlspaces are typically not practical in a floodplain where flood vents are required.

Sprinkler systems used for landscaping and other exterior water distribution systems (e.g., fountains) must be carefully tested so they do not create or increase water collection where metal connectors are fastened. Water collection can be prevented easily during installation of the exterior water distribution system by making sure the water distribution pattern does not increase the moisture that is present in the building materials.

14.1.3 Weathering

The combined effects of sun and water on many building materials, particularly several types of roof and wall coverings, cause weathering damage, including:

- Fading of finishes
- Accelerated checking and splitting of wood
- Gradual loss of thickness of wood
- Degradation of physical properties (e.g., embrittlement of asphalt shingles)

In combination, the effects of weathering reduce the life of building materials unless they are naturally resistant to weathering or are protected from it, either naturally or by maintenance. Even finishes intended to protect exterior materials fade in the sun, sometimes in only a few years.

14.1.4 Termites

The likelihood of termite infestation in coastal buildings can be reduced by maintenance that makes the building site drier and otherwise less hospitable to termites, specifically:

- Storing firewood and other wood items that are stored on the ground, including wood mulch, well away from the building
- Keeping gutters and downspouts free of debris and positioned to direct water away from the building
- Keeping water pipes, water fixtures, and drainpipes in good repair
- Avoiding dampness in crawlspaces by providing adequate ventilation or installing impervious ground cover membranes
- Avoiding frequent plant watering adjacent to the house and trimming plants away from the walls

If any wood must be replaced under the house in or near contact with the ground, the new wood should be treated. Removing moisture and treating the cellulose in wood, which is the termite's food source, are the most frequently used remedies to combat termites.

14.2 Building Elements That Require Frequent Maintenance

To help ensure that a coastal building is properly maintained, this Manual recommends that buildings be inspected annually by professionals with the appropriate expertise. The following building elements should be inspected annually:

- Building envelope – wall coverings, doors, windows, shutters, skylights, roof coverings, soffits, and attic vents
- Foundation, attic, and the exposed structural frame
- Exterior-mounted mechanical and electrical equipment

Table 14-1 provides a maintenance inspection checklist. Items requiring repair or replacement should be documented and the required work scheduled.

Table 14-1. Maintenance Inspection Checklist

Item	Element	Condition			Repair/Replace	
		Good	Fair	Poor	Yes	No
Foundation	**Wood pile** – decay, termite infestation, severe splits, connection to framing					
	Sill plates – deterioration, splits, lack of attachment to foundation					
	Masonry – deteriorated mortar joints, cracked block, step cracks indicating foundation settlement					
	Concrete – spalling, exposed or corroding reinforcing steel, ≥ 1/4-inch vertical cracks or horizontal cracks with lateral shift in the concrete across the crack					
Exterior Walls	**Siding** – deterioration, nail withdrawal, discoloration, buckling, attachment to studs (nails missing, withdrawn, or not attached to studs), sealant cracked/dried out					
	Trim – deterioration, discoloration, separation at joints, sealant cracked/dried out					
Porches/Columns	**Top and bottom connections to framing** – corrosion in connectors					
	Base of wood columns – deterioration					
Floors	**Joists or beams** – decay, termite infestation, corrosion at tiedown connectors, splits, excessive holes or notching, excessive sagging					
	Sheathing – deterioration, "squeaky" floors, excessive sagging, attachment to framing (nails missing, withdrawn, or not attached to framing)					

Table 14-1. Maintenance Inspection Checklist (concluded)

Item	Element	Condition			Repair/Replace	
		Good	Fair	Poor	Yes	No
Floors	**Sheathing under floors** – attachment to framing, nail corrosion fastening sheathing to floor joists, buckling/warping caused by excessive moisture					
Windows/ Doors	**Glazing** – cracked panes, condensation between panes of insulated glass, nicks in glass surface, sealant cracked/dried out					
	Trim – deterioration, discoloration, separation at joints, caulking dried out or separated					
	Shutters – permanent shutters should be operated at least twice/year and temporary panels should be checked once/year for condition					
Roof	**Asphalt shingles** – granule loss, shingles curled, nails withdrawing from sheathing, de-bonding of tabs along eaves and corners					
	Wood shakes – splits, discoloration, deterioration, moss growth, attachment to framing (nails missing, withdrawn, or not attached to framing)					
	Metal – corrosion, discoloration, connection of fasteners or fastening system adequacy					
	Flashings – corrosion, joints separated, nails withdrawing					
Attic	**Framing** – condition of truss plates sagging or bowed rafters or truss chords, deterioration of underside of roof sheathing, evidence of water leaks, adequate ventilation					

Other items that should be inspected include cavities through which air can freely circulate (e.g., above soffits and behind brick or masonry veneers) and, depending on structural system characteristics and access, the structural system. For example, painted, light-gauge, cold-formed steel framing is vulnerable to corrosion, and the untreated cores of treated timber framing are vulnerable to decay and termite damage. Depending on visual findings, it may be prudent to determine the condition of concealed items through nondestructive or destructive tests (e.g., test cuts).

The following sections provide information on the building elements that require frequent maintenance in coastal environments: glazing, siding, roofs, outdoor mechanical and electrical equipment, decks and exterior wood, and metal connectors.

14.2.1 Glazing

Glazing includes glass or a transparent or translucent plastic sheet in windows, doors, skylights, and shutters. Glazing is particularly vulnerable to damage in hurricane-susceptible coastal areas because high winds create wind-borne debris that can strike the glazing. Maintenance suggestions for glazing include the following:

- Checking glazing gaskets/sealants for deterioration and repairing or replacing as needed. Broken seals in insulated glass are not uncommon in coastal areas.
- Checking wood frames for decay and termite attack, and checking metal frames for corrosion. Frames should be repainted periodically (where appropriate), and damaged wood should be replaced. Maintaining the putty in older wood windows minimizes sash decay. Metal frames should be cleaned of corrosion or pitting and the operation of the windows tested on some frequency.
- Checking vinyl frames for cracks especially in the corners and sealing any cracks with a sealant to prevent water entry into the window frame. Vinyl may become discolored from the ultraviolet (UV) rays of the sun.
- Checking for signs of water damage (e.g., water stains, rust streaks from joints) and checking sealants for substrate bond and general condition. Repair or replace as needed.
- Checking glazing for stress cracks in corners. Stress cracks might be an indication of either settlement of the house or of lateral movement that is causing excessive stress in the lateral load system.
- Checking shutters for general integrity and attachment and repainting periodically where appropriate.
- Replacing or strengthening the attachment of the shutter system to the building as appropriate.
- Checking the shutters for ease of operation. Sand can easily get into the hinges and operators and render shutters inoperable.
- Checking locks and latches frequently for corrosion and proper operation. Lock mechanisms are vulnerable to attack by salt-laden air. Applying a lubricant or rust inhibitor improves the operation of these mechanisms over the short term.
- Installing double hung and awning windows, which generally perform better than sliding or jalousie windows in the coastal environment, primarily because the sliding and jalousie windows allow more water, sand, and air infiltration because of the way the windows open and close.
- Replacing sliding and jalousie windows to reduce infiltration.

14.2.2 Siding

Solar UV degradation occurs at a rate of about 1/16 inch over 10 years on exposed wood. This rate of degradation is not significant for dimension lumber, but it is significant for plywood with 1/8-inch veneers. If the exterior plywood is the shearwall sheathing, the loss will be significant over time. Maintenance suggestions for siding materials include the following:

- Protecting plywood from UV degradation with pigmented finishes rather than clear finishes. Pigmented finishes are also especially recommended for exposed shearwall sheathing.
- Protecting wood siding with a protective sealant—usually a semi-transparent stain or paint. The coating should be re-applied regularly because the degradation will occur nearly linearly if re-application is done but will progress faster if allowed to weather with no regular sealing.
- Keeping siding surfaces free of salt and mildew and washing salt from siding surfaces not washed by rain, taking care to direct the water stream downward. Mildew should be washed as needed from siding using commercially available products or the homemade solution of bleach and detergent described in Finishes for Exterior Wood: Section, Application and Maintenance (Williams et al. 1996). Power washing is another technique to keep the siding clean as long as the siding sealant is not removed. Mildew grows on almost any surface facing north, no matter how small the surface.
- Caulking seams, joints, and building material discontinuities with a sealant intended for severe exterior exposures and renew the sealant every 5 years at a minimum or when staining or painting the siding and trim. Sealant applied at large wood members should be renewed about 1 year after the wood has shrunk away from the caulked joint.
- Caulking carefully to avoid closing off weep or water drainage holes below windows or in veneers that are intended to drain will prevent sealing the moisture inside the wall cavity, which can lead to significant, long-term deterioration.
- Renailing siding when nails withdraw (pop out) and renailing at a new location so the new nail does not go into the old nail hole.
- Ensuring vinyl siding has the ability to expand and contract with temperature changes. Buckling in the siding is an indication that the siding was installed too tightly to the wall sheathing with an insufficient amount of room under the siding nails to allow for the normal horizontal movement of the siding.

14.2.3 Roofs

Roof coverings are typically the building envelope material most susceptible to deterioration from weathering. Also, depending on roof system design, minor punctures or tears in the roof covering can allow water infiltration, which can lead to serious damage to the roof system and other building elements. Maintenance suggestions for roof materials include the following:

- Checking the general condition of the roof covering. Granule loss from asphalt shingles is always a sign of some deterioration, as is curling and clawing (reverse curling) although some minor loss is expected even from new shingles.
- Dabbing roofing cement under the tabs of the first layer of shingles, including the base course, to help ensure that this layer stays down in high winds.
- Dabbing roofing cement under any shingle tabs that have lifted up from the existing tack strip.
- Checking the nails that attach the shingles to the roof for corrosion or pullout.
- Checking metal flashings and replacing or repairing as necessary.
- Cleaning dirt, moss, leaves, vegetative matter, and mildew from wood shakes.

- Cleaning corroded surfaces of ferrous metal roofs and applying an appropriate paint or sealer.
- Checking the attachment of the roof surface to the deck. Screws and nails can become loose and may require tightening. Gasketed screws should be added to tighten the metal deck to the underlayment. Some roofing systems are attached to the underlayment with clips that can corrode—these clips should be inspected and any corroded clips replaced, but in many cases, the clips will be concealed and will require some destructive inspection to discover the corroded clips.
- Removing debris from the roof and ensuring that drains, scuppers, gutters, and downspouts are not clogged.
- Removing old asphalt shingles before recovering. This is recommended because installing an additional layer of shingles requires longer nails, and it is difficult to install the new asphalt shingles so that they lay flat over the old. New layers installed over old layers can therefore be susceptible to wind uplift and damage, even in relatively low wind speeds. New layers installed over old shingles could void the warranty for the new shingles.
- Checking attachments of eave and fascia boards. Deterioration in these boards will likely allow flashings attached to them to fail at lower than design wind speeds.

14.2.4 Exterior-Mounted Mechanical and Electrical Equipment

Most outdoor mechanical and electrical equipment includes metal parts that corrode in the coastal environment. Life expectancy improves if the salt is washed off the outside of the equipment frequently. This occurs naturally if the equipment is fully exposed to rainwater, but partially protected equipment is subject to greater corrosion because of the lack of the natural rinsing action.

Using alternative materials that do not include metal parts can also help reduce the problems caused by corrosion. In all cases, electrical switches should be the totally enclosed type to help prevent moisture intrusion into the switch, even if the switch is located on a screened porch away from the direct effects of the weather. Building owners should expect the following problems in the coastal environment:

- Electrical contacts can malfunction and either short out or cause intermittent operation
- Housings for electrical equipment; heating, ventilation, and air-conditioning condensers; ductwork; and other elements deteriorate more rapidly
- Fan coils for outside condensers can deteriorate more rapidly unless a coastal environment is specified
- Typical metal fasteners and clips used to secure equipment can deteriorate more rapidly in a coastal environment than a non-coastal environment

14.2.5 Decks and Exterior Wood

The approach to maintaining exterior wood 2x members is different from the approach for thicker members. The formation of small checks and splits in 2x wood members from cyclical wetting and drying can be reduced by using water-repellent finishes. The formation of larger checks and splits in thicker wood members is caused more by long-term drying and shrinking and is not as significantly reduced by the use of water-repellent finishes. Installation of horizontal 2x members with the cup (concave surface) down minimizes water retention and wood deterioration.

- Cyclical wetting and drying, such as from dew or precipitation, causes the exterior of a wood member to swell and shrink more quickly than the interior. This causes stress in the surface, which leads to the formation of checks and splits. This shrink-swell cycling is worst on southern and western exposures. Checks and splits, especially on horizontal surfaces, provide paths for water to reach the interior of a wood member and remain, where they eventually cause decay. Maintaining a water-repellent finish, such as a pigmented paint, semi-transparent stain, or clear finish, on the wood surface can reduce the formation of checks and splits. These finishes are not completely water- or vapor- repellent, but they significantly slow cyclical wetting and drying. Of the available finishes, pigmented paints and semi-transparent stains have the longest lifetime; clear finishes must be reapplied frequently to remain effective. Matte clear finishes are available that are almost unnoticeable on bare wood. These finishes are therefore attractive for decking and other "natural" wood, but they must be renewed when water no longer beads on the finished surface.

- Wood deck surfaces can be replaced with synthetic materials, which are sold under a variety of trade names. Many of these products should be attached with stainless screws or hidden clips to preservative-treated framing.

- Moisture-retaining debris can collect between deck boards and in the gaps in connections. Periodic cleaning of this debris from between wood members, especially at end grains, allows drying to proceed and inhibits decay.

- Larger timbers can also be vulnerable to checks, splits, and other weather-related problems. The best way to maintain larger timbers is to keep water away from joints, end grain surfaces, checks, and splits. Much can be learned by standing under the house (given sufficient headroom) during a rain with the prevailing wind blowing to see where the water goes. Measures, such as preservative treatments, can then be taken or renewed to minimize the effect of this water on the larger timbers.

- Connections of deck band boards to the structure should be inspected periodically for moisture intrusion. These connections frequently leak from wind-driven rain and moisture accumulation. Leakage can occur at the flashing to structure interface or at the bolts connecting the band board to the structure.

14.2.6 Metal Connectors

Most sheet-metal connectors, such as tiedown straps, joist hangers, and truss plates used in structural applications in the building, should be specified to last the lifetime of the building without the need for maintenance. However, the use of corrosion-prone connectors is a common problem in existing coastal houses.

CROSS REFERENCE

The selection of metal connectors for use within the building envelope and in exposed locations is addressed in Section 9.4 of this Manual.

- Galvanized connectors may have corrosion issues. If galvanized connectors remain gray, the original strength is generally unaffected by corrosion. When most of the surface of the connector turns rust red, the sacrificial galvanizing has been consumed and the corrosion rate of the unprotected steel can be expected to accelerate by up to a factor of 50 times. Figure 14-3 illustrates severe corrosion under an exterior deck.

- Sheet-metal connectors can be susceptible to rapid corrosion and are frequently without reserve strength. During routine inspections, any sheet-metal connectors found to have turned rust red or to show severe, localized rusting sufficient to compromise their structural capacity should be replaced immediately. However, the replacement of sheet metal connectors is usually difficult for a number of reasons: the connection may be under load, the nails or bolts used to secure connectors are usually hard to remove, and the location of a connector often makes removal awkward.

- Salt-laden air can increase corrosion rates in building materials. Covering exposed connectors with a sheathing material reduces their exposure and therefore increases their life expectancy.

WARNING

Using corrosion-prone sheet metal connectors increases maintenance requirements and potentially compromises structural integrity.

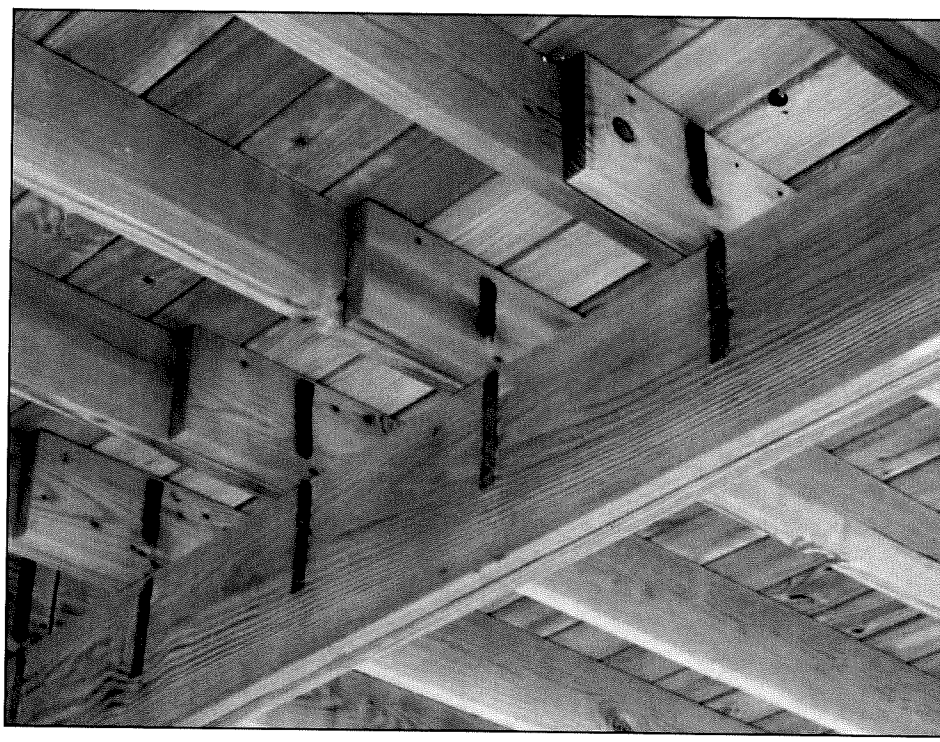


Figure 14-3.
Severely corroded deck connectors

14.3 Hazard-Specific Maintenance Techniques

The maintenance practices described above for minimizing corrosion, wood decay, termite infestation, and UV degradation will improve the resistance of a coastal building to flood, wind, and seismic damage by maintaining the strength of the structural elements. The additional measures described in the following sections will further maintain the building's resistance to natural hazards.

14.3.1 Flooding

When designing for the lateral force capacity of an unbraced or braced pile foundation, the designer should allow for a certain amount of scour. Scour in excess of the amount allowed for reduces the embedment of the piles and causes them to be overstressed in bending during the maximum design flood, wind, or earthquake. As allowed by local regulations and practicality, the grade level should be maintained at the original design elevation.

Scour and long-term beach erosion may affect pile maintenance requirements. If tidal wetting was not anticipated in the original design, the piles may have received the level of preservative treatment required only for ground contact and not the much higher marine treatment level that provides borer resistance. If the pile foundation is wetted by high tides or runup, borer infestation is possible. Wrapping treatments that minimize borer infestation are available for the portions of the piles above grade that are subject to wetting.

14.3.2 Seismic and Wind

Many seismic and wind tiedowns at shearwall vertical chords use a vertical threaded rod as the tension member. Each end of the threaded rod engages the tiedown hardware or a structural member. Over time, cross-grain shrinkage in the horizontal wood members between the threaded rod connections loosens the threaded rod, allowing more rocking movement and possible damage to the structure. Whenever there is an opportunity to access the tiedowns, the nuts on the rods should be tightened firmly. New proprietary tiedown systems that do this automatically are available.

Shearwall sill plates bearing directly on continuous footings or concrete slabs-on-grade, if used in coastal construction, are particularly susceptible to decay in moist conditions. Figure 14-4 shows a deteriorated sill plate. Even if the decay of the preservative-treated sill plate is retarded, the attached untreated plywood can easily decay and the shearwall will lose strength. Conditions that promote sill and plywood decay include an outside soil grade above the sill, stucco without a weep screed at the sill plate, and sources of excessive interior water vapor. Correcting these conditions helps maintain the strength of the shearwalls.

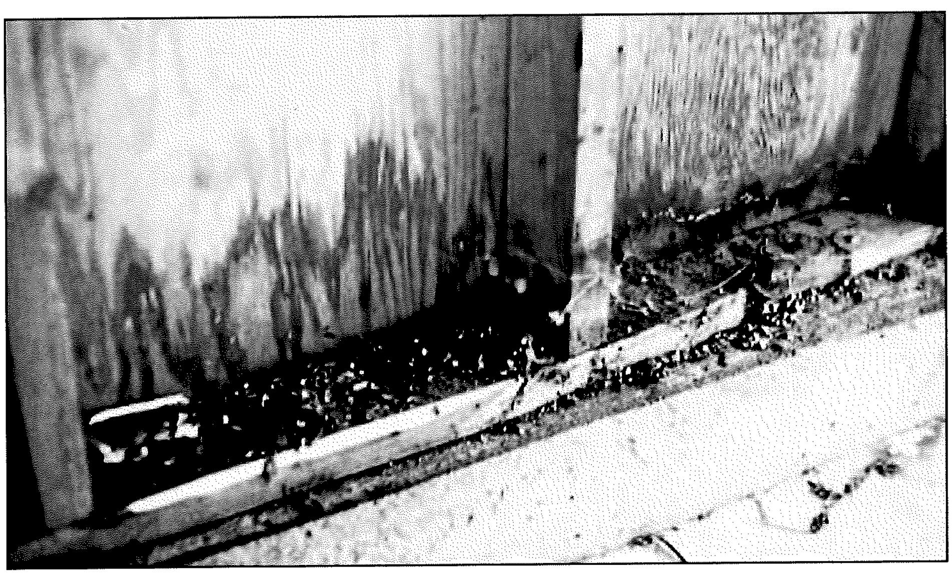


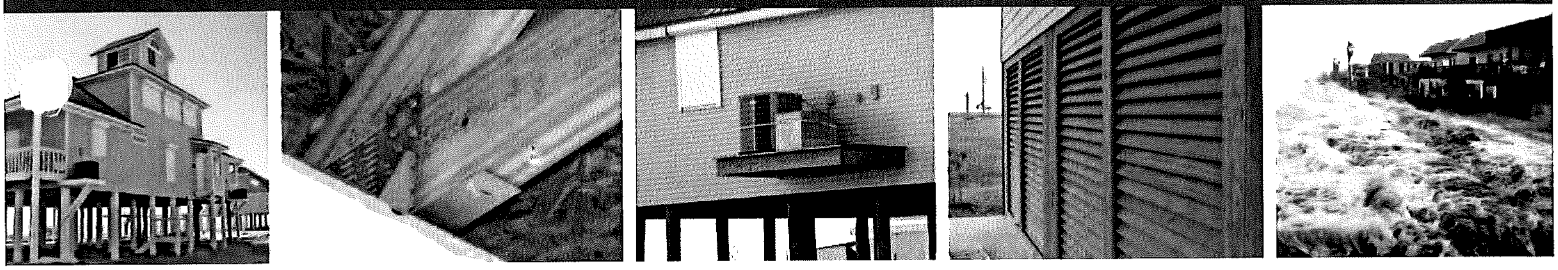
Figure 14-4. Deteriorated wood sill plate

14.4 References

FEMA (Federal Emergency Management Agency). 1996. *Corrosion Protection of Metal Connectors in Coastal Areas for Structures Located in Special Flood Hazard Areas.* NFIP Technical Bulletin 8-96.

Shifler, D.A. 2000. *Corrosion and Corrosion Control in Saltwater Environments.* Pennington, NJ: Electrochemical Society.

Williams, R., M. Knaebe, and W. Feist. 1996. *Finishes for Exterior Wood: Section, Application and Maintenance.* Forest Products Society.



Retrofitting Buildings for Natural Hazards

This chapter provides guidance on retrofitting existing residential structures to resist or mitigate the consequences of natural hazards in the coastal environment. The natural hazards that are addressed are wildfires, seismic events, floods, and high winds. Specific retrofitting methods and implementation are discussed briefly, and resources with more in-depth information are provided. Some retrofitting methods are presented together with broader, non-retrofitting mitigation methods when retrofitting and non-retrofitting methods are presented together in the referenced guidance. For retrofitting to mitigate high winds, the new three-tiered wind retrofit program that is provided in FEMA P-804, *Wind Retrofit Guide for Residential Buildings* (FEMA 2010c), is discussed. The program includes systematic and programmatic guidance.

Retrofitting opportunities present themselves every time maintenance is performed on a major element of a building. Retrofitting that increases resistance to natural hazards should focus on improvements that provide the largest benefit to the owner.

CROSS REFERENCE

For resources that augment the guidance and other information in this Manual, see the Residential Coastal Construction Web site (http://www.fema.gov/rebuild/mat/fema55.shtm).

NOTE

FEMA's Hazard Mitigation Assistance (HMA) grant programs provide funding for eligible mitigation activities that reduce disaster losses and protect life and property from future disaster damage. Currently, FEMA administers the following HMA grant programs: Hazard Mitigation Grant Program, Pre-Disaster Mitigation, Flood Mitigation Assistance, Repetitive Flood Claims, and Severe Repetitive Loss.

If an existing building is inadequate to resist natural hazard loads, retrofitting should be considered.

15.1 Wildfire Mitigation

Thousands of residential and non-residential buildings are damaged or destroyed every year by wildfires, resulting in more than $200 million in property damage annually. More than $100 million is spent every year on fire suppression and even more on recovering from catastrophic natural and manmade hazards. Studies cited by IBHS in *Mega Fires* (IBHS 2008) have shown that financial losses can be prevented if simple measures are implemented to protect existing buildings.

TERMINOLOGY: RETROFITTING

Retrofitting is a combination of adjustments or additions to existing building features that are intended to eliminate or reduce the potential for damage from natural hazards. Retrofitting is a specific type of hazard mitigation.

FEMA offers funding through the HMGP and the PDM Program for wildfire mitigation projects. Projects funded through these programs involve retrofits to buildings that help minimize the loss of life and damage to the buildings from wildfire. Eligible activities for wildfire mitigation per FEMA's *Hazard Mitigation Assistance Unified Guidance* (FEMA 2010a) may include:

- Provision of defensible space through the creation of perimeters around residential and non-residential buildings and structures by removing or reducing flammable vegetation. The three concentric zones of defensible space are shown in Figure 15-1.

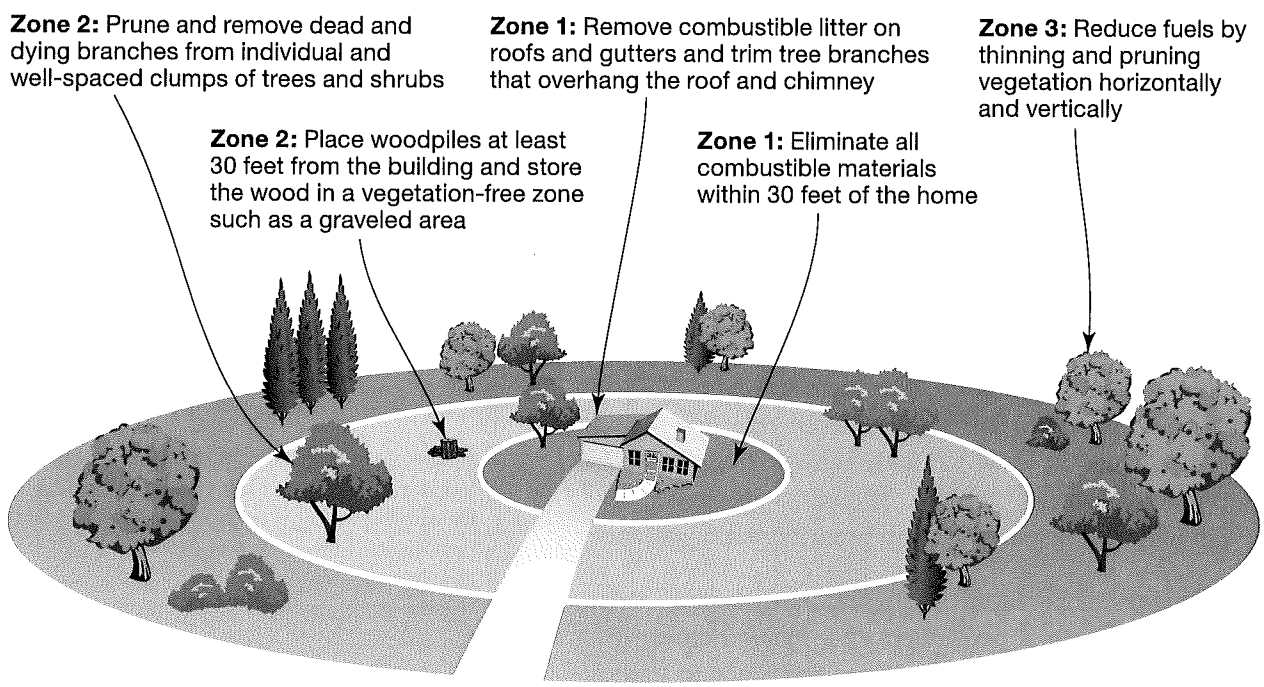


Figure 15-1.
The three concentric zones of defensible space
SOURCE: ADAPTED FROM FEMA P-737

- Application of non-combustible building envelope assemblies that can minimize the impact of wildfires through the use of ignition-resistant materials and proper retrofitting techniques. The components of the building envelope are shown in Figure 15-2.
- Reduction of hazardous fuels through vegetation management, vegetation thinning, or reduction of flammable materials. These actions protect life and property that are outside the defensible space perimeter but close to at-risk structures. Figure 15-3 shows a fire that is spreading vertically through vegetation.

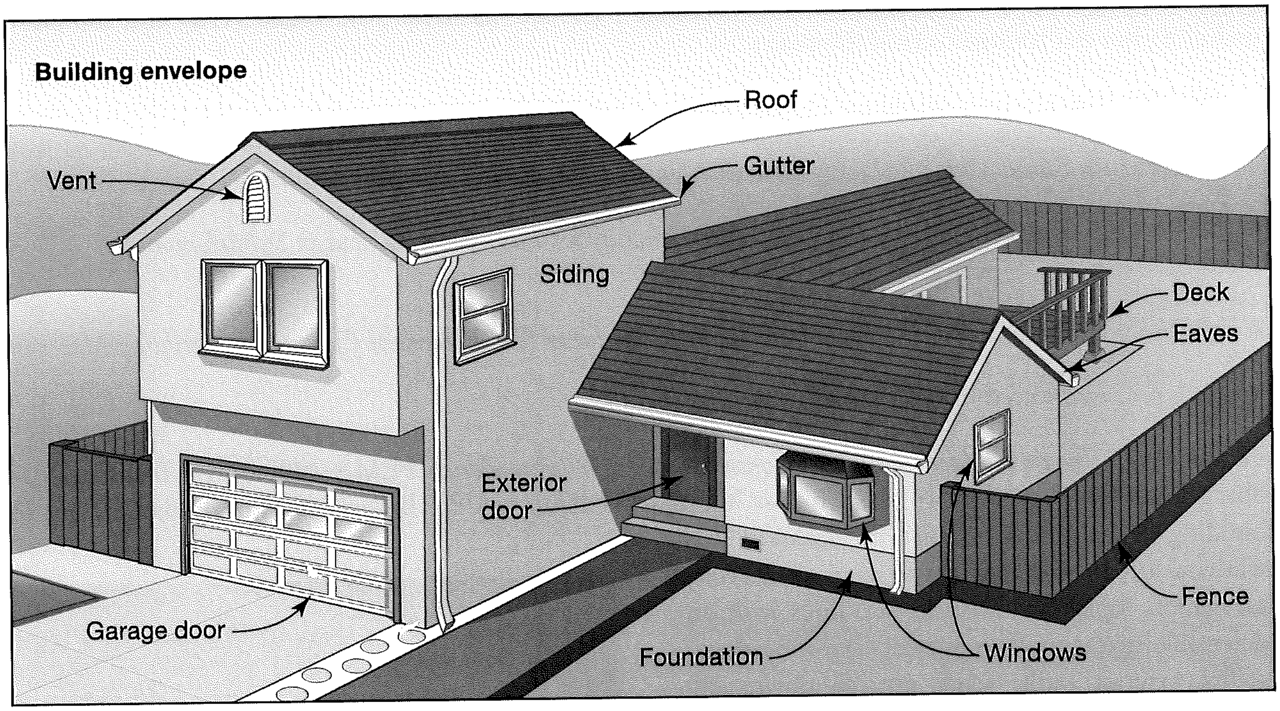


Figure 15-2.
The building envelope
SOURCE: ADAPTED FROM FEMA P-737

Figure 15-3.
Fire spreads vertically through vegetation

FEMA may fund above-code projects in communities with applicable fire-related codes. For homes and structures constructed or activities completed prior to the adoption of local building codes, FEMA may fund mitigation that meets or exceeds the codes currently in effect. For communities without fire codes, FEMA may fund mitigation when the materials and technologies are in accordance with the ICC, FEMA, U.S. Fire Administration, and the National Fire Protection Association (NFPA). Firewise recommendations, as appropriate. The Firewise program provides resources for communities and property owners to use in the creation of defensible space. Additional fire-related information and tools can be found at http://www.firewise.org and http://www.nfpa.org.

Wildfire mitigation is required to be in accordance with the applicable fire-related codes and standards, including but not limited to the following:

- IWUIC, *International Wildland-Urban Interface Code* (ICC)
- NFPA 1144, *Standard for Reducing Structure Ignition Hazards from Wildland Fire*
- NFPA 1141, *Standard for Fire Protection Infrastructure for Land Development in Suburban and Rural Areas*
- NFPA 703, *Standard for Fire-Retardant Treated Wood and Fire-Retardant Coatings for Building Materials*
- *Code for Fire Protection of Historical Structures* (NFPA)

FEMA P-737, *Home Builder's Guide to Construction in Wildfire Zones* (FEMA 2008a), is a Technical Fact Sheet Series (see Figure 15-4) that provides information about wildfire behavior and recommendations for building design and construction methods in the wildland/urban interface. The fact sheets cover mitigation topics for existing buildings including defensible space, roof assemblies, eaves, overhangs, soffits, exterior walls, vents, gutters, downspouts, windows, skylights, exterior doors, foundations, decks and other attached structures, landscape fencing and walls, fire sprinklers, and utilities and exterior equipment. Implementation of the recommended design and construction methods in FEMA P-737 can greatly increase the probability that a building will survive a wildfire.

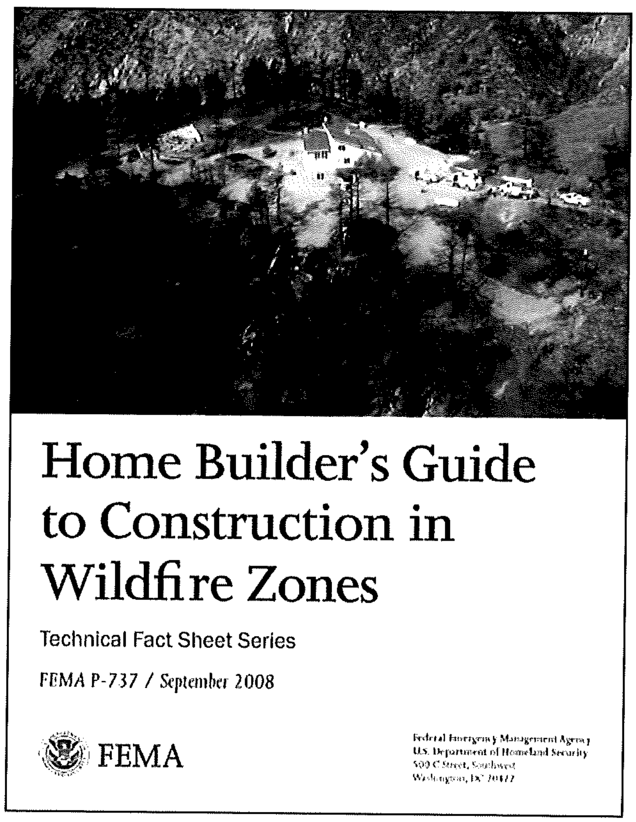


Figure 15-4.
FEMA P-737, *Home Builder's Guide to Construction in Wildlife Zones: Technical Fact Sheet Series*

Since it may not be financially possible for the homeowner to implement all of the measures that are recommended in FEMA P-737, homeowners should consult with local fire and building code officials or their fire management specialists to perform a vulnerability assessment and develop a customized, prioritized list of recommendations for remedial work on defensible space and the building envelope. Helpful information about the vulnerabilities of the building envelope is available at http://firecenter.berkeley.edu/building_in_wildfire_prone_areas. The homeowner can use the Homeowner's Wildfire Assessment survey on this Web site to learn about the risks a particular building has and the measures that can be taken to address them.

15.2 Seismic Mitigation

Seismic hazard, which is well documented and defined in the United States, is mitigated in existing residential buildings primarily through retrofitting. Although modifications to existing residential structures have the potential to reduce earthquake resistance, it is possible to take advantage of these modifications to increase resistance through earthquake retrofits (upgrades). FEMA has produced documents, including those referenced below, that address the evaluation and retrofit of buildings to improve performance during seismic events. For nationally applicable provisions governing seismic evaluation and rehabilitation, the design professional should reference ASCE 31 and ASCE 41.

In addition, FEMA offers funding for seismic retrofits through the HMGP and the PDM Program to reduce the risk of loss of life, injury, and damage to buildings. Seismic retrofits, which are classified as structural and non-structural, are subject to the same HMGP and PDM funding processes as wind retrofits (see Section 15.4.3).

FEMA 232, *Homebuilders' Guide to Earthquake Resistant Design and Construction* (FEMA 2006) (see Figure 15-5), contains descriptions of eight earthquake upgrades that address common seismic weaknesses in existing residential construction. The upgrades are foundation bolting, cripple wall bracing, weak- and soft-story bracing, open-front bracing, hillside house bracing, split-level floor interconnection, anchorage of masonry chimneys, and anchorage of concrete and masonry walls. The upgrades are summarized below. For in-depth information on these upgrades, see FEMA 232.

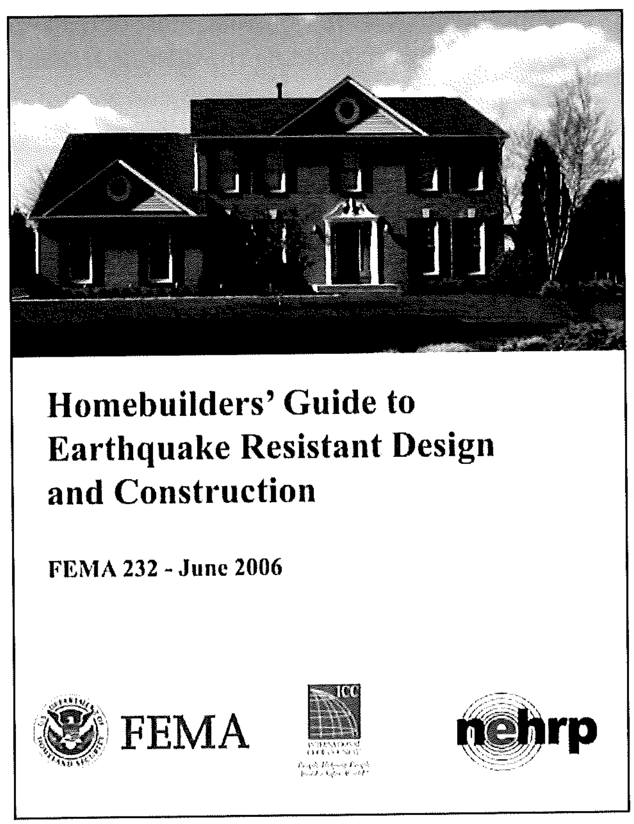


Figure 15-5.
FEMA 232, *Homebuilders Guide to Earthquake Resistant Design and Construction*

- **Foundation bolting.** Inadequate attachment of the sill plate to the foundation can allow the framed structure to separate and shift off the foundation. Sill plate anchor bolts (either adhesive or expansion type depending on the foundation material) can be added provided there is sufficient access to the top surface of the sill plate. Alternately, proprietary anchoring hardware is available that is typically attached to the face of the foundation wall for greater ease of installation when access is limited. Reinforcing sill plate anchorage offers a generally high benefit in return for low cost.

- **Cripple wall bracing.** Another relatively inexpensive foundation-level retrofit is bracing the cripple walls. Cripple walls are framed walls occasionally installed between the top of the foundation and first-floor framing in the above-grade wall sections of basements and crawl spaces. Because of their location, cripple walls are particularly vulnerable to seismic loading, as shown in Figure 15-6. These walls can be braced through the prescribed installation of wood structural panel sheathing to the interior and/or exterior wall surface.

- **Weak- and soft-story bracing.** Although first-story framed walls must bear greater seismic loads than the roof and walls above, they frequently have more openings and therefore less bracing. As a result, first-story framed walls, and any other level with underbraced wall sections, may be referred to as weak or soft stories. These walls can be retrofit by removing the interior finishes at wall corners and installing hold-down anchors between the corner studs and continuous reinforced foundation below. If renovations or repairs require removing larger areas of interior wall sheathing, additional hold-down anchors can be installed to tie in the floor or roof framing above. Additional wall bracing can be achieved by adding blocking for additional nailing and wood structural panel sheathing.

- **Open-front bracing.** An open-front configuration is one in which braced exterior walls are absent or grossly inadequate. Frequently, open-front configurations are found in garage entry walls where overhead garage doors consume most of the available wall area, as shown in Figure 15-7. Possible retrofits include reinforcing the existing framed end walls and replacing the framed wall ends with steel moment frames; common heights and lengths of steel moment frames are available commercially.

**Figure 15-6.
A house with severe damage due to cripple wall failure**

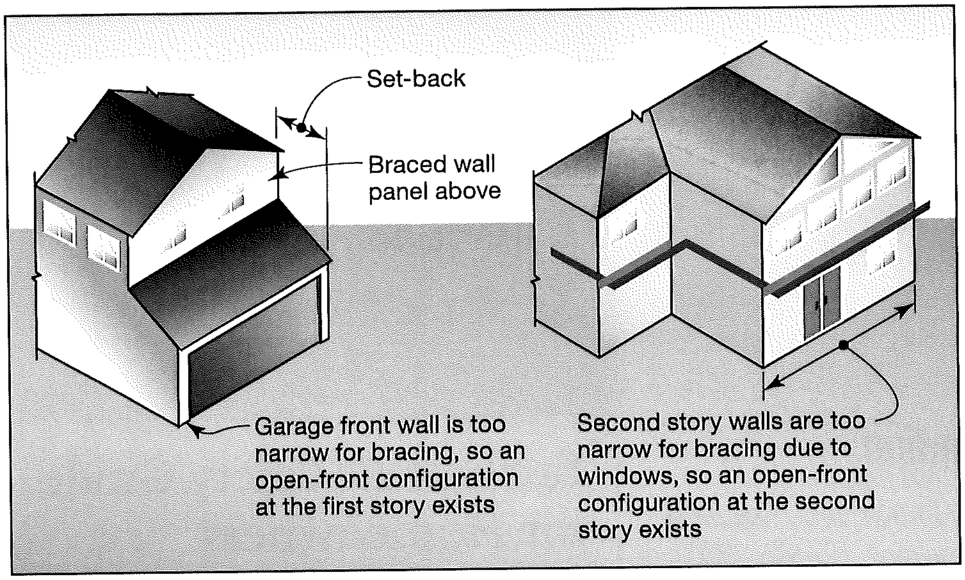


Figure 15-7.
Common open-front configurations in one- and two- family detached houses

- **Hillside house bracing.** Houses built on steep hillsides are vulnerable to damage when the floor system separates from the uphill foundation or foundation wall. Retrofitting to mitigate this type of seismic damage requires an engineered design that should include anchoring each floor system to the uphill foundation and the supplemental anchorage, strapping, and bracing of cripple walls.

- **Split-level floor interconnection.** Houses with vertical offsets between floor elevations on a common wall or support are exposed to seismic damage that is similar to hillside houses. The potential for separation of the floor system from the common wall may be reduced by adequately anchoring floor framing on either side of the common wall. Prescriptive solutions may apply where a direct tension tie can be provided between both floors, but an engineered design may be necessary where greater floor offsets exist.

- **Anchorage of masonry chimneys.** Unreinforced masonry chimneys can be anchored to the roof and adjacent or surrounding floor systems with metal straps but will still be subject to brittle failure. The benefit of this type of anchoring may be limited to collapse prevention. A chimney collapse reportedly caused one fatality in the 1992 earthquake in Landers, CA, but other mitigation measures may be more cost-effective. These measures include the practical approaches provided on the Association of Bay Area Governments Web site (http://quake.abag.ca.gov/residents/chimney).

- **Anchorage of concrete and masonry walls.** Floor systems in houses with full-height concrete or masonry walls may be supported by a weight-bearing ledger strip only. With this type of existing construction, a tension connection can be installed between the walls and floor system to provide the necessary direct anchorage. An engineering evaluation and design are recommended for this type of seismic retrofit.

FEMA 530, *Earthquake Safety Guide for Homeowners* (FEMA 2005) (Figure 15-8) includes guidance similar to FEMA 232 on seismic structural retrofits along with tips on strengthening a variety of existing foundation types. One non-structural retrofit in FEMA 530 is to brace water heaters, which can cause gas leaks, fires, or flooding if toppled during an earthquake. Written for the homeowner, FEMA 530 provides information on the relative cost of prevention versus the cost of post-disaster repair or replacement and on plans, permitting, and selecting contractors.

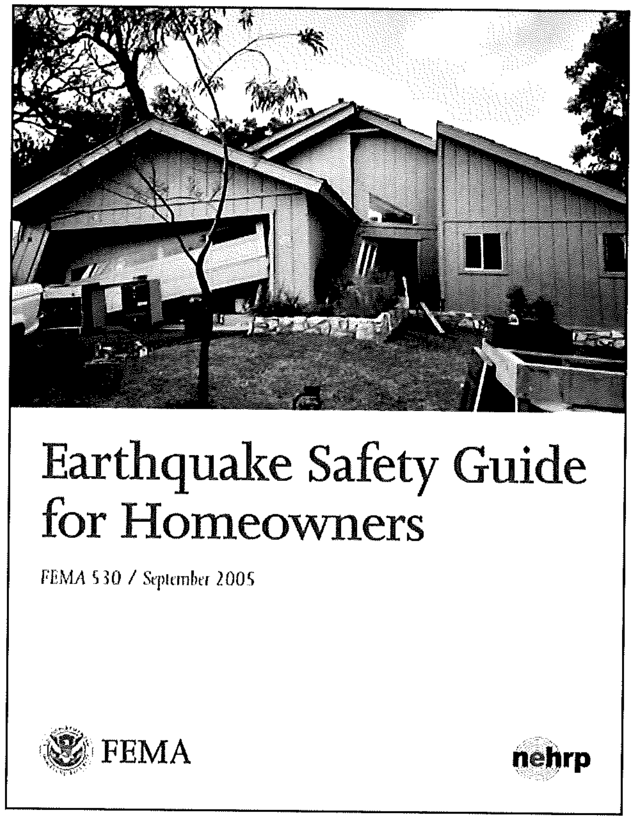


Figure 15-8.
FEMA 530, *Earthquake Safety Guide for Homeowners*

15.3 Flood Mitigation

FEMA 259, *Engineering Principles and Practices of Retrofitting Floodprone Structures* (FEMA 2011), addresses retrofitting flood-prone residential structures. The objective of the document is to provide engineering design and economic guidance to engineers, architects, and local code officials about what constitutes technically feasible and cost-effective retrofitting measures for flood-prone residential structures.

The focus in this chapter in regard to retrofitting for the flood hazard is retrofitting one- to four-family residences that are subject to flooding without wave action. The retrofitting measures that are described in this section include both active and passive efforts and wet and dry floodproofing. Active efforts require human intervention preceding the flood event and may include activities such as engaging protective shields at openings. Passive efforts do not require human intervention. The flood retrofitting measures are elevating the building in place, relocating the building, constructing barriers (levees and floodwalls), dry floodproofing (sealants, closures, sump pumps, and backflow valves), and wet floodproofing (using flood damage-resistant materials and protecting utilities and contents).

Flood retrofitting projects may be eligible for funding through the following FEMA Hazard Mitigation Programs: HMGP, PDM, Flood Mitigation Assistance, Repetitive Flood Claims, and Severe Repetitive Loss. More information on obtaining funding for flood retrofitting is available in *Hazard Mitigation Assistance Unified Guidance* (FEMA 2010a).

15.3.1 Elevation

Elevating a building to prevent floodwaters from reaching damageable portions of the building is an effective retrofitting technique. The building is raised so that the lowest floor is at or above the DFE to avoid damage from the design flood. Heavy-duty jacks are used to lift the building. Cribbing is used to support the building while a new or extended foundation is constructed. In lieu of constructing new support walls, open

CROSS REFERENCE

For definitions of DFE and BFE, see Section 8.5.1 of this Manual.

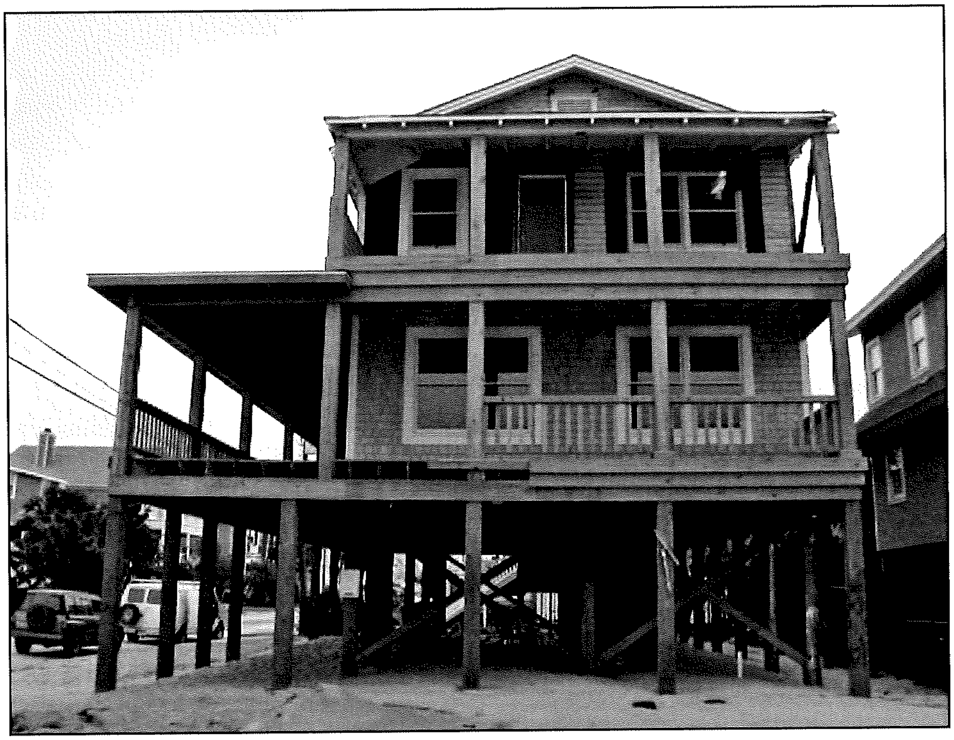


Figure 15-9.
Home elevated on piles

foundations such as piers, columns, posts, and piles are often used (see Figure 15-9). Elevating the building on fill may be an option. Closed foundations are not permitted in Zone V and are not recommended in Coastal A Zones. See Table 10-1 for the types of foundations that are acceptable in each flood zone.

The advantages and disadvantages of elevation are listed in Table 15-1.

Table 15-1. Advantages and Disadvantages of Elevation

Advantages	Disadvantages
• Brings a substantially damaged or improved building into compliance with the NFIP if the lowest horizontal member is elevated to the BFE • Reduces flood risk to the structure and its contents • Eliminates the need to relocate vulnerable items above the flood level during flooding • Often reduces flood insurance premiums • Uses established techniques • Requires qualified contractors who are often readily available • Reduces the physical, financial, and emotional strain that accompanies flood events • Does not require the additional land that may be needed for floodwalls or levees	• May be cost-prohibitive • May adversely affect the building's appearance • Prohibits the building from being occupying during a flood • May adversely affect access to the building • Cannot be used in areas with high-velocity water flow, fast-moving ice or debris flow, or erosion unless special measures are taken • May require additional costs to bring the building up to current building codes for plumbing, electrical, and energy systems • Requires a consideration of forces from wind and seismic hazards

SOURCE: FEMA 259

BFE = base flood elevation
NFIP = National Flood Insurance Program

15.3.2 Relocation

Relocation involves moving a structure to a location that is less prone to flooding or flood-related hazards such as erosion. The structure may be relocated to another portion of the current site or to a different site. The surest way to eliminate the risk of flood damage is to relocate the structure out of the floodplain. Relocation normally involves preparing the structure for the move (see Figure 15-10), placing it on a wheeled vehicle, transporting it to the new location, and setting it on a new foundation.

Relocation is an appropriate measure in high hazard areas where continued occupancy is unsafe and/or owners want to be free of the risk of flooding. Relocation is also a viable option in communities that are considering using the resulting open space for more appropriate floodplain activities. Relocation may offer an alternative to elevation for substantially damaged structures that are required under local regulations to meet NFIP requirements. Table 15-2 lists the advantages and disadvantages of relocation.

Figure 15-10.
Preparing a building for relocation

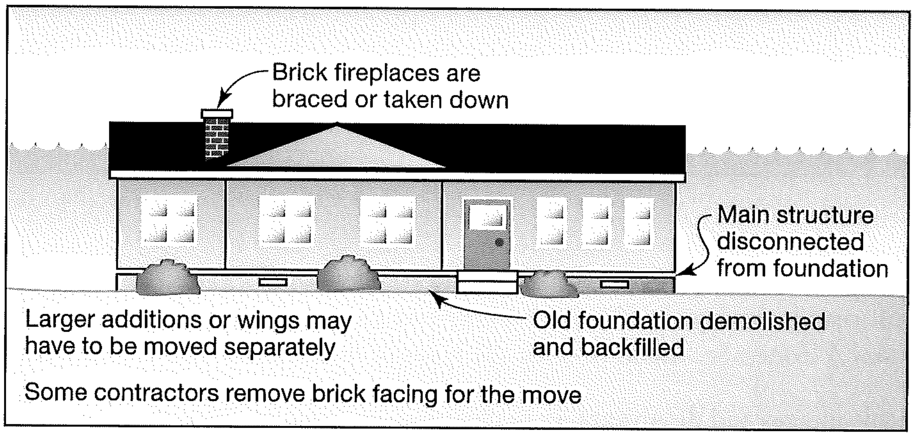


Table 15-2. Advantages and Disadvantages of Relocation

Advantages	Disadvantages
• Allows for substantially damaged or improved structure to be brought in to compliance with the NFIP • Significantly reduces flood risk to the structure and its contents • Uses established techniques • Requires qualified contractors who are often readily available • Can eliminate the need to purchase flood insurance or reduce the premium because the house is no longer in the floodplain • Reduces the physical, financial, and emotional strain that accompanies flood events	• May be cost-prohibitive • Requires locating a new site • Requires addressing disposition of the flood-prone site • May require additional costs to bring the structure up to current building codes for plumbing, electrical, and energy systems

SOURCE: FEMA 259

NFIP = National Flood Insurance Program

15.3.3 Dry Floodproofing

In dry floodproofing, the portion of a structure that is below the chosen flood protection level (walls and other exterior components) is sealed to make it watertight and impermeable to floodwaters. The objective is to make the walls and other exterior components impermeable to floodwaters. Watertight, impervious membrane sealant systems include wall coatings, waterproofing compounds, impermeable sheeting, and supplemental impermeable wall systems, such as cast-in-place concrete. Doors, windows, sewer and water lines, and vents are closed with permanent or removable shields or valves. Figure 15-11 is a schematic of a dry floodproofed home. Non-residential techniques are also applicable in residential situations. See Table 15-3 for the advantages and disadvantages of dry floodproofing.

WARNING

Dry floodproofing is not allowed under the NFIP for new and substantially damaged or improved residential structures in an SFHA. For additional information on dry floodproofing, see FEMA FIA-TB-3, *Non-Residential Floodproofing – Requirements and Certification for Buildings Located in Special Flood Hazard Areas in Accordance with the NFIP* (FEMA 1993a) and the *Substantial Improvement/Substantial Damage Desk Reference* (FEMA 2010b).

The expected duration of flooding is critical when deciding which sealant system to use because seepage can increase over time, rendering the floodproofing ineffective. Waterproofing compounds, sheeting, and sheathing may deteriorate or fail if exposed to floodwaters for extended periods. Sealant systems are also subject to damage (puncture) in areas that experience water flow of significant velocity, ice, or debris flow.

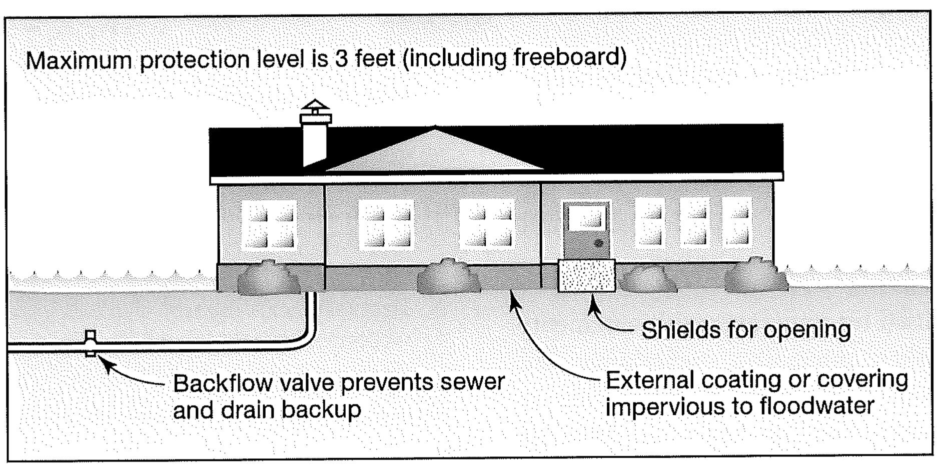


Figure 15-11. Dry floodproofed structure

Table 15-3. Advantages and Disadvantages of Dry Floodproofing

Advantages	Disadvantages
• Reduces the flood risk to the structure and contents even when the DFE is not exceeded • May be less costly than other retrofitting measures • Does not require the extra land that may be needed for floodwalls or reduced levees • Reduces the physical, financial, and emotional strain that accompanies flood events • Retains the structure in its present environment and may avoid significant changes in appearance	• Does not satisfy the NFIP requirement for bringing substantially damaged or improved residential structures into compliance • Requires ongoing maintenance • Does not reduce flood insurance premiums for residential structures unless community-wide basement exception is granted • Usually requires human intervention and adequate warning time for installation of protective measures • May provide no protection if measures fail or are exceeded during large floods • May result in more damage than flooding if design loads are exceeded, walls collapse, floors buckle, or the building floats • Prohibits the building from being occupied during a flood • May adversely affect the appearance of the building if shields are not aesthetically pleasing • May not reduce damage to the exterior of the building and other property • May lead to damage of the building and its contents if the sealant system leaks

SOURCE: FEMA 259

NFIP = National Flood Insurance Program
DFE = design flood elevation

15.3.4 Wet Floodproofing

Wet floodproofing involves modifying a building to allow floodwaters to enter it in such a way that damage to the structure and its contents is minimized. A schematic of a home that has been wet floodproofed is shown in Figure 15-12. See Table 15-4 for a list of the advantages and disadvantages of wet floodproofing.

Wet floodproofing is often used for structures with basements and crawlspaces when other mitigation techniques are technically infeasible or too costly. Wet floodproofing is generally appropriate if a structure has space available to temporarily store damageable items during the flood event. Utilities and furnaces situated below the DFE should be relocated to higher ground while remaining sub-DFE materials vulnerable to flood damage should be replaced with flood damage-resistant building materials. FEMA TB-2, *Flood Damage-Resistant Materials Requirements* (FEMA 2008b), provides guidance concerning the use of flood damage-resistant building components.

WARNING

Wet floodproofing is not allowed under the NFIP for new and substantially damaged or improved structures located in an SFHA. Refer to FEMA FIA-TB-7, *Wet Floodproofing Requirements for Structures Located in Special Flood Hazard Areas in Accordance with the NFIP* (FEMA 1993b).

CROSS REFERENCE

For additional information about wet floodproofing, see FEMA P-348, *Protecting Building Utilities From Flood Damage: Principles and Practices for the Design and Construction of Flood Resistant Building Utility Systems* (FEMA 1999).

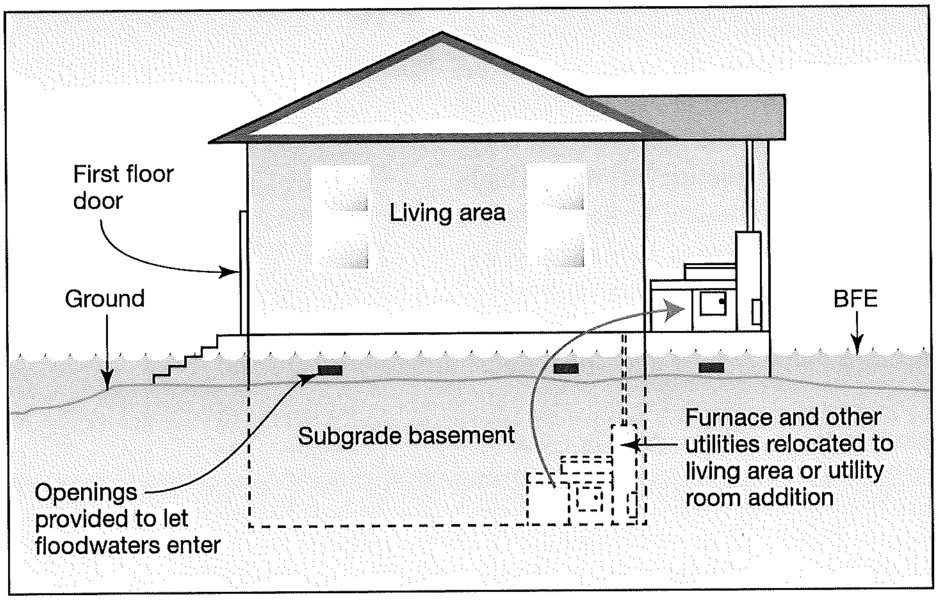


Figure 15-12. Wet floodproofed structure

Table 15-4. Advantages and Disadvantages of Wet Floodproofing

Advantages	Disadvantages
• Reduces the risk of flood damage to a building and its contents, even with minor mitigation • Greatly reduces loads on walls and floors due to equalized hydrostatic pressure • May be eligible for flood insurance coverage of cost of relocating or storing contents, except basement contents, after a flood warning is issued • Costs less than other measures • Does not require extra land • Reduces the physical, financial, and emotional strain that accompanies flood events	• Does not satisfy the NFIP requirement for bringing substantially damaged or improved structures into compliance • Usually requires a flood warning to prepare the building and contents for flooding • Requires human intervention to evacuate contents from the flood-prone area • Results in a structure that is wet on the inside and possibly contaminated by sewage, chemicals, and other materials borne by floodwaters and may require extensive cleanup • Prohibits the building from being occupied during a flood • May make the structure uninhabitable for some period after flooding • Limits the use of the floodable area • May require ongoing maintenance • May require additional costs to bring the structure up to current building codes for plumbing, electrical, and energy systems • Requires care when pumping out basements to avoid foundation wall collapse

SOURCE: FEMA 259

NFIP = National Flood Insurance Program

15.3.5 Floodwalls and Levees

Another retrofitting approach is to construct a barrier between the structure and source of flooding. The two basic types of barriers are floodwalls and levees. Small levees that protect a single home can be built to any height but are usually limited to 6 feet due to cost, aesthetics, access, water pressure, and space. The height of floodwalls is usually limited to 4 feet. Local zoning and building codes may also restrict use, size, and location.

A levee is typically a compacted earthen structure that blocks floodwaters from coming into contact with the structure. To be effective over time, levees must be constructed of suitable materials (i.e., impervious soils) and have the correct side slopes for stability. Levees may completely surround the structure or tie to high ground at each end. Levees are generally limited to homes where floodwaters are less than 5 feet deep. Otherwise, the cost and the land area required for such barriers usually make them impractical for the average owner. See Table 15-5 for a list of the advantages and disadvantages for retrofitting a home against flooding hazards using floodwalls and levees.

WARNING

While floodwalls and levees are allowed under NFIP regulations, they do not make a noncompliant structure compliant under the NFIP.

Table 15-5. Advantages and Disadvantages of a Floodwall or Levee

Advantages	Disadvantages
• Protects the area around the structure from inundation without significant changes to the structure • Eliminates pressure from floodwaters that would cause structural damage to the home or other structures in the protected area • Costs less to build than elevating or relocating the structure • Allows the structure to be occupied during construction • Reduces flood risk to the structure and its contents • Reduces the physical, financial, and emotional strain that accompanies flood events	• Does not satisfy the NFIP requirements for bringing substantially damaged or improved structures into compliance • May fail or be overtopped by large floods or floods of long duration • May be expensive • Requires periodic maintenance • Requires interior drainage • May affect local drainage, possibly resulting in water problems for others • Does not reduce flood insurance premiums • May restrict access to structure • Requires considerable land (levees only) • Does not eliminate the need to evacuate during floods • May require warning and human intervention for closures • May violate applicable codes or regulations

SOURCE: FEMA 259
NFIP = National Flood Insurance Program

Floodwalls are engineered barriers designed to keep floodwaters from coming into contact with the structure. Floodwalls can be constructed in a wide variety of shapes and sizes but are typically built of reinforced concrete and/or masonry materials.

See Figure 15-13 for an example of a home protected by both a floodwall and a levee.

15.3.6 Multihazard Mitigation

The architect, engineer, or code official must recognize that retrofitting a residential structure for flooding may affect how the structure will react to hazards other than flooding. Non-flood-related hazards such as earthquake and wind forces should also be considered when retrofitting for flood-related hazards such as water-borne ice and debris-impact forces, erosion forces, and mudslide impacts. Retrofitting a structure to withstand only floodwater forces may impair the structure's resistance to the multiple hazards mentioned above. Thus, it is important to approach retrofitting with a multi-hazard perspective.

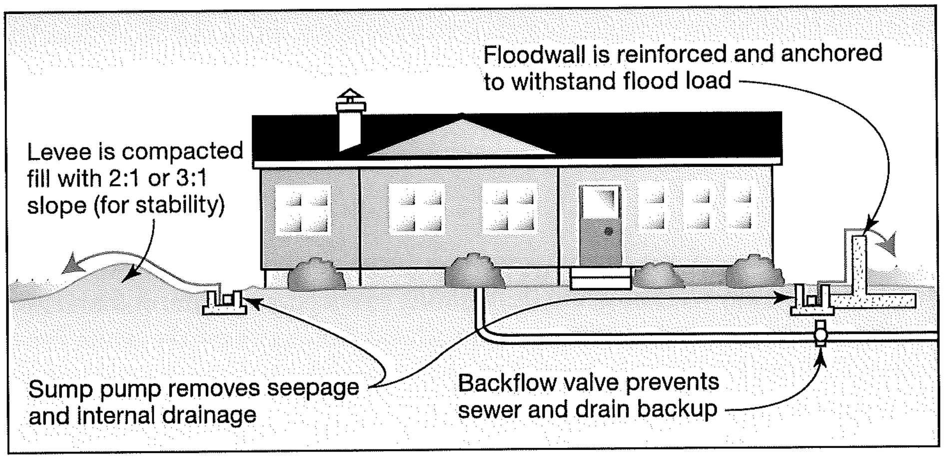


Figure 15-13.
Home protected by a floodwall and a levee

15.4 High-Wind Mitigation

The high-wind natural hazards that affect the hurricane-prone regions of the United States are hurricanes, tropical storms, typhoons, nor'easters, and tornadoes. This section addresses protecting existing residential structures from hurricane damage. The evaluation process and implementation methods for wind retrofit projects discussed in this section are described more fully in FEMA P-804, *Wind Retrofit Guide for Residential Building* (FEMA 2010c) (see Figure 15-14).

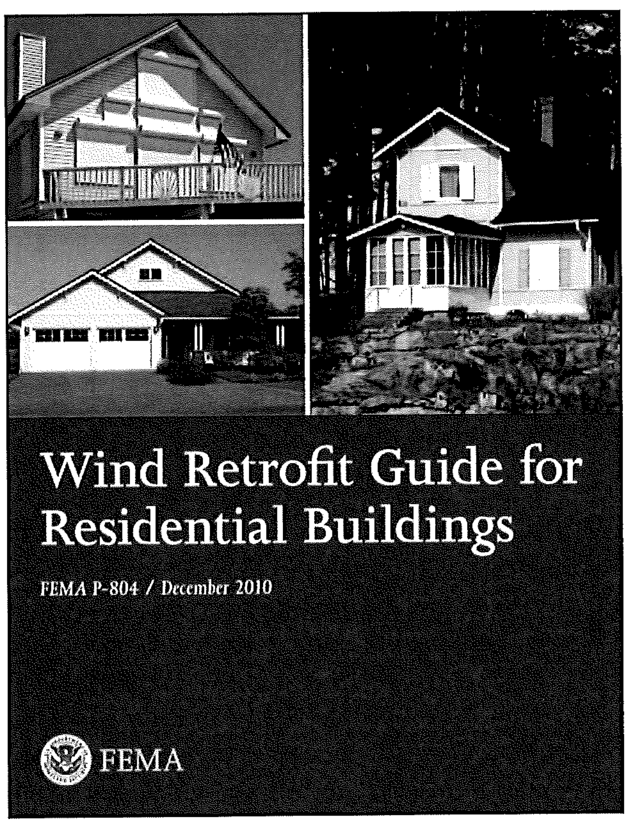


Figure 15-14.
FEMA P-804, *Wind Retrofit Guide for Residential Buildings*

NOTE

Unless otherwise stated, all wind speeds in FEMA P-804 are ASCE 7-05 3-second gust wind speeds and correspond to design requirements set forth in ASCE 7-05 and 2006 IRC and 2009 IRC. Because of the changes in the ASCE 7-10 wind speed map, it is not appropriate to use the ASCE 7-10 wind speed map in combination with the provisions of ASCE 7-05 and the older codes.

Hurricane-force winds are most common in coastal areas but also occur in other areas. ASCE 7-05 defines the hurricane-prone regions as the U.S. Atlantic Ocean and Gulf of Mexico coasts where the design wind speed is greater than 90 mph, and Hawaii, Puerto Rico, Guam, Virgin Islands, and American Samoa.

15.4.1 Evaluating Existing Homes

Executing a successful retrofit on any home requires an evaluation of its existing condition to determine age and condition; overall structural integrity; any weaknesses in the building envelope, structure, or foundation; whether the home can be retrofitted to improve resistance to wind-related damage; how the home can be retrofit for the Mitigation Packages (see Section 15.4.2); how much the Mitigation Packages would cost; and the most cost-effective retrofit project for the home.

A qualified individual should evaluate the home and provide recommendations to the homeowner. Qualified professionals may include building science professionals such as registered architects and engineers, building officials, and evaluators who are certified through other acceptable wind retrofit programs such as the FORTIFIED *for Existing Homes* Program from the Insurance Institute for Business & Home Safety (IBHS 2010).

The purposes of the evaluation are to identify any repairs that are needed before a wind retrofit project can be undertaken, the feasibility of the retrofit project, whether prescriptive retrofits can be performed on the home or whether an engineering solution should be developed, and whether the home is a good candidate for any of the wind retrofit Mitigation Packages described in Section 15.4.2. The purpose of the evaluation is ***not*** to determine whether the building meets the current building code.

15.4.2 Wind Retrofit Mitigation Packages

The wind retrofit projects described in this section, and more fully in FEMA P-804, are divided into the Basic Mitigation Package, Intermediate Mitigation Package, and Advanced Mitigation Package. Additional mitigation measures are presented at the end of this section. The packages should be implemented cumulatively, beginning with the Basic Mitigation Package. This means that for a home to successfully meet the criteria of the Advanced Mitigation Package, it must also meet the criteria of the Basic and Intermediate Mitigation Packages. The retrofits in each package are shown in Figure 15-15.

NOTE

In wind retrofitting, the most cost-effective techniques normally involve strengthening the weakest structural links and improving the water penetration resistance of the building envelope. To identify the weakest links, the designer should start at the top of the building and work down the load path.

The wind mitigation retrofits for each package, if implemented correctly, will improve the performance of residential buildings when subjected to high winds. Although the information in this section can be helpful to homeowners, it is intended primarily for evaluators, contractors, and design professionals. The retrofits described for each Mitigation Package and throughout this section are not necessarily listed in the order in which they should be performed. The order in which retrofits should be performed depends on the configuration of the home and should be determined once the desired Mitigation Package is chosen. For example, when the Advanced Mitigation Package is selected, the homeowner should consider retrofitting the roof-to-wall connections when retrofitting the soffits (part of the Basic Mitigation Package).

Figure 15-15. Wind Retrofit Mitigation Packages
SOURCE: FEMA P-804

15.4.2.1 Basic Mitigation Package

The Basic Mitigation Package focuses on securing the roof system and improving the water intrusion resistance of the home. Figures 15-16 and 15-17 show two retrofits that fall into the Basic Mitigation Package. One of the first decisions to make when implementing the Basic Mitigation Package is whether to use Option 1 or Option 2. The evaluation will identify whether the roof covering needs to be replaced (see Section 3.1.1 of FEMA P-804 for more information).

If the home is located in a wind-borne debris region, the opening protection measures described in the Intermediate Mitigation Package should be performed for the Basic Mitigation Package in addition to the other retrofits. The opening protection measures include installing an approved impact-resistant covering or component at each exterior window, skylight, entry door, and garage door opening.

FEMA P-804 includes procedures, material specifications, and fastening schedules (when applicable) to facilitate implementation of the Basic Mitigation Package. Alternative methods and materials are also discussed to facilitate installation for a variety of as-built conditions.

Figure 15-16.
Bracing gable end overhangs

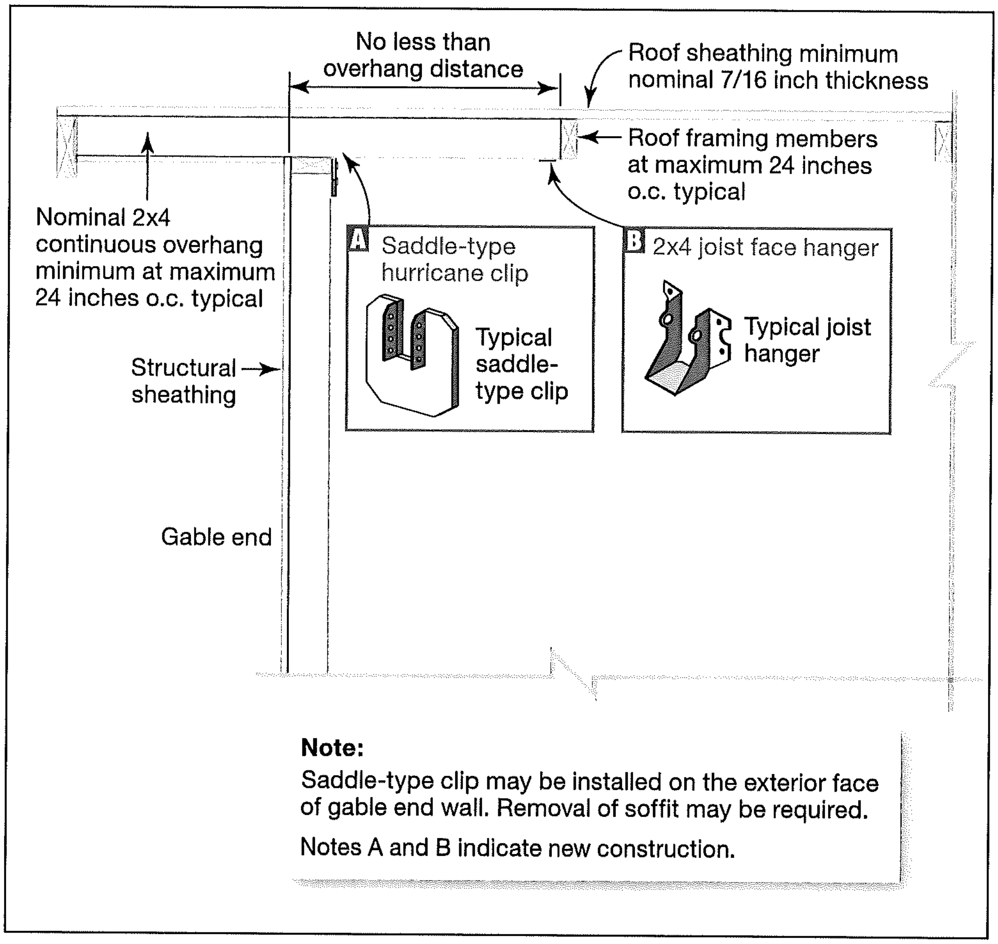


Figure 15-17.
Sprayed polyurethane foam adhesive to secure roof deck panels

15.4.2.2 Intermediate Mitigation Package

For the Intermediate Mitigation Package to be effective, the measures in the Basic Mitigation Package must first be successfully completed. The Intermediate Mitigation Package includes protecting windows and entry doors from wind-borne debris, protecting garage doors from wind pressure and garage door glazing from wind-borne debris, bracing gable end walls over 4 feet tall, and strengthening the connections of attached structures such as porches and carports.

15.4.2.3 Advanced Mitigation Package

The Advanced Mitigation Package is the most comprehensive package of retrofits. This package can be effective only if the Basic Mitigation Package (with or without replacing the roof covering) and Intermediate Mitigation Package are also implemented. The Advanced Mitigation Package requires a more invasive inspection than the other two packages. Homes that are undergoing substantial renovation or are being rebuilt after a disaster are typically the best candidates for the Advanced Mitigation Package. The Advanced Mitigation Package requires the homeowner to provide a continuous load path as shown in Figure 15-18 and further protect openings.

15.4.2.4 Additional Mitigation Measures

The wind retrofit Mitigation Packages include important retrofits that reduce the risk of wind-related damage, but the risk cannot be eliminated entirely. By maintaining an awareness of vulnerabilities of and around a home, the homeowner can reduce the risk of wind-related damage even further. Although the mitigation measures prescribed to address these vulnerabilities are important to understand, they are not a part of the Mitigation Packages and are not eligible for HMA program funding. These additional measures, described in greater detail in FEMA P-804, include securing the exterior wall covering, implementing tree fall prevention measures, and protecting exterior equipment.

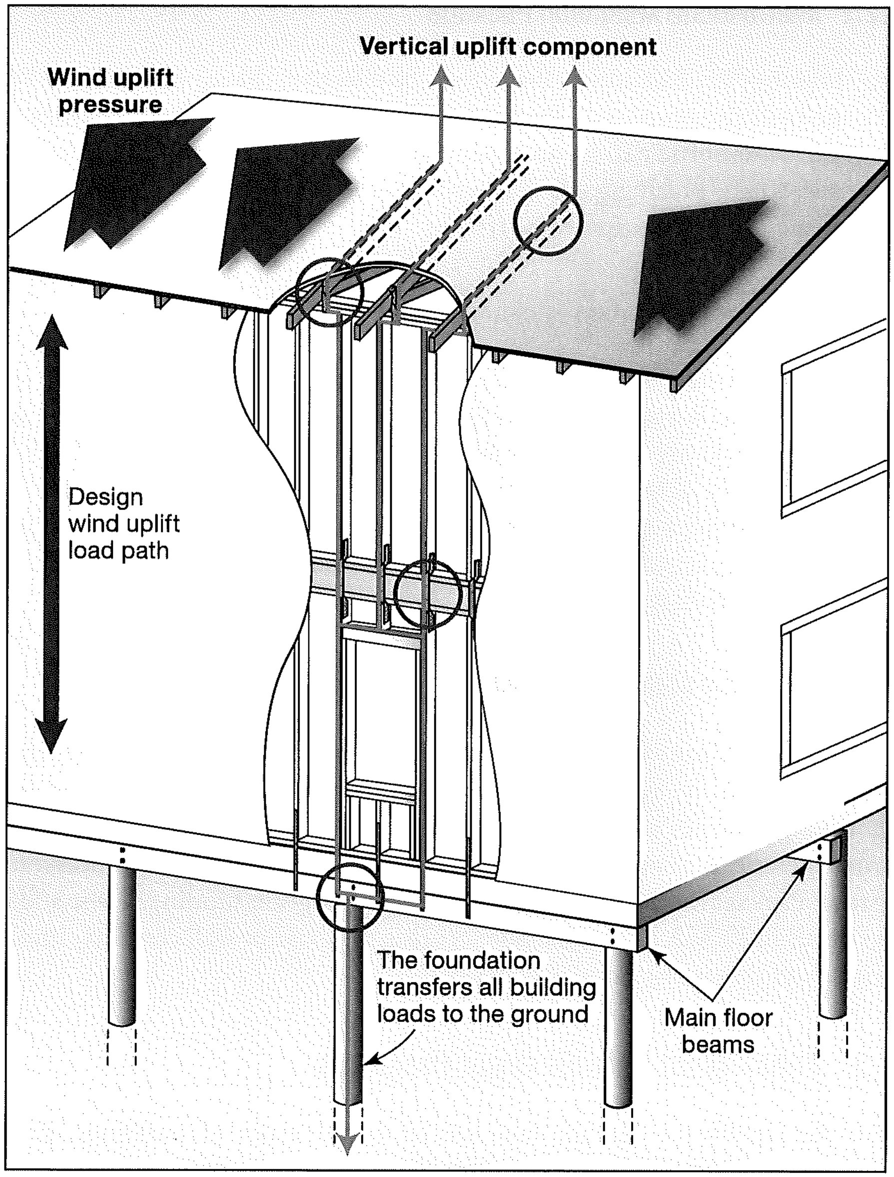
15.4.3 FEMA Wind Retrofit Grant Programs

Despite the significant damage experienced by all types of buildings during high-wind events, grant applications for wind retrofit projects have focused more on non-residential and commercial buildings than on residential buildings. FEMA developed FEMA P-804 to encourage wind mitigation of existing residential buildings.

FEMA administers two HMA grant programs that fund wind retrofit projects: HMGP and the PDM Program. Hazard mitigation is defined as any sustained action taken to reduce or eliminate long-term risk to people and property from natural hazards and their effects. The HMA process has five stages, starting with mitigation planning and ending with successful execution of a project (see Figure 15-19).

Through FEMA's HMA grant programs, applications for an individual home or groups of homes undergoing wind retrofit projects can be submitted for approval. If applications are approved, Federal funding is provided for 75 percent of the total project cost, significantly reducing the homeowner's expenses for the project. The remaining 25 percent of eligible project costs can be paid for directly or covered by donated labor, time, and materials. Refer to current HMA guidance for more details on cost-sharing (FEMA 2010a). More information on Federal assistance through HMA programs is also available in Chapter 5 of FEMA P-804.

Figure 15-18. Continuous load path for wind-uplift of a residential, wood-frame building



Homeowners should consider both qualitative and quantitative benefits and costs when deciding on a wind retrofit project. Applying for Federal assistance through HMA programs (as described in Chapter 5 of FEMA P-804) requires an analysis or comparison of the benefits to society compared to the cost of the project. Benefits such as reduced insurance premiums are not considered because they are an individual benefit. To assist with calculating the quantitative benefits and costs of implementing a project, FEMA developed Benefit-Cost Analysis (BCA) software, Version 4.5.5 (FEMA 2009). See Appendix C of FEMA P-804 for additional information on using the BCA software. Communities are encouraged to use the software regardless of whether they will apply for Federal funding. The software can be used to calculate project benefits such as avoided damage to the home, avoided displacement costs, and avoided loss of building contents. The evaluation discussed in Section 15.4.1 should identify all of the necessary input data needed for using the BCA software. Appendix C of FEMA P-804 provides a step-by-step guide to using the software to evaluate the cost-effectiveness of a wind retrofit project.

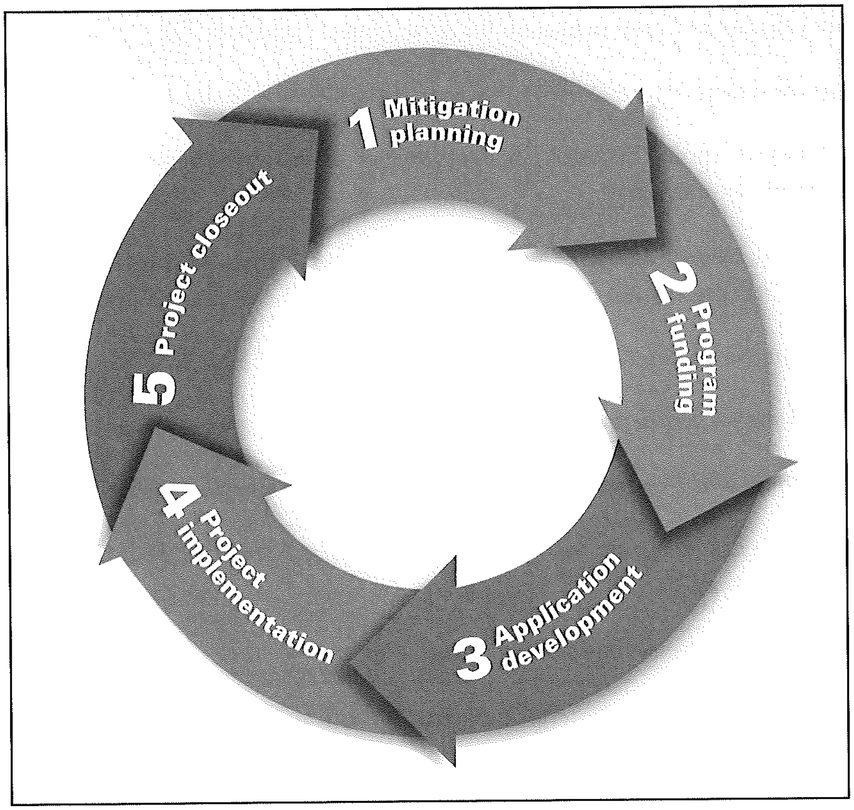


Figure 15-19.
HMA grant process
SOURCE: FEMA P-804

15.5 References

ASCE (American Society of Civil Engineers). 2005. *Minimum Design Loads for Buildings and Other Structures*. ASCE 7-05.

ASCE. *Seismic Evaluation of Existing Buildings*. ASCE 31

ASCE. *Seismic Rehabilitation of Existing Buildings*. ASCE 41.

FEMA (Federal Emergency Management Agency). 1993a. *Non-Residential Floodproofing – Requirements and Certification for Buildings Located in Special Flood Hazard Areas in Accordance with the National Flood Insurance Program*. FIA-TB-3.

FEMA. 1993b. *Wet Floodproofing Requirements for Structures Located in Special Flood Hazard Areas in Accordance with the National Flood Insurance Program*. FIA-TB-7.

FEMA. 1999. *Protecting Building Utilities from Flood Damage*. FEMA P-348.

FEMA. 2005. *Earthquake Safety Guide for Homeowners*. FEMA 530.

FEMA. 2006. *Homebuilders' Guide to Earthquake-Resistant Design and Construction*. FEMA 232.

FEMA. 2008a. *Home Builder's Guide to Construction in Wildfire Zones*. FEMA P-737.

FEMA. 2008b. *Flood Damage-Resistant Materials Requirements*. Technical Bulletin 2.

FEMA. 2009. Benefit-Cost Analysis Tool, Version 4.5.5. Available at http://www.bchelpline.com/Download.aspx. Accessed January 2011.

FEMA. 2010a. *Hazard Mitigation Assistance Unified Guidance*. Available at http://www.fema.gov/library/viewRecord.do?id=4225. Accessed June 2011.

FEMA. 2010b. *Substantial Improvement/Substantial Damage Desk Reference*. FEMA P-758.

FEMA. 2010c. *Wind Retrofit Guide for Residential Buildings*. FEMA P-804.

FEMA. 2011. *Engineering Principles and Practices of Retrofitting Floodprone Structures*. FEMA 259.

IBHS (Insurance Institute for Business & Home Safety). 2008. *Mega Fires: The Case for Mitigation – The Witch Creek Wildfire, October 21-31, 2007.*

IBHS. 2010. *FORTIFIED for Existing Homes Engineering Guide.*

ICC (International Code Council). 2006. *International Residential Code for One- and Two-Family Dwellings*. 2006 IRC.

ICC. 2009a. *International Residential Code for One- and Two-Family Dwellings*. 2009 IRC.

ICC. *International Wildland-Urban Interface Code* (IWUIC).

NFPA (National Fire Protection Association). *Code for Fire Protection of Historical Structures.*

NFPA. *Standard for Fire Protection Infrastructure for Land Development in Suburban and Rural Areas.* NFPA 1141.

NFPA. *Standard for Fire-Retardant Treated Wood and Fire-Retardant Coatings for Building Materials.* NFPA 703.

NFPA. *Standard for Reducing Structure Ignition Hazards from Wildland Fire.* NFPA 1144.

Acronyms

A

AAMA	American Architectural Manufacturers Association
ACI	American Concrete Institute
AF&PA	American Forest & Paper Association
AHJ	Authority Having Jurisdiction
AISI	American Iron and Steel Institute
ANSI	American National Standards Institute
ASCE	American Society of Civil Engineers
ASD	Allowable Stress Design
ASTM	American Society for Testing and Materials
AWPA	American Wood Protection Association

B

BCA	Benefit-Cost Analysis
BCEGS	Building Code Effectiveness Grading Schedule
BFE	base flood elevation
BUR	built-up roof

C

C&C	components and cladding

CBRA	Coastal Barrier Resources Act
CBRS	Coastal Barrier Resource System
CCM	Coastal Construction Manual
CEA	California Earthquake Authority
CMU	concrete masonry unit
CRS	Community Rating System

D

DASMA	Door & Access Systems Manufacturers Association
DFE	design flood elevation

E

EIFS	exterior insulating finishing system
ELF	Equivalent Lateral Force

F

FBC	Florida Building Code
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FM	Factory Mutual
FRP	fiber-reinforced polymer
FS	factor of safety

G

GSA	General Services Administration

H

HMA	Hazard Mitigation Assistance
HMGP	Hazard Mitigation Grant Program

I

IBC	International Building Code
IBHS	Institute for Business and Home Safety
ICC	International Code Council
IRC	International Residential Code
ISO	Insurance Services Office

L

lb	pound(s)
LEED	Leadership in Energy and Environmental Design
LiMWA	Limit of Moderate Wave Action
LPS	lightning protection system
LRFD	Load and Resistance Factor Design

M

MEPS	molded expanded polystyrene
mph	miles per hour
MWFRS	main wind force-resisting system

N

NAHB	National Association of Home Builders

NAVD North American Vertical Datum

NDS National Design Specification

NFIP National Flood Insurance Program

NFPA National Fire Protection Association

NGVD National Geodetic Vertical Datum

NRCA National Roofing Contractors Association

NRCS Natural Resources Conservation Service

O

o.c. on center

OH overhang

OSB oriented strand board

P

PDM Pre-Disaster Mitigation (Program)

plf pound(s) per linear foot

psf pound(s) per square foot

psi pound(s) per square inch

S

SBC Standard Building Code

SBS styrene-butadiene-styrene

S-DRY surface-dry lumber with <=19 percent moisture content

SFHA Special Flood Hazard Area

SFIP Standard Flood Insurance Policy

SPRI Single-Ply Roofing Institute

T

TMS	The Masonry Society

U

UBC	Uniform Building Code
UL	Underwriters Laboratories
USACE	U.S. Army Corps of Engineers
USDN	U.S. Department of the Navy
USGBC	U.S. Green Buildings Council
USGS	U.S. Geological Survey
UV	ultraviolet

W

WFCM	Wood Frame Construction Manual
Wind-MAP	Windstorm Market Assistance Program (New Jersey)
WPPC	Wood Products Promotion Council

Y

yr	year(s)

Glossary

0-9

100-year flood – See *Base flood.*

500-year flood – Flood that has as 0.2-percent probability of being equaled or exceeded in any given year.

A

Acceptable level of risk – The level of risk judged by the building owner and designer to be appropriate for a particular building.

Adjacent grade – Elevation of the natural or graded ground surface, or structural fill, abutting the walls of a building. See also *Highest adjacent grade* and *Lowest adjacent grade.*

Angle of internal friction (soil) – A measure of the soil's ability to resist shear forces without failure.

Appurtenant structure – Under the National Flood Insurance Program, an "appurtenant structure" is "a structure which is on the same parcel of property as the principal structure to be insured and the use of which is incidental to the use of the principal structure."

B

Barrier island – A long, narrow sand island parallel to the mainland that protects the coast from erosion.

Base flood – Flood that has as 1-percent probability of being equaled or exceeded in any given year. Also known as the 100-year flood.

Base Flood Elevation (BFE) – The water surface elevation resulting from a flood that has a 1 percent chance of equaling or exceeding that level in any given year. Elevation of the base flood in relation to a specified datum, such as the National Geodetic Vertical Datum or the North American Vertical Datum. The Base Flood Elevation is the basis of the insurance and floodplain management requirements of the National Flood Insurance Program.

Basement – Under the National Flood Insurance Program, any area of a building having its floor subgrade on all sides. (Note: What is typically referred to as a "walkout basement," which has a floor that is at or above grade on at least one side, is not considered a basement under the National Flood Insurance Program.)

Beach nourishment – A project type that typically involve dredging or excavating hundreds of thousands to millions of cubic yards of sediment, and placing it along the shoreline.

Bearing capacity (soils) – A measure of the ability of soil to support gravity loads without soil failure or excessive settlement.

Berm – Horizontal portion of the backshore beach formed by sediments deposited by waves.

Best Practices – Techniques that exceed the minimum requirements of model building codes; design and construction standards; or Federal, State, and local regulations.

Breakaway wall – Under the National Flood Insurance Program, a wall that is not part of the structural support of the building and is intended through its design and construction to collapse under specific lateral loading forces without causing damage to the elevated portion of the building or supporting foundation system. Breakaway walls are required by the National Flood Insurance Program regulations for any enclosures constructed below the Base Flood Elevation beneath elevated buildings in Coastal High Hazard Areas (also referred to as Zone V). In addition, breakaway walls are recommended in areas where flood waters flow at high velocities or contain ice or other debris.

Building code – Regulations adopted by local governments that establish standards for construction, modification, and repair of buildings and other structures.

Building use – What occupants will do in the building. The intended use of the building will affect its layout, form, and function.

Building envelope – Cladding, roofing, exterior walls, glazing, door assemblies, window assemblies, skylight assemblies, and other components enclosing the building.

Building systems – Exposed structural, window, or roof systems.

Built-up roof covering – Two or more layers of felt cemented together and surfaced with a cap sheet, mineral aggregate, smooth coating, or similar surfacing material.

Bulkhead – Wall or other structure, often of wood, steel, stone, or concrete, designed to retain or prevent sliding or erosion of the land. Occasionally, bulkheads are used to protect against wave action.

C

Cladding – Exterior surface of the building envelope that is directly loaded by the wind.

Closed foundation – A foundation that does not allow water to pass easily through the foundation elements below an elevated building. Examples of closed foundations include crawlspace foundations and stem wall foundations, which are usually filled with compacted soil, slab-on-grade foundations, and continuous perimeter foundation walls.

Coastal A Zone – The portion of the coastal SFHA referenced by building codes and standards, where base flood wave heights are between 1.5 and 3 feet, and where wave characteristics are deemed sufficient to damage many NFIP-compliant structures on shallow or solid wall foundations.

Coastal barrier – Depositional geologic feature such as a bay barrier, tombolo, barrier spit, or barrier island that consists of unconsolidated sedimentary materials; is subject to wave, tidal, and wind energies; and protects landward aquatic habitats from direct wave attack.

Coastal Barrier Resources Act of 1982 (CBRA) – Act (Public Law 97-348) that established the Coastal Barrier Resources System (CBRS). The act prohibits the provision of new flood insurance coverage on or after October 1, 1983, for any new construction or substantial improvements of structures located on any designated undeveloped coastal barrier within the CBRS. The CBRS was expanded by the Coastal Barrier Improvement Act of 1991. The date on which an area is added to the CBRS is the date of CBRS designation for that area.

Coastal flood hazard area – An area subject to inundation by storm surge and, in some instances, wave action caused by storms or seismic forces. Usually along an open coast, bay, or inlet.

Coastal geology – The origin, structure, and characteristics of the rocks and sediments that make up the coastal region.

Coastal High Hazard Area – Under the National Flood Insurance Program, an area of special flood hazard extending from offshore to the inland limit of a primary frontal dune along an open coast and any other area subject to high-velocity wave action from storms or seismic sources. On a Flood Insurance Rate Map, the Coastal High Hazard Area is designated Zone V, VE, or V1-V30. These zones designate areas subject to inundation by the base flood, where wave heights or wave runup depths are 3.0 feet or higher.

Coastal processes – The physical processes that act upon and shape the coastline. These processes, which influence the configuration, orientation, and movement of the coast, include tides and fluctuating water levels, waves, currents, and winds.

Coastal sediment budget – The quantification of the amounts and rates of sediment transport, erosion, and deposition within a defined region.

Coastal Special Flood Hazard Area – The portion of the Special Flood Hazard Area where the source of flooding is coastal surge or inundation. It includes Zone VE and Coastal A Zone.

Code official – Officer or other designated authority charged with the administration and enforcement of the code, or a duly authorized representative, such as a building, zoning, planning, or floodplain management official.

Column foundation – Foundation consisting of vertical support members with a height-to-least-lateral-dimension ratio greater than three. Columns are set in holes and backfilled with compacted material. They are usually made of concrete or masonry and often must be braced. Columns are sometimes known as posts, particularly if they are made of wood.

Components and Cladding (C&C) – American Society of Civil Engineers (ASCE) 7-10 defines C&C as "... elements of the building envelope that do not qualify as part of the MWFRS [Main Wind Force Resisting System]." These elements include roof sheathing, roof coverings, exterior siding, windows, doors, soffits, fascia, and chimneys.

Conditions Greater than Design Conditions – Design loads and conditions are based on some probability of exceedance, and it is always possible that design loads and conditions can be exceeded. Designers can anticipate this and modify their initial design to better accommodate higher forces and more extreme conditions. The benefits of doing so often exceed the costs of building higher and stronger.

Connector – Mechanical device for securing two or more pieces, parts, or members together, including anchors, wall ties, and fasteners.

Consequence – Both the short- and long-term effects of an event for the building. See *Risk*.

Constructability – Ultimately, designs will only be successful if they can be implemented by contractors. Complex designs with many custom details may be difficult to construct and could lead to a variety of problems, both during construction and once the building is occupied.

Continuous load paths – The structural condition required to resist loads acting on a building. The continuous load path starts at the point or surface where loads are applied, moves through the building, continues through the foundation, and terminates where the loads are transferred to the soils that support the building.

Corrosion-resistant metal – Any nonferrous metal or any metal having an unbroken surfacing of nonferrous metal, or steel with not less than 10 percent chromium or with not less than 0.20 percent copper.

D

Dead load – Weight of all materials of construction incorporated into the building, including but not limited to walls, floors, roofs, ceilings, stairways, built-in partitions, finishes, cladding, and other similarly incorporated architectural and structural items and fixed service equipment. See also *Loads*.

Debris – Solid objects or masses carried by or floating on the surface of moving water.

Debris impact loads – Loads imposed on a structure by the impact of floodborne debris. These loads are often sudden and large. Though difficult to predict, debris impact loads must be considered when structures are designed and constructed. See also *Loads*.

Deck – Exterior floor supported on at least two opposing sides by an adjacent structure and/or posts, piers, or other independent supports.

Design event – The minimum code-required event (for natural hazards, such as flood, wind, and earthquake) and associated loads that the structure must be designed to resist.

Design flood – The greater of either (1) the base flood or (2) the flood associated with the flood hazard area depicted on a community's flood hazard map, or otherwise legally designated.

Design Flood Elevation (DFE) – Elevation of the design flood, or the flood protection elevation required by a community, including wave effects, relative to the National Geodetic Vertical Datum, North American Vertical Datum, or other datum. The DFE is the locally adopted regulatory flood elevation. If a community regulates to minimum National Flood Insurance Program (NFIP) requirements, the

DFE is identical to the Base Flood Elevation (BFE). If a community chooses to exceed minimum NFIP requirements, the DFE exceeds the BFE.

Design flood protection depth – Vertical distance between the eroded ground elevation and the Design Flood Elevation.

Design stillwater flood depth – Vertical distance between the eroded ground elevation and the design stillwater flood elevation.

Design stillwater flood elevation – Stillwater elevation associated with the design flood, excluding wave effects, relative to the National Geodetic Vertical Datum, North American Vertical Datum, or other datum.

Development – Under the National Flood Insurance Program, any manmade change to improved or unimproved real estate, including but not limited to buildings or other structures, mining, dredging, filling, grading, paving, excavation, or drilling operations or storage of equipment or materials.

Dry floodproofing – A flood retrofitting technique in which the portion of a structure below the flood protection level (walls and other exterior components) is sealed to be impermeable to the passage of floodwaters.

Dune – See *Frontal dune* and *Primary frontal dune.*

Dune toe – Junction of the gentle slope seaward of the dune and the dune face, which is marked by a slope of 1 on 10 or steeper.

E

Effective Flood Insurance Rate Map – See *Flood Insurance Rate Map.*

Elevation – Raising a structure to prevent floodwaters from reaching damageable portions.

Enclosure – The portion of an elevated building below the lowest floor that is partially or fully shut in by rigid walls.

Encroachment – The placement of an object in a floodplain that hinders the passage of water or otherwise affects the flood flows.

Erodible soil – Soil subject to wearing away and movement due to the effects of wind, water, or other geological processes during a flood or storm or over a period of years.

Erosion – Under the National Flood Insurance Program, the process of the gradual wearing away of land masses.

Erosion analysis – Analysis of the short- and long-term erosion potential of soil or strata, including the effects of flooding or storm surge, moving water, wave action, and the interaction of water and structural components.

Exterior-mounted mechanical equipment – Includes, but is not limited to, exhaust fans, vent hoods, air conditioning units, duct work, pool motors, and well pumps.

F

Federal Emergency Management Agency (FEMA) – Independent agency created in 1979 to provide a single point of accountability for all Federal activities related to disaster mitigation and emergency preparedness, response, and recovery. FEMA administers the National Flood Insurance Program.

Federal Insurance and Mitigation Administration (FIMA) – The component of the Federal Emergency Management Agency directly responsible for administering the flood insurance aspects of the National Flood Insurance Program as well as a range of programs designed to reduce future losses to homes, businesses, schools, public buildings, and critical facilities from floods, earthquakes, tornadoes, and other natural disasters.

Fill – Material such as soil, gravel, or crushed stone placed in an area to increase ground elevations or change soil properties. See also *Structural fill.*

Flood – Under the National Flood Insurance Program, either a general and temporary condition or partial or complete inundation of normally dry land areas from:

(1) the overflow of inland or tidal waters;

(2) the unusual and rapid accumulation or runoff of surface waters from any source;

(3) mudslides (i.e., mudflows) that are proximately caused by flooding as defined in (2) and are akin to a river of liquid and flowing mud on the surfaces of normally dry land areas, as when the earth is carried by a current of water and deposited along the path of the current; or

(4) 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 flash flood or abnormal tidal surge, or by some similarly unusual and unforeseeable event which results in flooding as defined in (1), above.

Flood-damage-resistant material – Any construction material capable of withstanding direct and prolonged contact (i.e., at least 72 hours) with flood waters without suffering significant damage (i.e., damage that requires more than cleanup or low-cost cosmetic repair, such as painting).

Flood elevation – Height of the water surface above an established elevation datum such as the National Geodetic Vertical Datum, North American Vertical Datum, or mean sea level.

Flood hazard area – The greater of the following: (1) the area of special flood hazard, as defined under the National Flood Insurance Program, or (2) the area designated as a flood hazard area on a community's legally adopted flood hazard map, or otherwise legally designated.

Flood insurance – Insurance coverage provided under the National Flood Insurance Program.

Flood Insurance Rate Map (FIRM) – Under the National Flood Insurance Program, an official map of a community, on which the Federal Emergency Management Agency has delineated both the special hazard areas and the risk premium zones applicable to the community. (Note: The latest FIRM issued for a community is referred to as the "effective FIRM" for that community.)

Flood Insurance Study (FIS) – Under the National Flood Insurance Program, an examination, evaluation, and determination of flood hazards and, if appropriate, corresponding water surface elevations, or an examination, evaluation, and determination of mudslide (i.e., mudflow) and flood-related erosion hazards in a community or communities. (Note: The National Flood Insurance Program regulations refer to Flood Insurance Studies as "flood elevation studies.")

Flood-related erosion area or flood-related erosion prone area – A land area adjoining the shore of a lake or other body of water, which due to the composition of the shoreline or bank and high water levels or wind-driven currents, is likely to suffer flood-related erosion.

Flooding – See *Flood.*

Floodplain – Under the National Flood Insurance Program, any land area susceptible to being inundated by water from any source. See also *Flood.*

Floodplain management – Operation of an overall program of corrective and preventive measures for reducing flood damage, including but not limited to emergency preparedness plans, flood control works, and floodplain management regulations.

Floodplain management regulations – Under the National Flood Insurance Program, zoning ordinances, subdivision regulations, building codes, health regulations, special purpose ordinances (such as floodplain ordinance, grading ordinance, and erosion control ordinance), and other applications of police power. The term describes State or local regulations, in any combination thereof, that promulgate standards for the purpose of flood damage prevention and reduction.

Floodwall – A flood retrofitting technique that consists of engineered barriers designed to keep floodwaters from coming into contact with the structure.

Footing – Enlarged base of a foundation wall, pier, post, or column designed to spread the load of the structure so that it does not exceed the soil bearing capacity.

Footprint – Land area occupied by a structure.

Freeboard – Under the National Flood Insurance Program, a factor of safety, usually expressed in feet above a flood level, for the purposes of floodplain management. Freeboard is intended to compensate for the many unknown factors that could contribute to flood heights greater than the heights calculated for a selected size flood and floodway conditions, such as the hydrological effect of urbanization of the watershed. Freeboard is additional height incorporated into the Design Flood Elevation, and may be required by State or local regulations or be desired by a property owner.

Frontal dune – Ridge or mound of unconsolidated sandy soil extending continuously alongshore landward of the sand beach and defined by relatively steep slopes abutting markedly flatter and lower regions on each side.

Frontal dune reservoir – Dune cross-section above 100-year stillwater level and seaward of dune peak.

G

Gabion – Rock-filled cage made of wire or metal that is placed on slopes or embankments to protect them from erosion caused by flowing or fast-moving water.

Geomorphology – The origin, structure, and characteristics of the rocks and sediments that make up the coastal region.

Glazing – Glass or transparent or translucent plastic sheet in windows, doors, skylights, and shutters.

Grade beam – Section of a concrete slab that is thicker than the slab and acts as a footing to provide stability, often under load-bearing or critical structural walls. Grade beams are occasionally installed to provide lateral support for vertical foundation members where they enter the ground.

H

High-velocity wave action – Condition in which wave heights or wave runup depths are 3.0 feet or higher.

Highest adjacent grade – Elevation of the highest natural or regraded ground surface, or structural fill, that abuts the walls of a building.

Hurricane – Tropical cyclone, formed in the atmosphere over warm ocean areas, in which wind speeds reach 74 miles per hour or more and blow in a large spiral around a relatively calm center or "eye." Hurricane circulation is counter-clockwise in the northern hemisphere and clockwise in the southern hemisphere.

Hurricane clip or strap – Structural connector, usually metal, used to tie roof, wall, floor, and foundation members together so that they resist wind forces.

Hurricane-prone region – In the United States and its territories, hurricane-prone regions are defined by The American Society of Civil Engineers (ASCE) 7-10 as: (1) The U.S. Atlantic Ocean and Gulf of Mexico coasts where the basic wind speed for Risk Category II buildings is greater than 115 mph, and (2) Hawaii, Puerto Rico, Guam, the Virgin Islands, and American Samoa.

Hydrodynamic loads – Loads imposed on an object, such as a building, by water flowing against and around it. Among these loads are positive frontal pressure against the structure, drag effect along the sides, and negative pressure on the downstream side.

Hydrostatic loads – Loads imposed on a surface, such as a wall or floor slab, by a standing mass of water. The water pressure increases with the square of the water depth.

I

Initial costs – Include property evaluation, acquisition, permitting, design, and construction.

Interior mechanical equipment – Includes, but is not limited to, furnaces, boilers, water heaters, and distribution ductwork.

J

Jetting (of piles) – Use of a high-pressure stream of water to embed a pile in sandy soil. See also *Pile foundation*.

Jetty – Wall built from the shore out into the water to restrain currents or protect a structure.

Joist – Any of the parallel structural members of a floor system that support, and are usually immediately beneath, the floor.

L

Lacustrine flood hazard area – Area subject to inundation from lakes.

Landslide – Occurs when slopes become unstable and loose material slides or flows under the influence of gravity. Often, landslides are triggered by other events such as erosion at the toe of a steep slope, earthquakes, floods, or heavy rains, but can be worsened by human actions such as destruction of vegetation or uncontrolled pedestrian access on steep slopes.

Levee – Typically a compacted earthen structure that blocks floodwaters from coming into contact with the structure, a levee is a manmade structure built parallel to a waterway to contain, control, or divert the flow of water. A levee system may also include concrete or steel floodwalls, fixed or operable floodgates and other closure structures, pump stations for rainwater drainage, and other elements, all of which must perform as designed to prevent failure.

Limit of Moderate Wave Action (LiMWA) – A line indicating the limit of the 1.5-foot wave height during the base flood. FEMA requires new flood studies in coastal areas to delineate the LiMWA.

Littoral drift – Movement of sand by littoral (longshore) currents in a direction parallel to the beach along the shore.

Live loads – Loads produced by the use and occupancy of the building or other structure. Live loads do not include construction or environmental loads such as wind load, snow load, rain load, earthquake load, flood load, or dead load. See also *Loads*.

Load-bearing wall – Wall that supports any vertical load in addition to its own weight. See also *Non-load-bearing wall*.

Loads – Forces or other actions that result from the weight of all building materials, occupants and their possessions, environmental effects, differential movement, and restrained dimensional changes. Loads can be either permanent or variable. Permanent loads rarely vary over time or are of small magnitude. All other loads are variable loads.

Location – The location of the building determines the nature and intensity of hazards to which the building will be exposed, loads and conditions that the building must withstand, and building regulations that must be satisfied. See also *Siting.*

Long-term costs – Include preventive maintenance and repair and replacement of deteriorated or damaged building components. A hazard-resistant design can result in lower long-term costs by preventing or reducing losses from natural hazards events.

Lowest adjacent grade (LAG) – Elevation of the lowest natural or regraded ground surface, or structural fill, that abuts the walls of a building. See also *Highest adjacent grade.*

Lowest floor – Under the National Flood Insurance Program (NFIP), "lowest floor" of a building includes the floor of a basement. The NFIP regulations define a basement as "... any area of a building having its floor subgrade (below ground level) on all sides." For insurance rating purposes, this definition applies even when the subgrade floor is not enclosed by full-height walls.

Lowest horizontal structural member – In an elevated building, the lowest beam, joist, or other horizontal member that supports the building. Grade beams installed to support vertical foundation members where they enter the ground are not considered lowest horizontal structural members.

M

Main Wind Force Resisting System (MWFRS) – Consists of the foundation; floor supports (e.g., joists, beams); columns; roof raters or trusses; and bracing, walls, and diaphragms that assist in transferring loads. The American Society of Civil Engineers (ASCE) 7-10 defines the MWFRS as "... an assemblage of structural elements assigned to provide support and stability for the overall structure."

Manufactured home – Under the National Flood Insurance Program, a structure, transportable in one or more sections, built on a permanent chassis and designed for use with or without a permanent foundation when attached to the required utilities. Does not include recreational vehicles.

Marsh – Wetland dominated by herbaceous or non-woody plants often developing in shallow ponds or depressions, river margins, tidal areas, and estuaries.

Masonry – Built-up construction of building units made of clay, shale, concrete, glass, gypsum, stone, or other approved units bonded together with or without mortar or grout or other accepted methods of joining.

Mean return period – The average time (in years) between landfall or nearby passage of a tropical storm or hurricane.

Mean water elevation – The surface across which waves propagate. The mean water elevation is calculated as the stillwater elevation plus the wave setup.

Mean sea level (MSL) – Average height of the sea for all stages of the tide, usually determined from hourly height observations over a 19-year period on an open coast or in adjacent waters having free access to the sea. See also *National Geodetic Vertical Datum.*

Metal roof panel – Interlocking metal sheet having a minimum installed weather exposure of 3 square feet per sheet.

Minimal Wave Action area (MiWA) – The portion of the coastal Special Flood Hazard Area where base flood wave heights are less than 1.5 feet.

Mitigation – Any action taken to reduce or permanently eliminate the long-term risk to life and property from natural hazards.

Mitigation Directorate – Component of the Federal Emergency Management Agency directly responsible for administering the flood hazard identification and floodplain management aspects of the National Flood Insurance Program.

Moderate Wave Action area (MoWA) – See *Coastal A Zone.*

N

National Flood Insurance Program (NFIP) – Federal program created by Congress in 1968 that makes flood insurance available in communities that enact and enforce satisfactory floodplain management regulations.

National Geodetic Vertical Datum (NGVD) – Datum established in 1929 and used as a basis for measuring flood, ground, and structural elevations, previously referred to as Sea Level Datum or Mean Sea Level. The Base Flood Elevations shown on most of the Flood Insurance Rate Maps issued by the Federal Emergency Management Agency are referenced to NGVD or, more recently, to the *North American Vertical Datum.*

Naturally decay-resistant wood – Wood whose composition provides it with some measure of resistance to decay and attack by insects, without preservative treatment (e.g., heartwood of cedar, black locust, black walnut, and redwood).

New construction – ***For the purpose of determining flood insurance rates*** under the National Flood Insurance Program, structures for which the start of construction commenced on or after the effective date of the initial Flood Insurance Rate Map or after December 31, 1974, whichever is later, including any subsequent improvements to such structures. (See also *Post-FIRM structure.*) ***For floodplain management purposes***, new construction means structures for which the start of construction commenced on or after the effective date of a floodplain management regulation adopted by a community and includes any subsequent improvements to such structures.

Non-load-bearing wall – Wall that does not support vertical loads other than its own weight. See also *Load-bearing wall.*

Nor'easter – A type of storm that occurs along the East Coast of the United States where the wind comes from the northeast. Nor'easters can cause coastal flooding, coastal erosion, hurricane-force winds, and heavy snow.

North American Vertical Datum (NAVD) – Datum established in 1988 and used as a basis for measuring flood, ground, and structural elevations. NAVD is used in many recent Flood Insurance Studies rather than the National Geodetic Vertical Datum.

O

Open foundation – A foundation that allows water to pass through the foundation of an elevated building, which reduces the lateral flood loads the foundation must resist. Examples of open foundations are pile, pier, and column foundations.

Operational costs – Costs associated with the use of the building, such as the cost of utilities and insurance. Optimizing energy efficiency may result in a higher initial cost but save in operational costs.

Oriented strand board (OSB) – Mat-formed wood structural panel product composed of thin rectangular wood strands or wafers arranged in oriented layers and bonded with waterproof adhesive.

Overwash – Occurs when low-lying coastal lands are overtopped and eroded by storm surge and waves such that the eroded sediments are carried landward by floodwaters, burying uplands, roads, and at-grade structures.

P

Pier foundation – Foundation consisting of isolated masonry or cast-in-place concrete structural elements extending into firm materials. Piers are relatively short in comparison to their width, which is usually greater than or equal to 12 times their vertical dimension. Piers derive their load-carrying capacity through skin friction, end bearing, or a combination of both.

Pile foundation – Foundation consisting of concrete, wood, or steel structural elements driven or jetted into the ground or cast-in-place. Piles are relatively slender in comparison to their length, which usually exceeds 12 times their horizontal dimension. Piles derive their load-carrying capacity through skin friction, end bearing, or a combination of both.

Platform framing – A floor assembly consisting of beams, joists, and a subfloor that creates a platform that supports the exterior and interior walls.

Plywood – Wood structural panel composed of plies of wood veneer arranged in cross-aligned layers. The plies are bonded with an adhesive that cures when heat and pressure are applied.

Post-FIRM structure – For purposes of determining insurance rates under the National Flood Insurance Program, structures for which the start of construction commenced on or after the effective date of an initial Flood Insurance Rate Map or after December 31, 1974, whichever is later, including any subsequent improvements to such structures. This term should not be confused with the term new construction as it is used in floodplain management.

Post foundation – Foundation consisting of vertical support members set in holes and backfilled with compacted material. Posts are usually made of wood and usually must be braced. Posts are also known as columns, but columns are usually made of concrete or masonry.

Precast concrete – Structural concrete element cast elsewhere than its final position in the structure. See also *Cast-in-place concrete.*

Pressure-treated wood – Wood impregnated under pressure with compounds that reduce the susceptibility of the wood to flame spread or to deterioration caused by fungi, insects, or marine borers.

Premium – Amount of insurance coverage.

Primary frontal dune – Under the National Flood Insurance Program, a continuous or nearly continuous mound or ridge of sand with relatively steep seaward and landward slopes immediately landward and adjacent to the beach and subject to erosion and overtopping from high tides and waves during major coastal storms. The inland limit of the primary frontal dune occurs at the point where there is a distinct change from a relatively steep slope to a relatively mild slope.

R

Rating factor (insurance) – A factor used to determine the amount to be charged for a certain amount of insurance coverage (premium).

Recurrence interval – The frequency of occurrence of a natural hazard as referred to in most design codes and standards.

Reinforced concrete – Structural concrete reinforced with steel bars.

Relocation – The moving of a structure to a location that is less prone to flooding and flood-related hazards such as erosion.

Residual risk – The level of risk that is not offset by hazard-resistant design or insurance, and that must be accepted by the property owner.

Retrofit – Any change or combination of adjustments made to an existing structure intended to reduce or eliminate damage to that structure from flooding, erosion, high winds, earthquakes, or other hazards.

Revetment – Facing of stone, cement, sandbags, or other materials placed on an earthen wall or embankment to protect it from erosion or scour caused by flood waters or wave action.

Riprap – Broken stone, cut stone blocks, or rubble that is placed on slopes to protect them from erosion or scour caused by flood waters or wave action.

Risk – Potential losses associated with a hazard, defined in terms of expected probability and frequency, exposure, and consequences. Risk is associated with three factors: threat, vulnerability, and consequence.

Risk assessment – Process of quantifying the total risk to a coastal building (i.e., the risk associated with all the significant natural hazards that may impact the building).

Risk category – As defined in American Society of Civil Engineers (ASCE) 7-10 and the 2012 International Building Code, a building's risk category is based on the risk to human life, health, and welfare associated with potential damage or failure of the building. These risk categories dictate which design event is used when calculating performance expectations of the building, specifically the loads the building is expected to resist.

Risk reduction – The process of reducing or offsetting risks. Risk reduction is comprised of two aspects: physical risk reduction and risk management through insurance.

Risk tolerance – Some owners are willing and able to assume a high degree of financial and other risks, while other owners are very conservative and seek to minimize potential building damage and future costs.

Riverine SFHA – The portion of the Special Flood Hazard Area mapped as Zone AE and where the source of flooding is riverine, not coastal.

Roof deck – Flat or sloped roof surface not including its supporting members or vertical supports.

S

Sand dunes – Under the National Flood Insurance Program, natural or artificial ridges or mounds of sand landward of the beach.

Scour – Removal of soil or fill material by the flow of flood waters. Flow moving past a fixed object accelerates, often forming eddies or vortices and scouring loose sediment from the immediate vicinity of the object. The term is frequently used to describe storm-induced, localized conical erosion around pilings and other foundation supports, where the obstruction of flow increases turbulence. See also *Erosion*.

Seawall – Solid barricade built at the water's edge to protect the shore and prevent inland flooding.

Setback – For the purpose of this Manual, a State or local requirement that prohibits new construction and certain improvements and repairs to existing coastal buildings in areas expected to be lost to shoreline retreat.

Shearwall – Load-bearing wall or non-load-bearing wall that transfers in-plane lateral forces from lateral loads acting on a structure to its foundation.

Shoreline retreat – Progressive movement of the shoreline in a landward direction; caused by the composite effect of all storms over decades and centuries and expressed as an annual average erosion rate. Shoreline retreat is essentially the horizontal component of erosion and is relevant to long-term land use decisions and the siting of buildings.

Single-ply membrane – Roofing membrane that is field-applied with one layer of membrane material (either homogeneous or composite) rather than multiple layers. The four primary types of single-ply membranes are chlorosulfonated polyethylene (CSPE) (Hypalon), ethylene propylene diene monomer (EPDM), polyvinyl chloride (PVC), and thermoplastic polyolefin (TPO).

Siting – Choosing the location for the development or redevelopment of a structure.

Special Flood Hazard Area (SFHA) – Under the National Flood Insurance Program, an area having special flood, mudslide (i.e., mudflow), or flood-related erosion hazards, and shown on a Flood Hazard Boundary Map or Flood Insurance Rate Map as Zone A, AO, A1-A30, AE, A99, AH, V, V1-V30, VE, M, or E. The area has a 1 percent chance, or greater, of flooding in any given year.

Start of construction (for other than new construction or substantial improvements under the Coastal Barrier Resources Act) – Under the National Flood Insurance Program, date the building permit was issued, provided the actual start of construction, repair, reconstruction, rehabilitation, addition placement, or other improvement was within 180 days of the permit date. The actual start means either the first placement of permanent construction of a structure on a site such as the pouring of slab or footings, the installation of piles, the construction of columns, or any work beyond the stage of excavation; or the placement of a manufactured home on a foundation. Permanent construction does not include land preparation, such as clearing, grading, and filling; nor the installation of streets or walkways; excavation for a basement, footings, piers, or foundations or the erection of temporary forms; or the installation on the property of accessory buildings, such as garages or sheds not occupied as dwelling units or not part of the main structure. For a substantial improvement, the actual start of construction means the first alteration of any wall, ceiling, floor, or other structural part of a building, whether or not that alteration affects the external dimensions of the building.

State Coordinating Agency – Under the National Flood Insurance Program, the agency of the State government, or other office designated by the Governor of the State or by State statute to assist in the implementation of the National Flood Insurance Program in that State.

Stillwater elevation – The elevations of the water surface resulting solely from storm surge (i.e., the rise in the surface of the ocean due to the action of wind and the drop in atmospheric pressure association with hurricanes and other storms).

Storm surge – Water pushed toward the shore by the force of the winds swirling around a storm. It is the greatest cause of loss of life due to hurricanes.

Storm tide – Combined effect of storm surge, existing astronomical tide conditions, and breaking wave setup.

Structural concrete – All concrete used for structural purposes, including plain concrete and reinforced concrete.

Structural fill – Fill compacted to a specified density to provide structural support or protection to a structure. See also *Fill.*

Structure – ***For floodplain management purposes*** under the National Flood Insurance Program (NFIP), a walled and roofed building, gas or liquid storage tank, or manufactured home that is principally above ground. ***For insurance coverage purposes*** under the NFIP, structure means a walled and roofed building, other than a gas or liquid storage tank, that is principally above ground and affixed to a permanent site, as well as a manufactured home on a permanent foundation. For the latter purpose, the term includes a building undergoing construction, alteration, or repair, but does not include building materials or supplies intended for use in such construction, alteration, or repair, unless such materials or supplies are within an enclosed building on the premises.

Substantial damage – Under the National Flood Insurance Program, damage to a building (regardless of the cause) is considered substantial damage if the cost of restoring the building to its before-damage condition would equal or exceed 50 percent of the market value of the structure before the damage occurred.

Substantial improvement – Under the National Flood Insurance Program, improvement of a building (such as reconstruction, rehabilitation, or addition) is considered a substantial improvement if its cost equals or exceeds 50 percent of the market value of the building before the start of construction of the improvement. This term includes structures that have incurred substantial damage, regardless of the actual repair work performed. The term does not, however, include either (1) any project for improvement of a structure to correct existing violations of State or local health, sanitary, or safety code specifications which have been identified by the local code enforcement official and which are the minimum necessary to ensure safe living conditions, or (2) any alteration of a "historic structure," provided that the alteration will not preclude the structure's continued designation as a "historic structure."

Super typhoons – Storms with sustained winds equal to or greater than 150 mph.

T

Threat – The probability that an even of a given recurrence interval will affect the building within a specified period. See *Risk*.

Tornado – A rapidly rotating vortex or funnel of air extending groundward from a cumulonimbus cloud

Tributary area – The area of the floor, wall, roof, or other surface that is supported by the element. The tributary area is generally a rectangle formed by one-half the distance to the adjacent element in each applicable direction.

Tropical cyclone – A low-pressure system that generally forms in the tropics, and is often accompanied by thunderstorms.

Tropical depression – Tropical cyclone with some rotary circulation at the water surface. With maximum sustained wind speeds of up to 39 miles per hour, it is the second phase in the development of a hurricane.

Tropical disturbance – Tropical cyclone that maintains its identity for at least 24 hours and is marked by moving thunderstorms and with slight or no rotary circulation at the water surface. Winds are not strong. It is a common phenomenon in the tropics and is the first discernable stage in the development of a hurricane.

Tropical storm – Tropical cyclone that has 1-minute sustained wind speeds averaging 39 to 74 miles per hour (mph).

Tsunami – Long-period water waves generated by undersea shallow-focus earthquakes, undersea crustal displacements (subduction of tectonic plates), landslides, or volcanic activity.

Typhoon – Name given to a hurricane in the area of the western Pacific Ocean west of 180 degrees longitude.

U

Underlayment – One or more layers of felt, sheathing paper, non-bituminous saturated felt, or other approved material over which a steep-sloped roof covering is applied.

Undermining – Process whereby the vertical component of erosion or scour exceeds the depth of the base of a building foundation or the level below which the bearing strength of the foundation is compromised.

Uplift – Hydrostatic pressure caused by water under a building. It can be strong enough lift a building off its foundation, especially when the building is not properly anchored to its foundation.

V

Variance – Under the National Flood Insurance Program, grant of relief by a community from the terms of a floodplain management regulation.

Violation – Under the National Flood Insurance Program (NFIP), the failure of a structure or other development to be fully compliant with the community's floodplain management regulations. A structure or other development without the elevation certificate, other certifications, or other evidence of compliance required in Sections 60.3(b)(5), (c)(4), (c)(10), (d)(3), (e)(2), (e)(4), or (e)(5) of the NFIP regulations is presumed to be in violation until such time as that documentation is provided.

Vulnerability – Weaknesses in the building or site location that may result in damage. See *Risk*.

W

Water surface elevation – Under the National Flood Insurance Program, the height, in relation to the National Geodetic Vertical Datum of 1929 (or other datum, where specified), of floods of various magnitudes and frequencies in the floodplains of coastal or riverine areas.

Wave – Ridge, deformation, or undulation of the water surface.

Wave height – Vertical distance between the wave crest and wave trough. Wave crest elevation is the elevation of the crest of a wave, referenced to the National Geodetic Vertical Datum, North American Vertical Datum, or other datum.

Wave overtopping – Occurs when waves run up and over a dune or barrier.

Wave runup – Is the rush of water up a slope or structure. Wave runup occurs as waves break and run up beaches, sloping surfaces, and vertical surfaces.

Wave runup depth – At any point is equal to the maximum wave runup elevation minus the lowest eroded ground elevation at that point.

Wave runup elevation – Is the elevation reached by wave runup, referenced to the National Geodetic Vertical Datum or other datum.

Wave setup – Increase in the stillwater surface near the shoreline due to the presence of breaking waves. Wave setup typically adds 1.5 to 2.5 feet to the 100-year stillwater flood elevation and should be discussed in the Flood Insurance Study.

Wave slam – The action of wave crests striking the elevated portion of a structure.

Wet floodproofing – A flood retrofitting technique that involves modifying a structure to allow floodwaters to enter it in such a way that damage to a structure and its contents is minimized.

Z

Zone A – Under the National Flood Insurance Program, area subject to inundation by the 100-year flood where wave action does not occur or where waves are less than 3 feet high, designated Zone A, AE, A1-A30, A0, AH, or AR on a Flood Insurance Rate Map.

Zone AE – The portion of the Special Flood Hazard Area (SFHA) not mapped as Zone VE. It includes the Moderate Wave Action area, the Minimal Wave Action area, and the riverine SFHA.

Zone B – Areas subject to inundation by the flood that has a 0.2-percent chance of being equaled or exceeded during any given year, often referred to the as 500-year flood. Zone B is provided on older flood maps, on newer maps this is referred to as "shaded Zone X."

Zone C – Designates areas where the annual probability of flooding is less than 0.2 percent. Zone C is provided on older flood maps, on newer maps this is referred to as "unshaded Zone X."

Zone V – See *Coastal High Hazard Area.*

Zone VE – The portion of the coastal Special Flood Hazard Area where base flood wave heights are 3 feet or greater, or where other damaging base flood wave effects have been identified, or where the primary frontal dune has been identified.

Zone X – Under the National Flood Insurance Program, areas where the flood hazard is lower than that in the Special Flood Hazard Area. Shaded Zone X shown on recent Flood Insurance Rate Maps (Zone B on older maps) designate areas subject to inundation by the 500-year flood. Unshaded Zone X (Zone C on older Flood Insurance Rate Maps) designate areas where the annual probability of flooding is less than 0.2 percent.

Zone X (Shaded) – Areas subject to inundation by the flood that has a 0.2-percent chance of being equaled or exceeded during any given year, often referred to the as 500-year flood.

Zone X (Unshaded) – Designates areas where the annual probability of flooding is less than 0.2 percent.

Index, Volume II

Bold text indicates chapter titles or major headings. Italicized page numbers indicates a figure or table.

A

B

C

D

E

F

G

H

I

J

L

M

N

O

P

FEMA

FEMA P-55
Catalog No. 08352-1