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Building sites or designs resulting in extreme or high risk should be avoided — the likelihood of building loss is great, and the long-term costs to the owner will be very high. Building sites or designs resulting in medium or low risk should be given preference.

Siting

Note that over a long period, poor siting decisions are rarely overcome by building design.

Design

- How much more expensive is it to build near the coast as opposed to inland areas? The table below suggests approximately 10 - 30 percent more.
- What about exceeding minimum design requirements in coastal areas? The table suggests that the added construction costs for meeting the practices recommended in the Home Builder's Guide to Coastal Construction (beyond typical minimum requirements) are nominal.

Design Item (Items with asterisk "*" are required by the National Flood Insurance Program (NFIP) and/or local building code.)	Cross-Reference to Fact Sheets	Added Initial Costs[2] Required by Code or NFIP	Added Initial Costs[3] for Home Builder's Guide to Coastal Construction Recommended Practices	Effect of Design on Cost: Reduce wind/storm damage	Reduce flood damage	Longer material life	Reduce maintenance	Lower insurance	Lower utility bills
A Zone, pile/column foundation	1.1, 1.4, 3.1	High	High	✔	✔		✔		
V Zone, pile/column foundation*	1.1, 1.4, 1.5, 3.1	High			✔		✔		
Joists sheathed on underside		Low	Low		✔	✔			✔
Structurally sheathed walls*		Medium		✔					
Corrosion protection*	1.1, 1.7	Low		✔	✔	✔	✔		
Decay protection*	1.1, 1.7	Medium		✔	✔	✔	✔		
Hip roof shape	1.1	Low	Low	✔					
Enhanced roof sheathing connection*	1.1, 7.1	Low	Low	✔					
Enhanced roof underlayment*	7.2	Low	Low	✔					
Upgraded roofing materials*	1.1, 7.3	Medium		✔		✔	✔		
Enhanced flashing*	1.1, 6.1, 5.2	Low		✔		✔	✔		
Housewrap*	1.1, 6.1, 5.1	Low		✔					✔
Superior siding and connection*	5.3	Medium	Medium	✔			✔		
Protected or impact-resistant glazing*	1.1, 6.2	High	Medium	✔				✔	
Connection hardware*	1.1, 1.7, 4.3	Low		✔	✔				
Flood-resistant materials*	1.1, 1.7	Low			✔	✔		✔	
Protected utilities and mechanicals*	1.1, 8.3	Low		✔	✔	✔	✔		✔
Estimated Total Additional Cost ($ thousands)		15-30	±5	✔	✔	✔	✔	✔	✔

Low	<0.5% of base building cost	Estimates are based on a 3,000-square-foot home with a moderate number of windows and special features. Many of the upgraded design features are required by local codes, but the level of protection beyond the code minimum can vary, depending on the owner's preference.
Medium	0.5% - 2.0% of base building cost	
High	>2.0% of base building cost	

Notes:

2 Added costs when compared to typical inland construction

3 Added initial costs to exceed Code/NFIP minimum requirements

Developed in association with the National Association of Home Builders Research Center

Selecting a Lot and Siting the Building

HOME BUILDER'S GUIDE TO COASTAL CONSTRUCTION Technical Fact Sheet No. 2.2

Purpose: *To provide guidance on lot selection and siting considerations for coastal residential buildings.*

Key Issues

- Purchase and siting decisions should be long-term decisions, not based on present-day shoreline and conditions.
- Parcel characteristics, infrastructure, regulations, environmental factors, and owner desires constrain siting options.
- Conformance with local/state shoreline setback lines does not mean buildings will be "safe."
- Information about site conditions and history is available from several sources.

Siting, design, and construction should be considered together (see Fact Sheet No. 2.1), but know that poor lot selection and siting decisions can rarely be overcome by improved design and construction. Building failures (see Fact Sheet No. 1.1) are often the result of poor siting.

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The Importance of Property Purchase and Siting Decisions

The single most common and costly siting mistake made by designers, builders, and owners is failing to consider future erosion and slope stability when an existing coastal home is purchased or when land is purchased and a new home is built. Purchase decisions—or siting, design, and construction decisions—based on present-day shoreline conditions often lead to future building failures.

Over a long period of time, owners of poorly sited coastal buildings may spend more money on erosion control and erosion-related building repairs than they spent on the building itself.

What Factors Constrain Siting Decisions?

Many factors affect and limit a home builder's or owner's ability to site coastal residential buildings, but the most influential is probably ***parcel size***, followed by ***topography, location of roads and other infrastructure, regulatory constraints***, and ***environmental constraints***.

Given the cost of coastal property, parcel sizes are often small and owners often build the largest building that will fit within the permissible development footprint. Buyers frequently fail to recognize that siting decisions in these cases have effectively been made at the time the land was platted or subdivided, and that shoreline erosion can render these parcels unsuitable for long-term occupation.

In some instances, however, parcel size may be large enough to allow a hazard-resistant coastal building to be sited and constructed, but an ***owner's desire*** to push the building as close to the shoreline as possible increases the likelihood that the building will be damaged or destroyed in the future.

2 PLANNING

Coastal Setback Lines – What Protection Do They Provide?

Many states require new buildings to be sited at or landward of coastal construction setback lines, which are usually based on ***long-term, average annual erosion rates***. For example, a typical minimum 50-year setback line with an erosion rate of 2.5 feet/year would require a setback of 125 feet, typically measured from a reference feature such as the dune crest, vegetation line, or high-water line.

Building at the 125-foot setback (in this case) does ***not*** mean that a building will be "safe" from erosion for 50 years.

- Storms can cause short-term erosion that far exceeds setbacks based on long-term averages.
- Erosion rates vary over time, and erosion could surpass the setback distance in just a few years' time. The rate variability must also be known to determine the probability of undermining over a given time period.

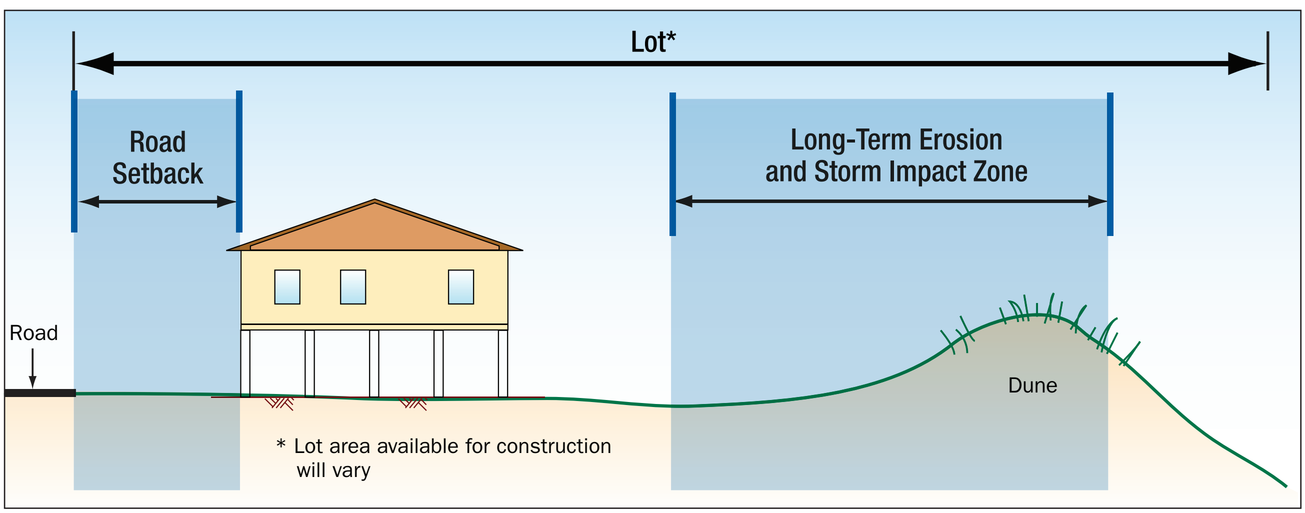
What Should Builders, Designers, and Owners Do?

- Consult local and state agencies, universities, and consultants for detailed, site-specific erosion and hazard information.
- Look for historical information on erosion and storm effects. How have older buildings in the area fared over time? Use the experience of others to guide siting decisions.
- Determine the owner's risk tolerance, and reject parcels or building siting decisions that exceed the acceptable level of risk.

Common Siting Problems

- Building on a ***small lot between a road and an eroding shoreline*** is a recipe for trouble.
- ***Odd-shaped lots*** that force buildings close to the shoreline increase the vulnerability of the buildings.
- Siting a building near the ***edge of a bluff*** increases the likelihood of building loss, because of both bluff erosion and changes in bluff stability resulting from development activities (e.g., clearing vegetation, building construction, landscaping, changes in surface drainage and groundwater flow patterns).
- Siting near a ***tidal inlet*** with a dynamic shoreline can result in the building being exposed to increasing flood and erosion hazards over time.
- Siting a building ***immediately behind an erosion control structure*** may lead to building damage from wave overtopping and may limit the owner's ability to repair or maintain the erosion control structure.
- Siting a new building ***within the footprint*** of a pre-existing building does not guarantee that the location is a good one.

Siting should consider both long-term erosion and storm impacts. Siting should consider site-specific experience, wherever available.



Recommended building location on a coastal lot.

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Foundations in Coastal Areas

Purpose: *To describe foundation types suitable for coastal environments.*

Key Issues

- Foundations in coastal areas should elevate buildings above the Design Flood Elevation (DFE) in accordance with ASCE 24-05, while withstanding flood forces, high winds, scour and erosion, and floating debris in ASCE 7-10.
- Foundations used for inland construction are generally not suitable for coastal construction. Some examples of foundation systems that have a history of poor performance in erosion prone areas are slab-on-ground, spread footings, and mat (or raft) foundations.
- Deeply embedded pile or column foundations are required for V Zone construction. In A Zones they are recommended instead of solid wall, crawlspace, slab, or other shallow foundations, which are more susceptible to scour. (For the reference of this document, the term deeply embedded means "sufficient penetration into the ground to accommodate storm-induced scour and erosion and to resist all design vertical and lateral loads without structural damage.")
- Areas below elevated buildings in V Zones must be "free of obstructions" that can transfer flood loads to the foundation and building (see Fact Sheet No. 8.1, Enclosures and Breakaway Walls). Areas below elevated buildings in A Zones should follow the same recommended principles as those areas for buildings located in V Zones.

Figure 1. Near collapse due to insufficient pile embedment in Dauphin Island, Alabama.

(SOURCE: FEMA 549, HURRICANE KATRINA IN THE GULF COAST)

Foundation Design Criteria

All foundations for buildings in flood hazard areas must be constructed with flood-damage-resistant materials (see Fact Sheet No. 1.7, Coastal Building Materials). In addition to meeting the requirements for conventional construction, these foundations must: (1) elevate the building above the Base Flood Elevation (BFE), and (2) prevent flotation, collapse, and lateral movement of the building, resulting from loads and conditions during the design flood event (in coastal areas, these loads and conditions include inundation by fast-moving water, breaking waves, floating debris, erosion, and high winds).

Because the most hazardous coastal areas are subject to erosion, scour, and extreme flood loads, ***the only practical way to perform these two functions is to elevate a building on a deeply embedded and "open" (i.e., pile or column) foundation.*** This approach resists storm-induced erosion and scour, and it minimizes the foundation surface area subject to lateral flood loads.

ASCE 24-05 is recommended as a best practice for flood resistance design and construction, especially in V Zones and Coastal A Zones. This standard has specific information on foundation requirements for Coastal High Hazard Areas and Coastal A Zones and it has stricter requirements than the NFIP. Elevation on open foundations is required by the National Flood Insurance Program (NFIP) in V Zones (even when the ground elevation lies above the BFE) and is strongly recommended for Coastal A Zones. Some states and communities have formally adopted open foundation requirements for Coastal A Zone construction.

While using the approach of elevation of structures on pile foundations improves performance and

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minimizes some effects, even a deeply embedded open pile foundation will not prevent eventual undermining and loss due to long-term erosion (see Fact Sheet No. 2.2, *Selecting a Lot and Siting the Building*).

Performance of Various Foundation Types in Coastal Areas

There are many ways to elevate buildings above the BFE: fill, slab-on-grade, crawlspace, stemwall, solid wall, pier (column), and pile. Not all of these are suitable for coastal areas. In fact, several of them are prohibited in V Zones and are not recommended for A Zone construction in coastal areas (see Fact Sheet 1.2, *Summary of Coastal Construction Requirements and Recommendations for Flood Effects*).

Pile: Pile foundations are recommended for V Zones and Coastal A Zones. These open foundations are constructed with square or round, wood, concrete, or steel piles, driven or jetted into the ground, or set into augered holes. Critical aspects of a pile foundation include the pile size, installation method and embedment depth, bracing, and the connections to the elevated structure (see Fact Sheets Nos. 3.2, *Pile Installation* and 3.3, *Wood-Pile-to-Beam Connections*). Pile foundations with inadequate embedment will lead to building collapse. Inadequately sized piles are vulnerable to breakage by waves and debris.

Fill: Using fill as a means of providing structural support to buildings in V Zones is prohibited because it is susceptible to erosion. Also, fill must not be used as a means of elevating buildings in any other coastal area subject to erosion, waves, or fast-moving water. However, minor quantities of fill are permitted for landscaping, site grading (not related to structural support of the building), drainage around and under buildings, and for the support of parking slabs, pool decks, patios and walkways (2009 IRC Section R322.3.2). These guidelines are consistent with NFIP Technical Bulletin 5, *Free-of-Obstruction Requirements for Buildings Located in Coastal High Hazard Areas (*08/08), which states: "Fill must not prevent the free passage of floodwaters and waves beneath elevated buildings. Fill must not divert floodwaters or deflect waves such that increased damage is sustained by adjacent or nearby buildings."

Slab-on-Grade: Slab-on-grade foundations are also susceptible to erosion and are prohibited in V Zones and are not recommended for A Zones in coastal areas. (Note that parking slabs are often permitted below elevated buildings, but are susceptible to undermining and collapse.) It is recommended that parking slabs be designed to be frangible (breakaway) or designed and constructed to be self-supporting structural slabs capable of remaining intact and functional under base flood conditions, including expected erosion. For more information, see NFIP Technical Bulletin 5, *Free-of-Obstruction Requirements for Buildings Located in Coastal High Hazard Areas* (08/08).

Crawlspace: Crawlspace foundations are prohibited in V Zones and are not recommended for A Zone construction in coastal areas. They are susceptible to erosion when the footing depth is inadequate to prevent undermining. Crawlspace walls are also vulnerable to wave forces. Where used, crawlspace foundations must be equipped with flood openings; grade elevations should be such that water is not trapped in the crawlspace (see Fact Sheets Nos. 3.5, *Foundation Walls* and 8.1, *Enclosures and Breakaway Walls*).

Figure 2. Performance comparison of pier foundations. Piers on discrete footings (foreground) failed by rotating and overturning while piers on more substantial footings (in this case a concrete mat) survived (Pass Christian, Mississippi)

Stemwall: Stemwall foundations are similar to crawlspace foundations in construction, but the interior space that would otherwise form the crawlspace is often backfilled with structural fill or sand that supports a floor slab. Stemwall foundations have been observed to perform better during storms than many crawlspace and pier foundations. Although the IRC allows for heights of up to six feet, it is usually more economical and a better design choice to use another foundation system if stemwalls are over a few feet in height. During periods of high water backfill, soils may become flooded and cause damage to the slab. The designer should ensure that this does not cause consolidation of the backfill. In addition, in some soils such as sand, capillary action can cause water and moisture to affect the slab. Flood openings are not required in a backfilled stemwall foundation. Stemwall foundations are prohibited in V Zones but are recommended in A Zone areas subject to limited wave action, as long as embedment of the wall is sufficient to resist erosion and scour (see FEMA 549, *Hurricane Katrina in the Gulf Coast*).

Solid Foundation Walls: The NFIP prohibits solid foundation walls in V Zones and are not recommended for A Zone areas subject to breaking waves or other large flood forces—the walls act as an obstruction to flood flow. Like crawlspace walls, they are susceptible to erosion when the footing depth is inadequate to prevent undermining. Solid walls have been used in some regions to elevate buildings one story in height. Where used, the walls must allow floodwaters to pass between or through the walls (using flood openings). (See Fact Sheets Nos. 3.5, *Foundation Walls* and 8.1, *Enclosures and Breakaway Walls*.)

Pier (column): Pier foundations are recommended for A Zone areas where erosion potential and flood forces are small. This open foundation is commonly constructed with reinforced and grouted masonry units atop a concrete footing. Shallow pier foundations are extremely vulnerable to erosion and overturning if the footing depth and size are inadequate. They are also vulnerable to breakage. Fact Sheet No. 3.4, *Reinforced Masonry Pier Construction*, provides guidance on how to determine whether pier foundations are appropriate, and how to design and construct them.

Foundations for High-Elevation Coastal Areas

Foundation design is problematic in bluff areas that are vulnerable to coastal erosion but outside mapped flood hazard areas. Although NFIP requirements may not apply, the threat of undermining is not diminished.

Moreover, both shallow and deep foundations will fail in such situations. Long-term solutions to the problem may involve better siting (see Fact Sheet No. 2.2, *Selecting a Lot and Siting the Building*), moving the building when it is threatened, or (where permitted and economically feasible) controlling erosion through slope stabilization and structural protection. Additionally FEMA 232, *Homebuilders' Guide to Earthquake Resistant Design and Construction*, provides information on foundation anchorage for hillside structures.

Foundations in V Zones with Ground Elevations Above the BFE

In some instances, coastal areas will be mapped on an NFIP Digital Flood Insurance Rate Map (DFIRM) as Zone V, but will have dunes or bluffs with ground elevations above the BFE shown on the DFIRM. During a design flood event, erosion of the bluffs and high dunes can be expected at these areas as well as waves and inundation. Therefore, the ground level can be expected to be lowered to a point that wave forces and loss of soil are a critical factor. The foundations for structures in these V Zone areas with high ground elevation are the same as V Zone areas with lower ground elevations. Deeply embedded pile or column foundations are still required in these areas, and solid or shallow foundations are still prohibited. The presence of a V Zone designation in these instances indicates that the dune or bluff is expected to erode during the base flood event and that V Zone wave conditions are expected after the erosion occurs. The presence of ground elevations above the BFE in a V Zone should not be taken to mean that the area is free from base flood and erosion effects.

Additional Resources

FEMA 550, *Recommended Residential Construction for the Gulf Coast: Building on Strong and Safe Foundations* (July 2006). (http://www.fema.gov/library/viewRecord.do?id=1853)

FEMA 549, *Hurricane Katrina in the Gulf Coast* (July 2006). (http://www.fema.gov/library/viewRecord.do?id=1857)

FEMA, NFIP Technical Bulletin 5, *Free-of-Obstruction Requirements for Buildings Located in Coastal High Hazard Areas*, FIA-TB-5, Washington, DC, August 2008. (http://www.fema.gov/library/viewRecord.do?id=1718)

FEMA 232, *Homebuilders' Guide to Earthquake Resistant Design and Construction*, Washington, DC, February 2001 (http://www.fema.gov/library/viewRecord.do?id=2103)

American Society of Civil Engineers (ASCE/SEI) Standard 7-10: *Minimum Design Loads for Buildings and Other Structures*, ASCE 7-10, (http://www.asce.org)

American Society of Civil Engineers (ASCE). *Flood Resistant Design and Construction*, ASCE/SEI 24-05. (http://www.asce.org)

FOUNDATIONS 3

Developed in association with the National Association of Home Builders Research Center

Pile Design and Installation

Purpose: *To provide basic information about pile design and installation.*

Key Factors

- Use a pile type that is appropriate for local conditions.
- Piles should resist coastal hazards such as high winds and flood loads in addition to withstanding erosion and scour. Erosion being the widespread loss of soil and scour being a localized loss of soil around a building or foundation element due to turbulent water movement.
- Have a registered engineer design piles for adequate layout, size, and length.
- Use installation methods that are appropriate for the conditions.
- Brace piles properly during construction.
- Make accurate field cuts, and treat all cuts and drilled holes to prevent decay.
- Have all pile-to-beam connections engineered, and use corrosion-resistant hardware (see Fact Sheet No. 1.7, C*oastal Building Materials*).

Pile Types

The most common pile types used are preservative treated wood, concrete, and steel. Contractors doing construction in coastal areas typically select preservative treated wood piles for pile foundations. They can be square or round in cross section. Wood piles are easily cut and adjusted in the field. Concrete and steel can also be used but are less common in residential construction. Concrete piles—may be an appropriate choice depending upon the pile capacity requirements and elevation needed by the design—are available in longer lengths and are usually installed by pile driving. Concrete piles tend to have higher strengths and are durable to many factors that are in the coastal environment when properly designed and detailed. Steel piles are rarely used because of potential corrosion problems.

Pile Size and Length

The foundation engineer is the one who determines pile size and length. Specified bearing and penetration requirements must be met. Round piles should have no less than an 8-inch tip diameter; square piles should have a minimum timber size of 8 by 8 inches. The total length of the pile is based on building code requirements [see the 2009 International Building Code (IBC) Section 1810 on deep foundations], calculated penetration requirements, erosion and scour potential, Design Flood Elevation (DFE), and allowance for cut-off and beam width (see Figure 1 and Table 1, which is an example of foundation design results). Substantial improvement in foundation performance can be achieved by increasing the minimum timber size for square piles to 12 by 12 inches or minimum tip diameter for round piles of 12 inches.

FOUNDATIONS 3

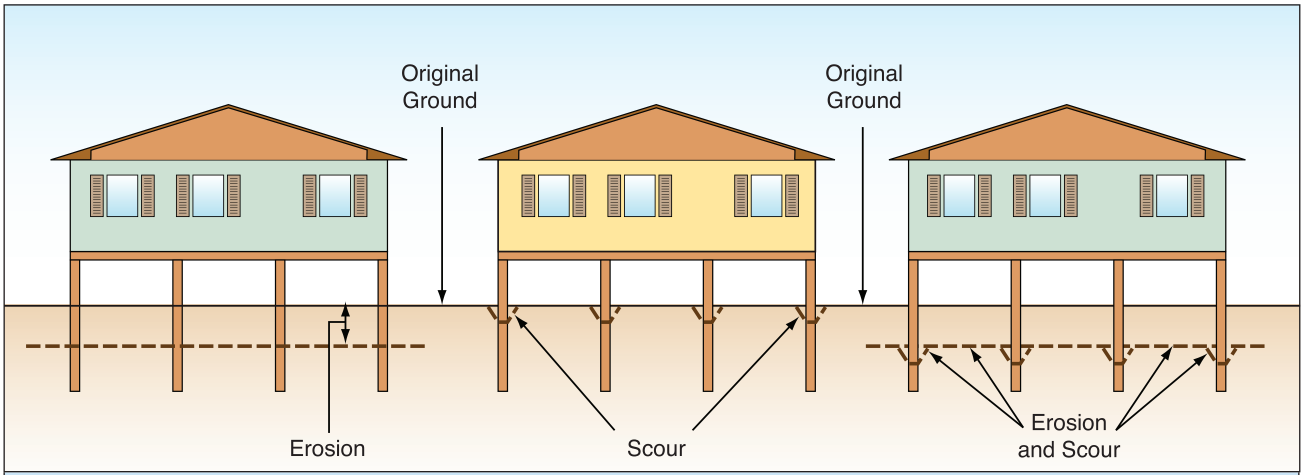


Figure 1. Distinguishing between coastal erosion and scour. A building may be subject to either or both, depending on the building location, soil characteristics, and flood conditions.

Table 1. Example foundation adequacy calculations for a two-story house supported on square timber piles and situated away from the shoreline, storm surge, and broken waves passing under the building, 130-mph basic wind speed per ASCE 7-05 (167-mph equivalent ASCE 7-10 basic wind speed for Risk Category II buildings), soil = medium dense sand. Shaded cells indicate the foundation fails to meet bending (P) and/or embedment (E) requirements.

Pile Embedment Before Erosion and Scour	Erosion and Scour Conditions	Pile Diameter, Ø		
		8 inch	10 inch	12 inch
10 feet	Erosion = 0, Scour = 0	P, E	E	OK
	Erosion = 0, Scour = 2.0Ø	P, E	E	E
	Erosion = 1, Scour = 2.5Ø	P, E	E	E
	Erosion = 1, Scour = 3.0Ø	P, E	E	E
	Erosion = 1, Scour = 4.0Ø	P, E	P, E	E
15 feet	Erosion = 0, Scour = 0	P	OK	OK
	Erosion = 0, Scour = 2.0Ø	P	OK	OK
	Erosion = 1, Scour = 2.5Ø	P	OK	OK
	Erosion = 1, Scour = 3.0Ø	P	OK	OK
	Erosion = 1, Scour = 4.0Ø	P, E	P, E	E
20 feet	Erosion = 0, Scour = 0	P	OK	OK
	Erosion = 0, Scour = 2.0Ø	P	OK	OK
	Erosion = 1, Scour = 2.5Ø	P	OK	OK
	Erosion = 1, Scour = 3.0Ø	P	OK	OK
	Erosion = 1, Scour = 4.0Ø	P	P	OK

Pile Layout

The foundation engineer and designer determine the pile layout together. Accurate placement and correction of misaligned piles is important. The use of a drive template for guiding the pile driving operation greatly increases the accuracy of the pile location and need for difficult remediation. A drive template is a temporary guide structure that is installed in a manner to restrict the lateral movement of the piles during driving. The pile template is reused for each row of piles to assure consistent spacing and alignment. Pile placement should not result in more than 50 percent of the pile cross section being cut for girder or other connections. Verify proper pile locations on drawings before construction and clarify any discrepancies. Layout can be done by a licensed design professional or surveyor, a construction surveyor, the foundation contractor, or the builder. The layout process must always include establishing an elevation for the finished first floor. Construction of the first-floor platform should not begin until this elevation is established (see Fact Sheet No. 1.4, *Lowest Floor Elevation*).

Installation Methods

Piles can be driven, augered, or jetted into place. The installation method will vary with soil conditions, bearing requirements, equipment available, and local practice. One common method is to initially jet the pile to a few feet short of required penetration, then complete the installation by driving with a drop hammer. Driving the pile even a few feet helps assure the pile is achieving some end-bearing capacity and some skin friction. Full depth driving where achievable provides for a pile foundation that has several advantages that merit consideration.

Pile Bracing

The engineer determines pile bracing layout. Common bracing methods include knee and diagonal bracing. Knee bracing is an effective method of improving the performance of a pile system without creating an obstruction to the flow of water and debris from a design event. Because slender bracing is susceptible to buckling, slender bracing should be considered as tension only. Bracing can become an obstruction, however, and increase a foundations exposure to wave and debris impact. Bracing is often oriented perpendicular to the shoreline so that it is not struck broadside by waves, debris, and velocity flow (see Figure 2). Temporary bracing or jacking to align piles and hold true during construction is the responsibility of the contractor.

It is recommended that pile bracing be used only for reducing the structure's sway and vibration for comfort. In other words, bracing should be used to address serviceability issues and not strength issues. The foundation design should consider the piles as being un-braced as the condition that may occur when floating debris removes or damages the bracing. If the pile foundation is not able to provide

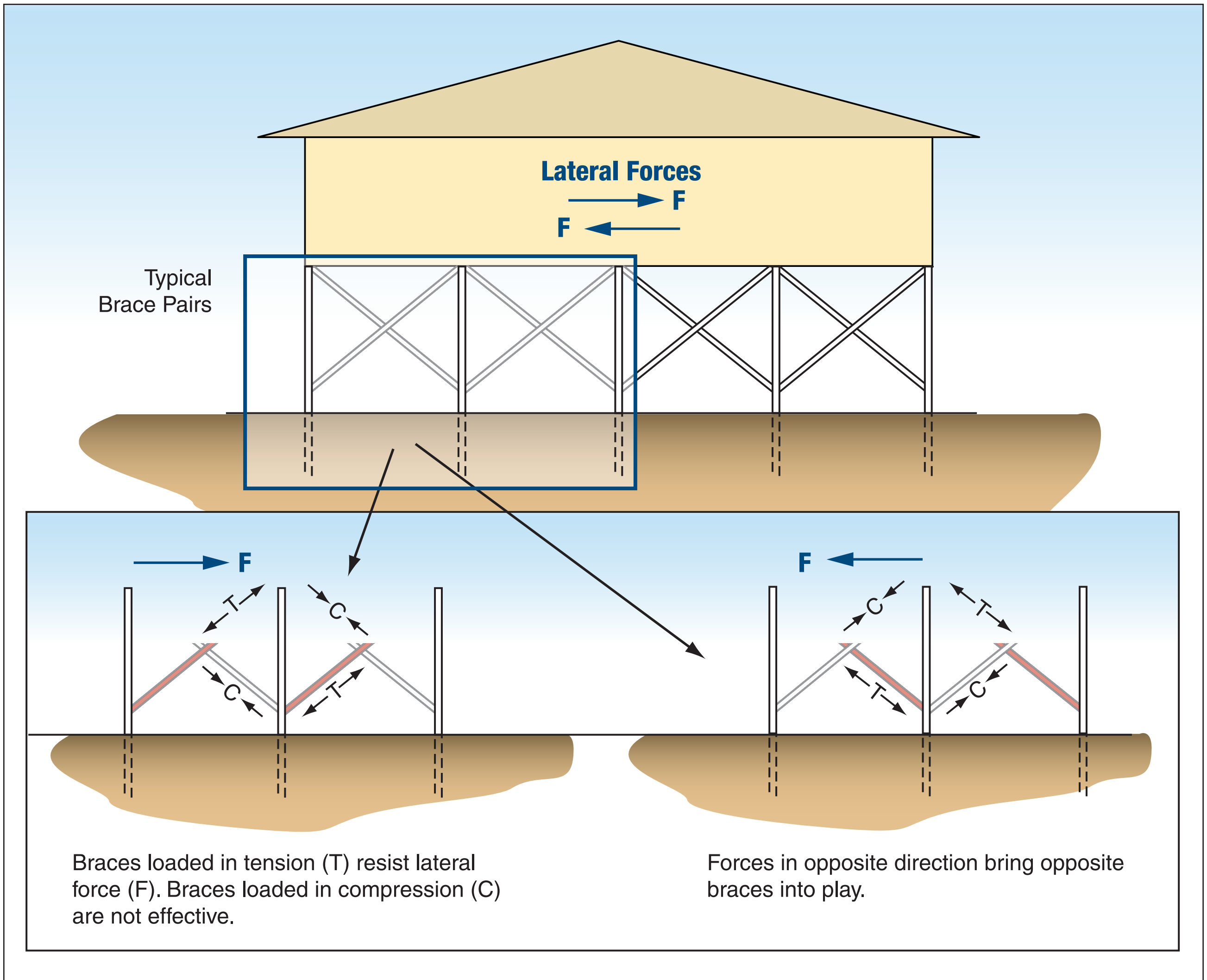


Figure 2. Diagonal bracing schematic.

the desired strength performance without bracing then the designer should consider increasing the pile size. Pile bracing should only be for comfort of the occupants, but not for stability of the home.

Field Cutting and Drilling

A chain saw is the common tool for making cuts and notches in wood piles. After making cuts, exposed areas should be field-treated with the proper wood preservative to prevent decay. This involves applying the preservative with a brush to the cut or drilled holes in the pile until no more fluid is drawn into the wood.

Connections

The connection of the pile to the structural members is one of the most critical connections in the structure. Always follow design specifications and use corrosion-resistant hardware. Strict attention to detail and good construction practices are critical for successful performance of the foundation (see Fact Sheet Nos. 1.7, *Coastal Building Materials*, and 3.3, *Wood-Pile-to-Beam Connections*).

Verification of Pile Capacity

Generally, pile capacity for residential construction is not verified in the field. If a specified minimum pile penetration is provided, bearing is assumed to be acceptable for the local soil conditions. Subsurface soil conditions can vary from the typical assumed conditions, so verification of pile capacity is prudent, particularly for expensive coastal homes. Various methods are available for predicting pile capacity. Consult a local foundation engineer for the most appropriate method for the site.

Additional Resources

American Concrete Institute (ACI), 543R-00: *Design, Manufacture, and Installation of Concrete Piles* (Reapproved 2005), (http://www.concrete.org)

American Forest and Paper Association (AF&PA). *National Design Specification for Wood Construction*. (http://www.afandpa.org)

American Society for Testing and Materials (ASTM). *Standard Specification for Round Timber Piles*, ASTM D25. (http://www.astm.org)

American Wood-Preservers Association (AWPA). *All Timber Products – Preservative Treatment by Pressure Processes, AWPA C1-00; Lumber, Timber, Bridge Ties and Mine Ties – Preservative Treatment by Pressure Processes, AWPA C2-01; Piles – Preservative Treatment by Pressure Process*, AWPA C3-99; and others. (http://www.awpa.com)

Pile Buck, Inc. *Coastal Construction*. (http://www.pilebuck.com)

Southern Pine Council (SPC) (http://www.southernpine.com/about.shtml)

Timber Pile Council, American Wood Preservers Institute, *Timber Pile Design and Construction Manual*, (http://www.wwpinstitute.org/pdffiles/TimberPileManual.pdf)

Developed in association with the National Association of Home Builders Research Center

Wood Pile-to-Beam Connections

Purpose: *To illustrate typical wood pile-to-beam connections, provide basic construction guidelines on various connection methods, and show pile bracing connection techniques.*

Key Issues

- Verify pile alignment and correct, if necessary, before making connections.
- Carefully cut piles to ensure required scarf depths.
- Limit cuts to no more than 50 percent of pile cross section.
- Use corrosion-resistant connectors and fasteners such as those fabricated from stainless steel, or connectors and fasteners with corrosion protection such as provided by hot-dip galvanized coating (see Fact Sheet No. 1.7, *Coastal Building Materials*).
- Accurately locate and drill bolt holes.
- Field-treat all cuts and holes to prevent decay.
- Use sufficient pile and beam sizes to allow proper bolt edge distances.

Built-up beams should be designed as continuous members and not be broken over the piles. Some homebuilders are using engineered wood products, such as glued laminated timber and parallel strand lumber, which can span longer distances without splices. The ability to span longer distances without splices eases installation and reduces fabrication costs.

Pile-to-beam connections must:

1. Provide required ***bearing*** area for beam to rest on pile.
2. Provide required ***uplift*** (tension) resistance.
3. Maintain beam in an ***upright*** position.
4. Be capable of resisting ***lateral*** loads (wind and seismic).
5. Be constructed with ***durable*** connectors and fasteners from corrosion-resistant materials or with corrosion protection in accordance with minimum requirements of the International Residential Code. The level of corrosion protection that can be expected will vary depending on the type of wood treatment and fastener type. Make sure the fastener is compatible with the wood variety selected for construction.

Note: Pile-to-beam connections must be designed by an engineer.

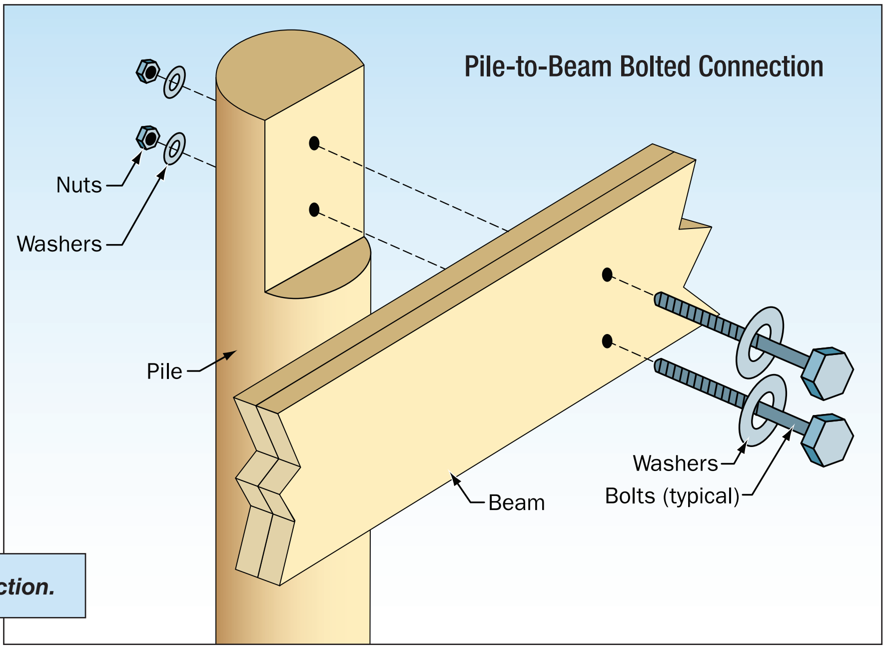
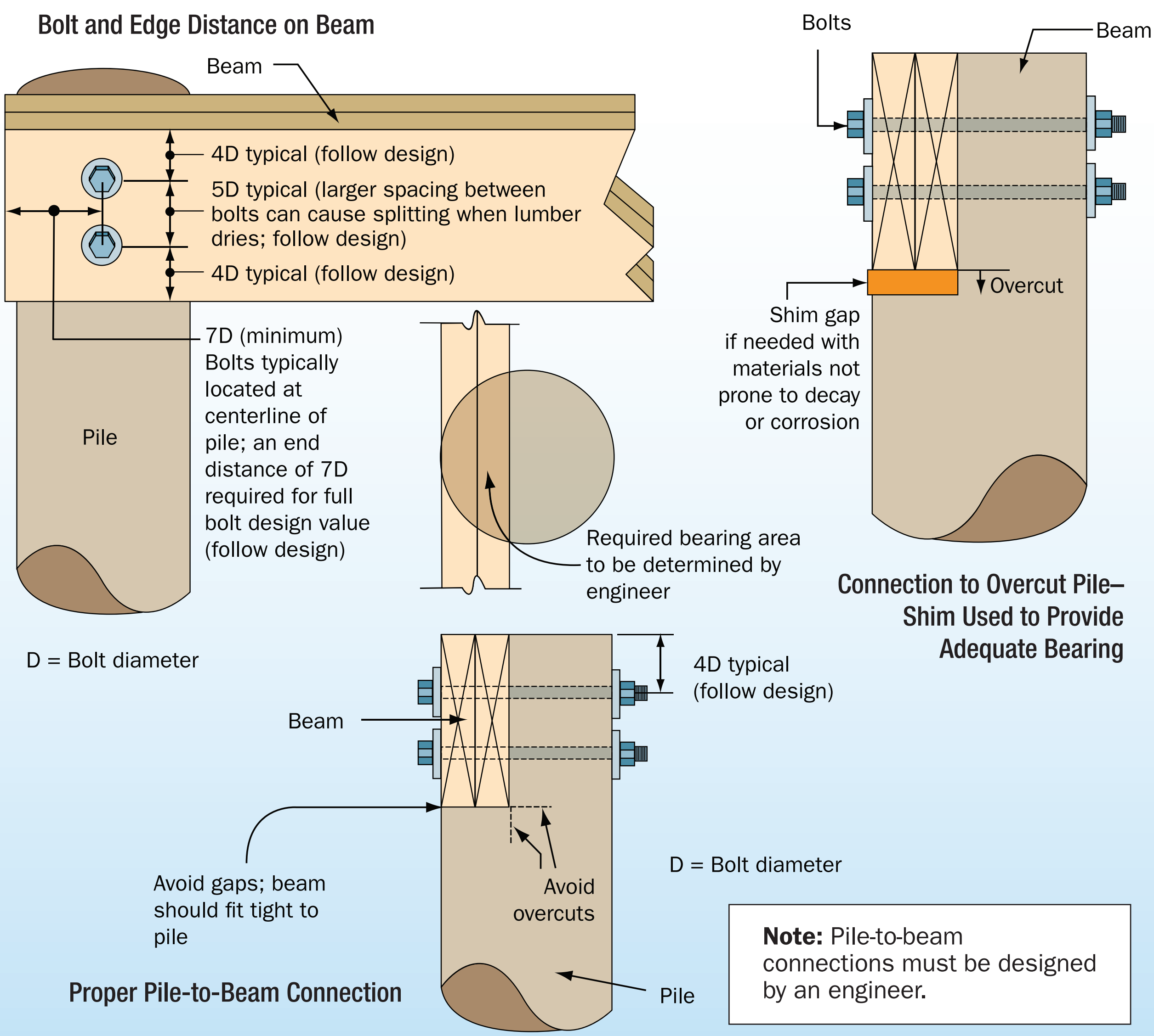


Figure 1. Pile-to-beam bolted connection.

Figure 2. Proper pile-to-beam bolted connection.



Note: Pile-to-beam connections must be designed by an engineer.

Problem: misaligned piles—some piles are shifted in or out from their intended (design) locations.

There are five possible solutions to fix the problem. (See figure 3 and details in figure 4):

Option 1 – beam cannot be shifted.

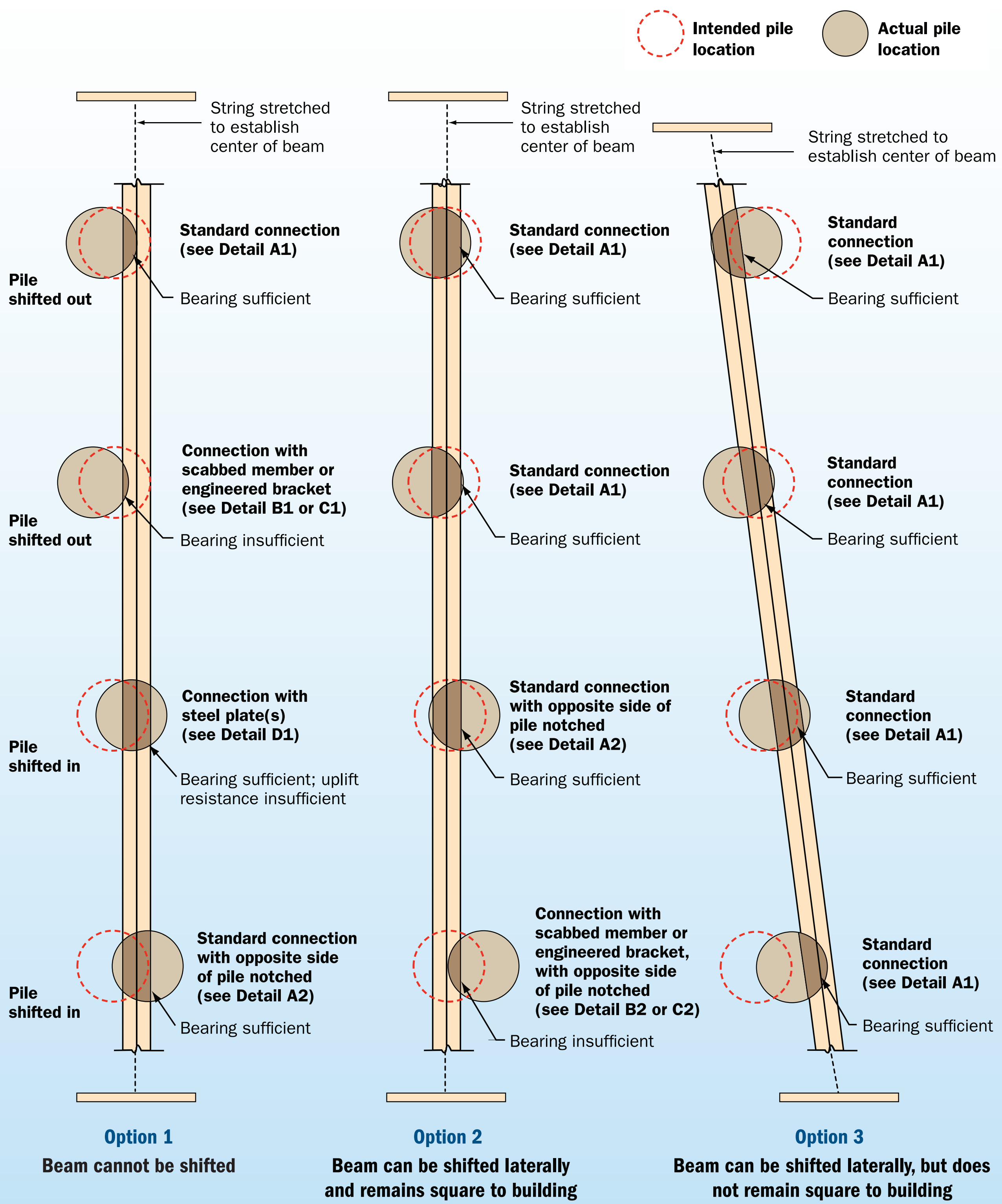
Option 2 – beam can be shifted laterally and remains square to building.

Option 3 – beam can be shifted laterally, but does not remain square to building.

Option 4 (not shown) – beam cannot be shifted, and connections shown in this fact sheet cannot be made; install and connect sister piles; an engineer must be consulted for this option.

Option 5 (not shown) – beam cannot be shifted, and connections shown in this fact sheet cannot be made; remove and reinstall piles, as necessary.

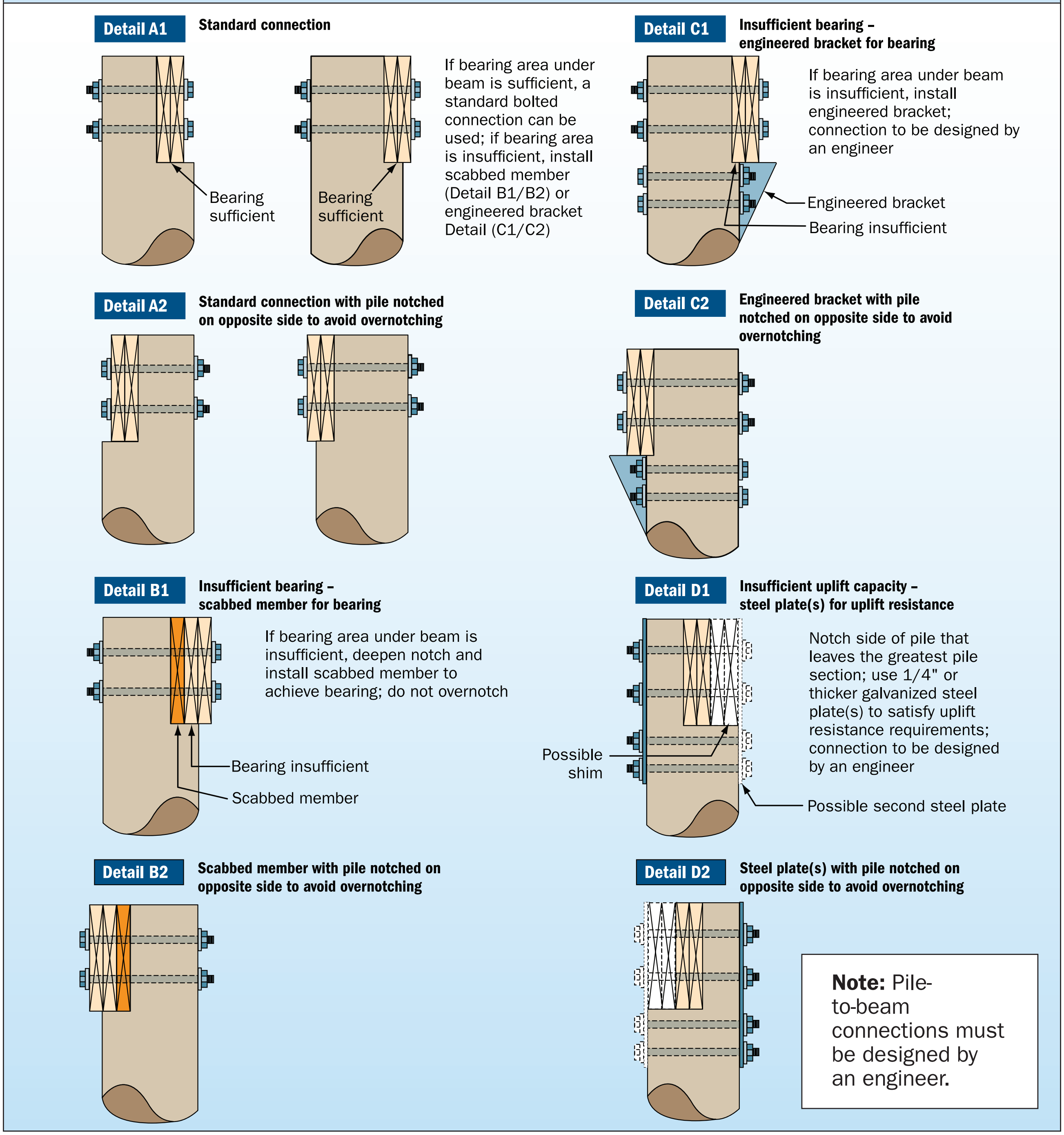
Figure 3. Connection of misaligned pile.



Note: Pile-to-beam connections must be designed by an engineer.

FOUNDATIONS 3

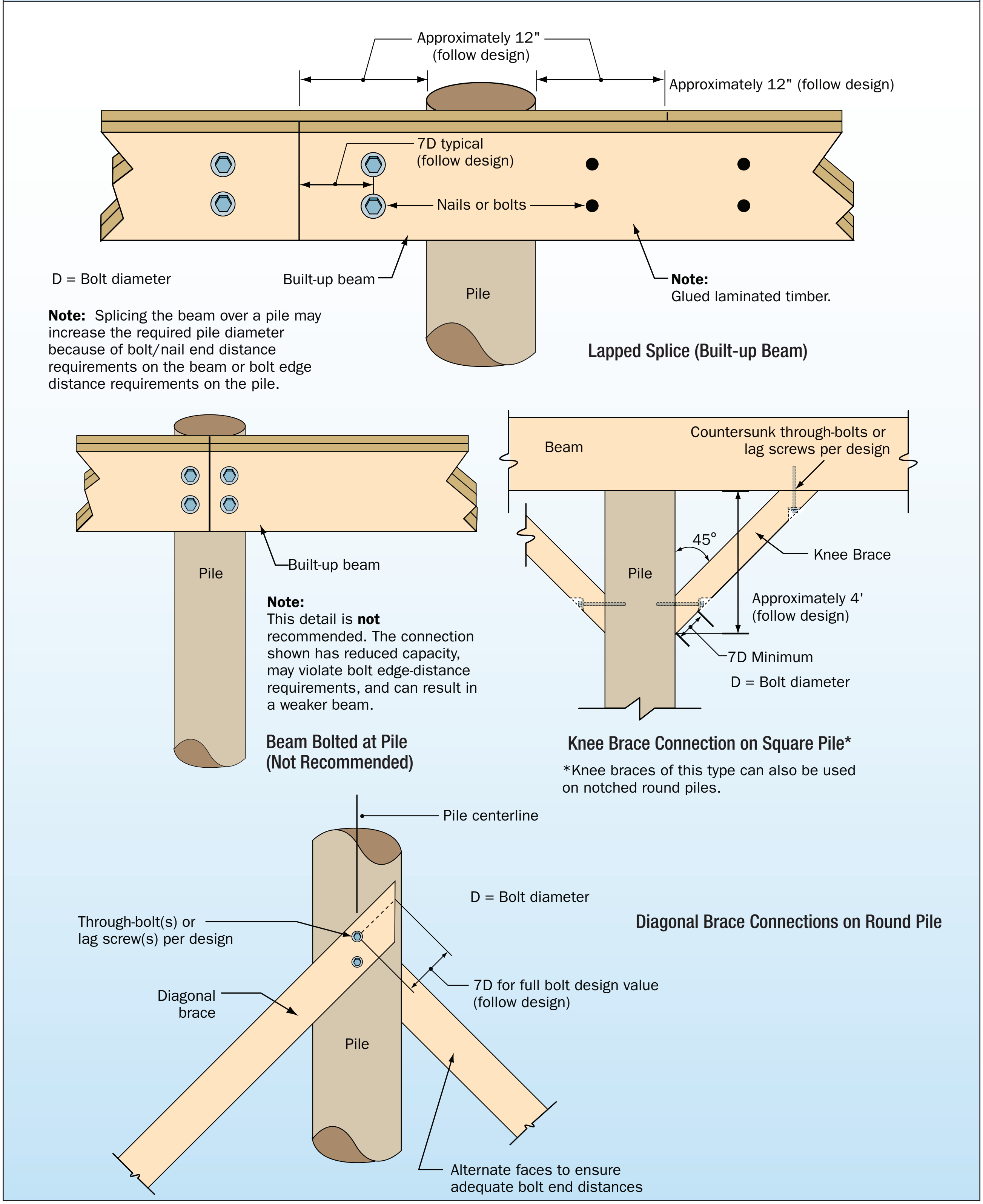
Figure 4. Connection details for misaligned piles.



Connections to misaligned piles (see drawings on figure 3 and details above)

1. The ability to construct the pile-to-beam connections designed by the engineer is directly dependent upon the accuracy of pile installation and alignment.
2. Misaligned piles will require the contractor to modify pile-to-beam connections in the field.
3. Badly misaligned piles will require removal and reinstallation, sister piles, or special connections, all to be determined by the engineer.

Figure 5. Built-up beam connections, knee brace connections, and diagonal brace connections.



Note: Pile-to-beam connections must be designed by an engineer.

Additional Resources

American Wood Council (AWC) (http://www.awc.org)

American Institute of Timber Construction (AITC) (http://www.aitc-glulam.org)

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Reinforced Masonry Pier Construction

Purpose: *To provide an alternative to piles in V Zones and A Zones in coastal areas where soil properties and other site conditions indicate that piers are an acceptable alternative to the usually recommended pile foundation. Examples of appropriate conditions for the use of piers are where rock is at or near the surface or where the potential for erosion and scour is low.*

Key Issues

- The footing must be designed for the soil conditions present. Pier foundations are generally not recommended in V Zones or in A Zones in coastal areas.
- The connection between the pier and its footing must be properly designed and constructed to resist separation of the pier from the footing and overturning due to lateral (flood, wind, debris) forces.
- The top of the footing must be below the anticipated erosion and scour depth.
- The piers must be reinforced with steel and fully grouted.
- The connection to the floor beam at the top of the pier must be through use of properly sized and detailed metal connectors.
- Special attention must be given to the application of mortar and the tooling of all the joints in order to help resist water intrusion into the pier core, where the steel can be corroded.
- Special attention must be given to corrosion protection of joint reinforcement, accessories, anchors, and reinforcement bars. Joint reinforcement that is exposed to weather or the earth shall be stainless steel, hot dipped galvanized, or epoxy coated. Wall ties, plates, bars, anchors, and inserts exposed to earth or weather shall also be stainless steel, hot dipped galvanized, or epoxy coated. Reinforcement bars shall be protected by proper use of masonry cover.

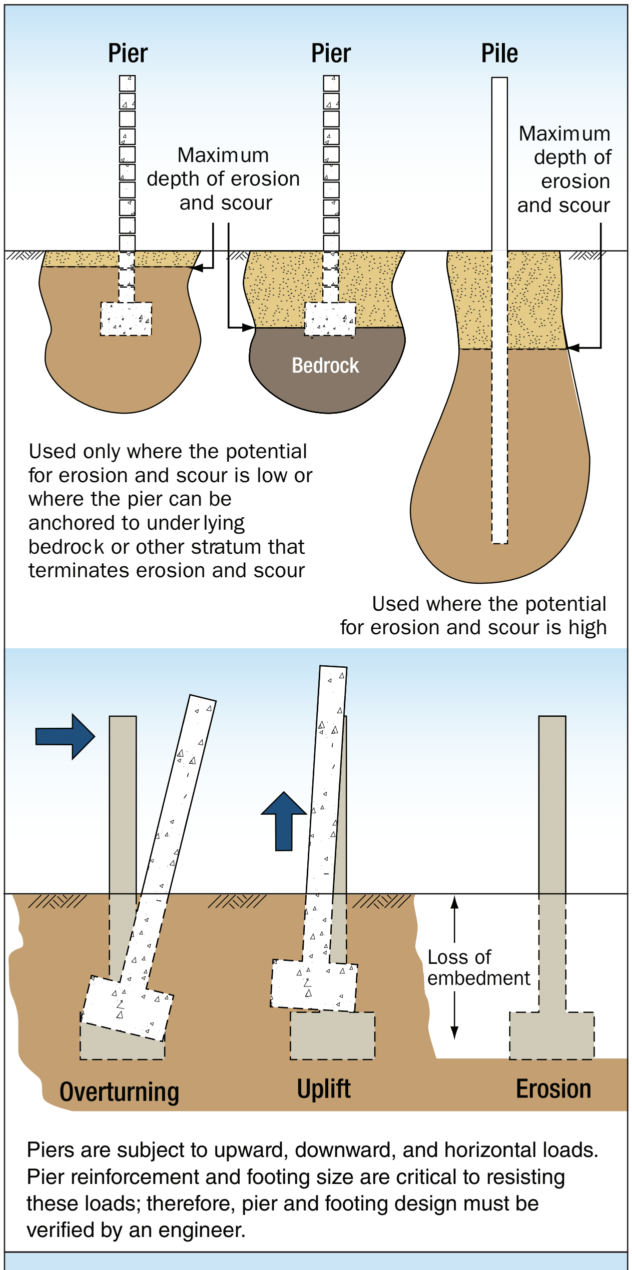

Figure 1. In coastal areas, masonry pier foundations are not recommended in V Zones with erodible soils, or in A Zones subject to waves and erosion — use pile foundations in these areas.

FOUNDATIONS 3

Piers vs. Piles

Pier foundations are most appropriate in areas where:

- Erosion and scour potential are low.
- Flood depths and lateral forces are low.
- Soil can help resist overturning of pier.

The combination of high winds and moist (sometimes salt-laden) air can have a damaging effect on masonry construction by forcing moisture into even the smallest of cracks or openings in the masonry joints. The entry of moisture into reinforced masonry construction can lead to corrosion of the steel reinforcement bars and subsequent cracking and spalling of the masonry. Moisture resistance is highly influenced by the quality of the materials and the quality of the masonry construction at the site.

Figure 2. Pier breakage (Long Beach, Mississippi)

Good Masonry Practice

If a masonry pier is determined to be an appropriate foundation for a building, there are some practices that should be followed during construction of the piers.

- Masonry units and packaged mortar and grout materials should be stored off the ground and covered.
- Masonry work in progress must be well protected from exposure to weather.
- Mortar and grouts must be carefully batched and mixed. The 2009 International Building Code (IBC 2009) and 2009 International Residential Code (IRC) specify grout proportions by volume for masonry construction.
- Connectors should be selected that are appropriate for masonry to wood connection. It is important to maintain a sufficient load path from the building into the ground. The connectors and fasteners should be a corrosion-resistant material or have corrosion protection at least equivalent to that provided by coatings in accordance with the 2009 IRC. Connectors should be properly embedded or attached to the pier. Wood in contact with masonry pier should be naturally durable or preservative-treated. Figure 3 illustrates the importance of maintaining a proper load path between the pier and the building's beams.
- Properly sized steel reinforcing bars should be installed throughout the masonry piers. Piers should be fully grouted and steel reinforcing bars should not be left exposed to weather for excessive amounts of time prior to installation. Lap splices should be properly located and of sufficient length to meet the standard masonry industry details and requirements to sufficiently carry the loads imposed on the structure.
- Consider incorporating grade beams into the foundation in order to achieve greater structural stability in the pier system.
- If the design of the pier system or any details are unclear, contact a structural engineer or appropriate design professional to clarify the foundation details.

Pros and Cons of Grade Beams

Grade beams are horizontal structural members cast against the ground or "grade." Grade beams can be a useful foundation method in areas with limited potential for erosion and scour. The type of force resisted by grade beams varies by application, but can range from continuous vertical and horizontal loads to axial loads. The grade beams used in this example are used primarily for axial loads generated by stability demands of the piers. The grade beams should be placed below the elevation of anticipated eroded grade so that there is no effect on scour and erosion of the supporting soils.

The pros of using grade beams with pier foundations are that they:

- Provide vertical and lateral support.
- Are less prone to rotation and overturning.
- Transfer loads imposed on the elevated home and foundation to the ground below.

Some cons of using grade beams with pier foundations are that they:

- Are susceptible to erosion and scour if too shallow
- Can become obstructions during flood events and can increase scour

Are grade beams allowed in the V Zone?

Yes, although the NFIP states that the ***lowest horizontal structural member*** is to be constructed above the BFE, it is referring to the ***lowest horizontal structural member*** above ***erodible*** grade. Based on this, both grade beams, cross bracing and knee bracing are allowed by the NFIP. Grade beams can provide significant structural support to an open foundation system provided they are placed ***below the expected eroded surface***.

Figure 3. Failure of pier-to-beam connections due to wave and flood forces acting on the elevated building (Long Beach, Mississippi)

Additional Resources

American Concrete Institute, 2004, SP-66(04): *ACI Detailing Manual*. (http://www.concrete.org)

Concrete Reinforcing Steel Institute. *Placing Reinforcing Bars – Recommended Practices*, PRB-2-99. (http://www.crsi.org)

International Code Council. *International Building Code.* 2009. (http://www.iccsafe.org)

International Code Council. *International Residential Code.* 2009. (http://www.iccsafe.org)

The Masonry Society. 2008. *Building Code Requirements for Masonry Structures*.
TMS 402-08/ACI 530-08/ASCE 5-08. (http://www.masonrysociety.org)

The Masonry Society. 2008. *Specifications for Masonry Structures*.
TMS 402-08/ACI 530.1 08/ASCE 6-08. (http://www.masonrysociety.org)

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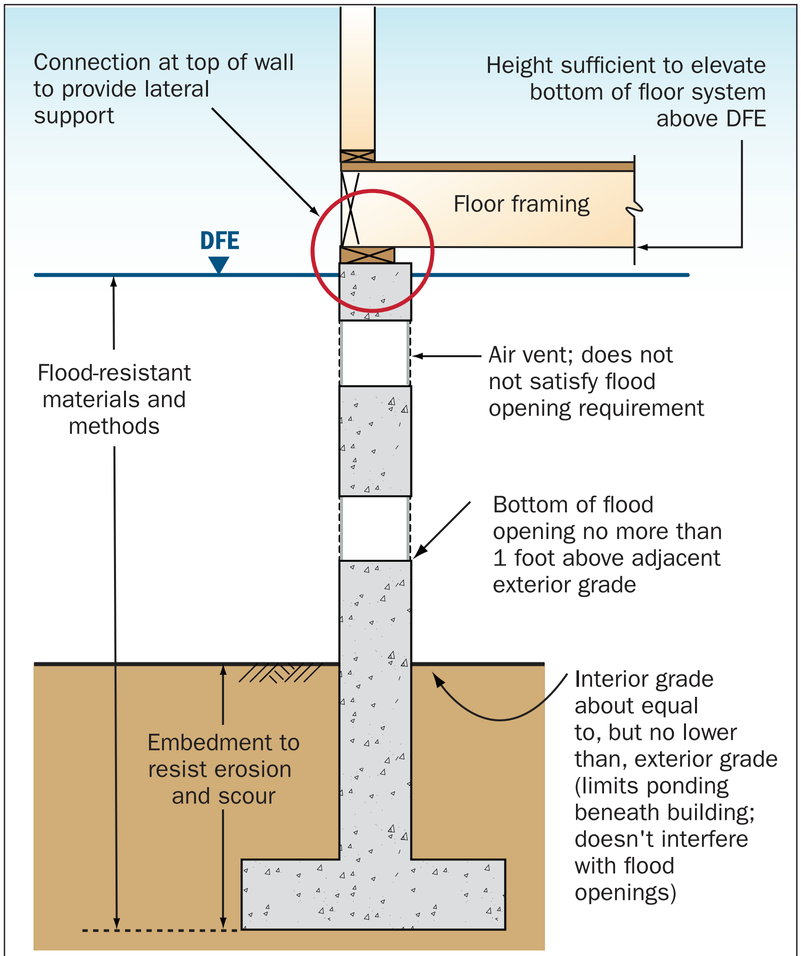
Foundation Walls

Purpose: *To discuss the use of foundation walls in coastal buildings.*

Key Issues

- Foundation walls include stemwalls, cripple walls, and other solid walls.
- Foundation walls are prohibited by the National Flood Insurance Program (NFIP) in Zone V.*
- Use of foundation walls in Zone A in coastal areas should be limited to locations where only shallow flooding occurs, and where the potential for erosion and breaking waves is low.
- Where foundation walls are used, flood-resistant design of foundation walls must consider embedment, height, materials and workmanship, lateral support at the top of the wall, flood openings and ventilation openings, and interior grade elevation.



Foundation walls – flood-resistant design considerations

Foundation Walls – When Are They Appropriate?

Use of foundation walls – such as those in crawlspace and other solid-wall foundations – is potentially troublesome in coastal areas for two reasons: (1) they present an obstruction to breaking waves and fast-moving flood waters, and (2) they are typically constructed on shallow footings, which are vulnerable to erosion. For these reasons, ***their use in coastal areas should be limited to sites subject to shallow flooding, where erosion potential is low and where breaking waves do not occur during the Base Flood***. The NFIP prohibits the use of foundation walls in Zone V*. This *Home Builder's Guide to Coastal Construction* recommends against their use in Zone A in coastal areas. ***Deeply embedded pile or column foundations are recommended*** because they present less of an obstruction to floodwaters and are less vulnerable to erosion.

* Note that the use of shearwalls below the Design Flood Elevation (DFE) may be permitted in limited circumstances (e.g., lateral wind/seismic loads cannot be resisted with a braced, open foundation. In such cases, minimize the length of shearwalls and the degree of obstruction to floodwaters and waves, orient shearwalls parallel to the direction of flow/waves, do not form enclosures). Consult the authority having jurisdiction for guidance concerning shearwalls below the DFE.

FOUNDATIONS 3

Design Considerations for Foundation Walls

The design of foundation walls is covered by building codes and standards (e.g., Standard for Residential Construction in High-Wind Regions, ICC 600-2008, by the International Code Council). For flood design purposes, there are six additional design considerations: (1) embedment, (2) height, (3) materials and workmanship, (4) lateral support at the top of the wall, (5) flood openings and ventilation openings, and (6) interior grade elevation.

Embedment – The top of the footing should be no higher than the anticipated depth of erosion and scour (this basic requirement is the same as that for piers; see figure at right and Fact Sheet No. 3.4). If the required embedment cannot be achieved without extensive excavation, consider a pile foundation instead.

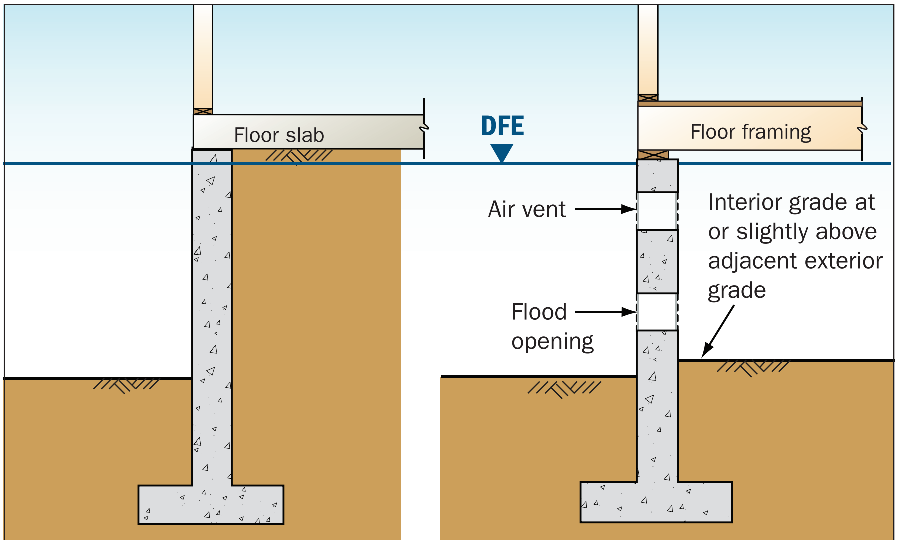
Height – The wall should be high enough to elevate the bottom of the floor system to or above the DFE (see Fact Sheet No. 1.4).

Materials and Workmanship – Foundation walls can be constructed from many materials, but masonry, concrete, and wood are the most common. Each material can be specified and used in a manner to resist damage due to moisture and inundation (see Fact Sheet No. 1.7). Workmanship for flood-resistant foundations is crucial. Wood should be preservative-treated for foundation or marine use (aboveground or ground-contact treatment will not be sufficient). Cuts and holes should be field-treated. Masonry should be reinforced and fully grouted (see Fact Sheet No. 4.2 for masonry details). Concrete should be reinforced and composed of a high-strength, low water-to-cement ratio mix.

Lateral Support at the Top of the Wall – Foundation walls must be designed and constructed to withstand all flood, wind, and seismic forces, as well as any unbalanced soil/hydrostatic loads. The walls will typically require lateral support from the floor system and diaphragm, and connections to the top of the walls must be detailed properly. Cripple walls, where used, should be firmly attached and braced.

Flood Openings and Ventilation Openings – Any area below the DFE enclosed by foundation walls must be equipped with openings capable of automatically equalizing the water levels inside and outside the enclosure. Specific flood opening requirements are included in Fact Sheet No. 8.1. Flood openings are not required for backfilled stemwall foundations supporting a slab. ***Air ventilation openings required by building codes do not generally satisfy the flood opening requirement***; the air vents are typically installed near the top of the wall, the flood vents must be installed near the bottom, and opening areas for air flow may be insufficient for flood flow.

Interior Grade Elevation – Conventional practice for crawlspace construction calls for excavation of the crawlspace and use of the excavated soil to promote drainage away from the structure (see left-hand figure on page 3). This approach may be acceptable for non-floodplain areas, but in floodplains, this practice can result in increased lateral loads (e.g., from saturated soil) against the foundation walls and ponding in the crawlspace area. If the interior grade of the crawlspace is below the DFE, NFIP requirements can be met by ensuring that the interior grade is at or above the lowest exterior grade adjacent to the building (see right-hand figure on page 3). When floodwaters recede, the flood openings in the foundation walls allow floodwaters to automatically exit the crawlspace. FEMA may accept a crawlspace elevation up to 2 feet below the lowest adjacent exterior grade; however, the community must adopt specific requirements in order for this type of crawlspace to be constructed in a floodplain.



Floor slab atop backfilled stemwall foundation

Floor joist system and crawlspace

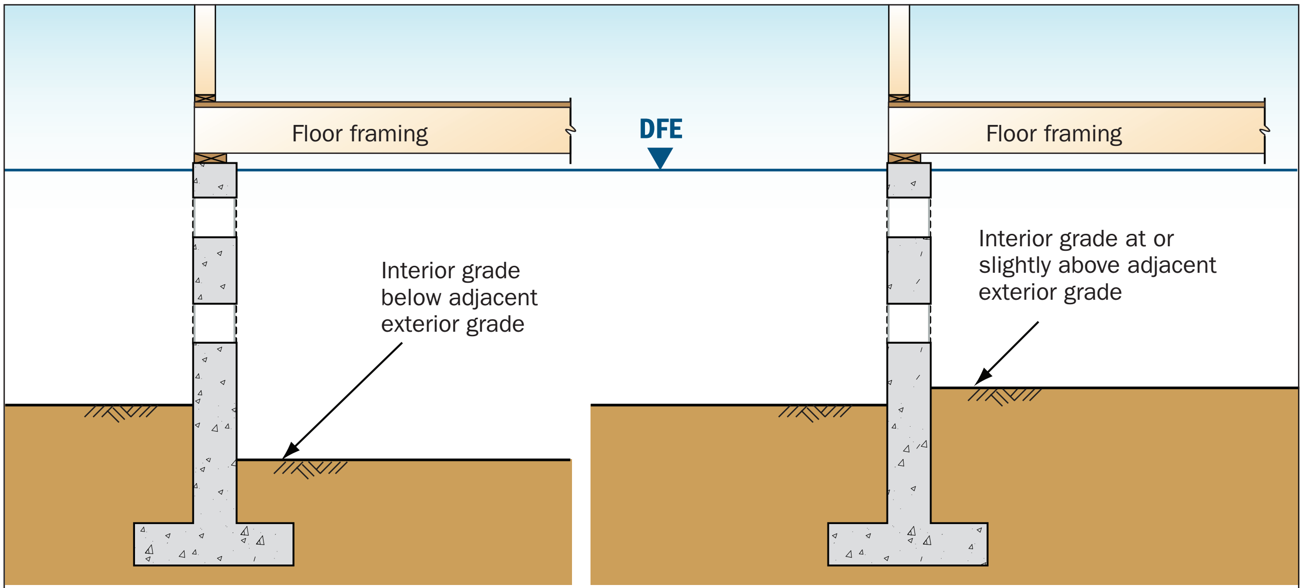
If a stemwall and floor slab system is used, the interior space beneath the slab should be backfilled with compacted gravel (or such materials as required by the building code). As long as the system can act monolithically, it will resist most flood forces. However, if the backfill settles or washes out, the slab will collapse and the wall will lose lateral support.

Additional Resources

FEMA. NFIP Technical Bulletin 1-08, *Openings in Foundation Walls and Walls of Enclosures.* 2008. (http://www.fema.gov/plan/prevent/floodplain/techbul.shtm)

FEMA. NFIP Technical Bulletin 11-01, C*rawlspace Construction.* 2001. (http://www.fema.gov/plan/prevent/floodplain/techbul.shtm)

FEMA. *Recommended Residential Construction for the Gulf Coast, Building on Strong and Safe Foundations.* FEMA 550. 2010. (http://www.fema.gov/library)



Crawlspace construction: Interior grade elevation for Zone A not subject to breaking waves and erosion

FOUNDATIONS 3

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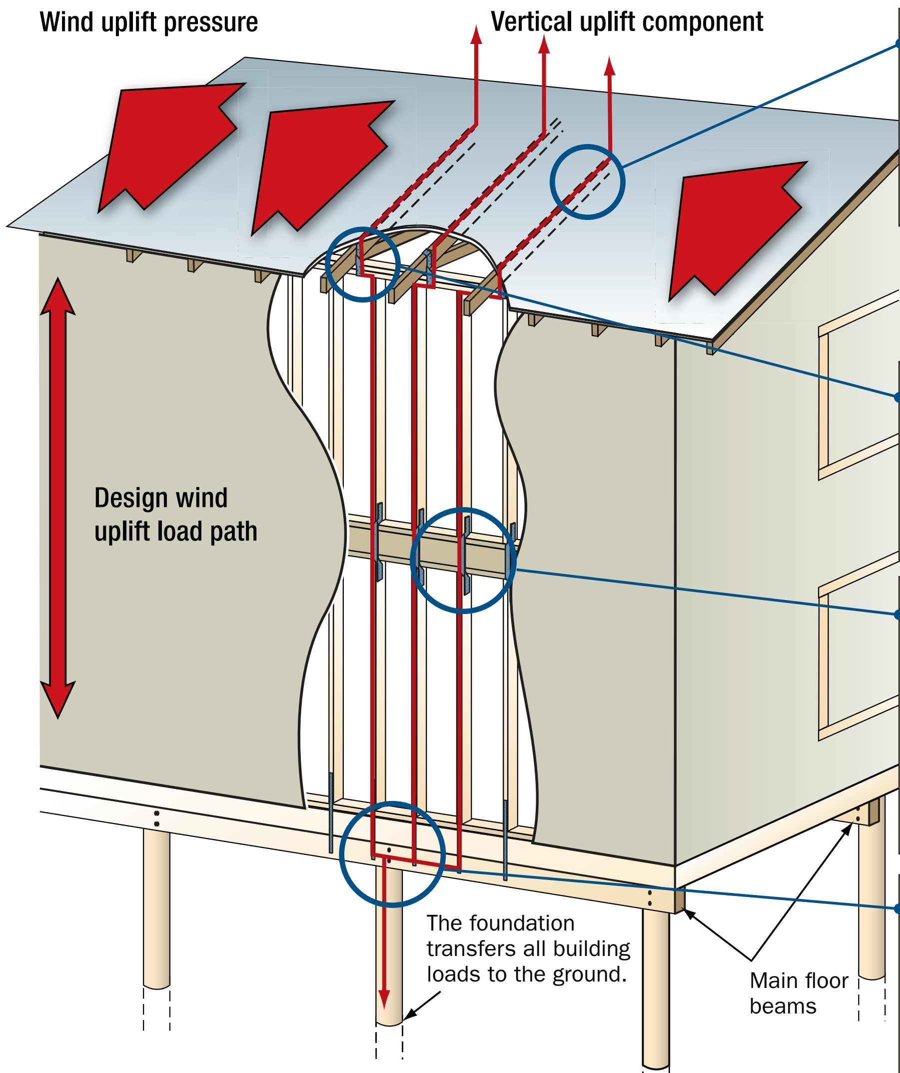
Load Paths

Purpose: *To illustrate the concept of load paths and highlight important connections in a wind uplift load path.*

Key Issues

- Loads acting on a building follow many paths through the building and must eventually be resisted by the ground, or the building will fail.
- Loads accumulate as they are routed through key connections in a building.
- Member connections are usually the weak link in a load path.
- Failed or missed connections cause loads to be rerouted through unintended load paths.



Vertical load path from roof to ground on a platform-and-pile-construction building. Note: Load paths will vary depending on construction type and design. Adjacent framing members will receive more load if a connection fails.

LINK 1
High winds lift the roof upward. Roofing fasteners link the roof covering to the sheathing*, and sheathing fasteners link the sheathing to the roof framing members (see Fact Sheet No. 7.1).

* Although not a structural connection, the attachment of the roof covering to the roof sheathing is an essential part of protecting the building envelope.

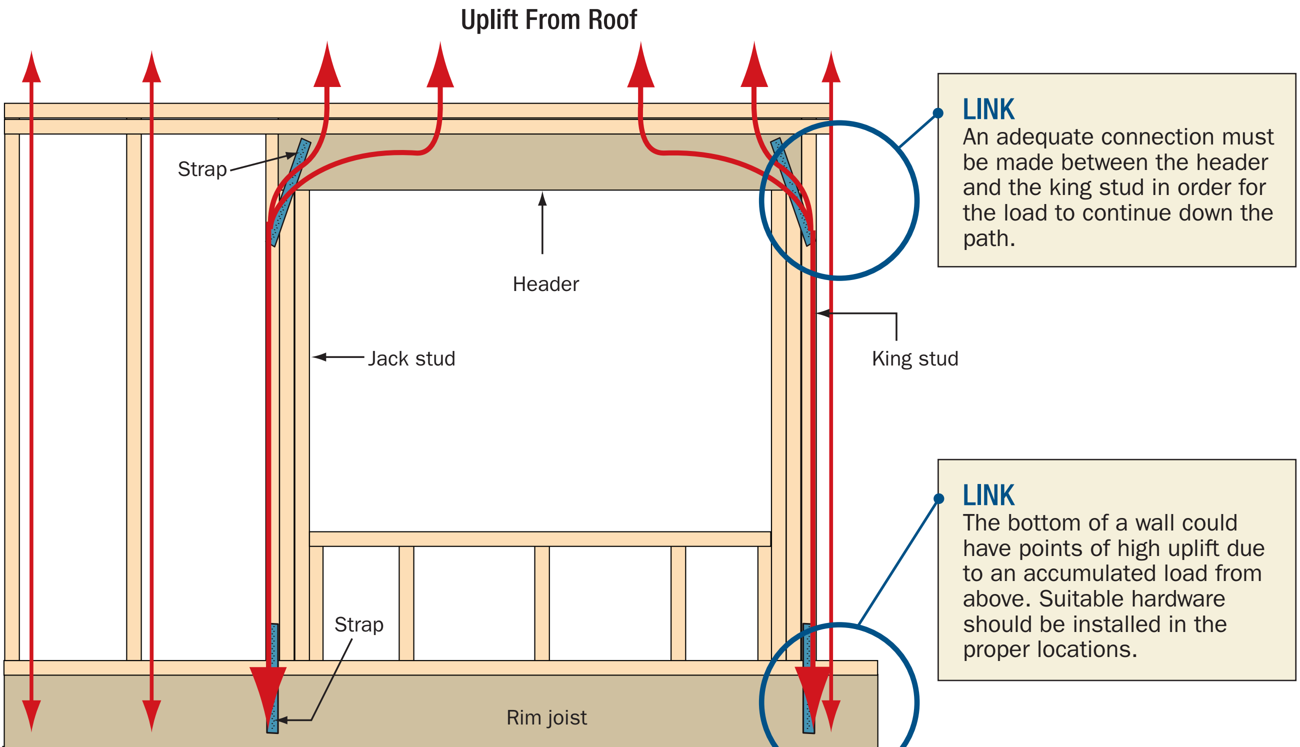
LINK 2
Accumulated roof load is routed through roof-to-wall connections. Special roof ties connect the roof framing to the bearing walls (see Fact Sheet No. 4.3).

LINK 3
Upper walls transfer loads directly to the lower walls. The floor framing is bypassed by using metal straps or extended exterior sheathing that directly connects upper wall studs to the lower wall studs. A similar connection is used to connect the lower wall to the main floor beam.

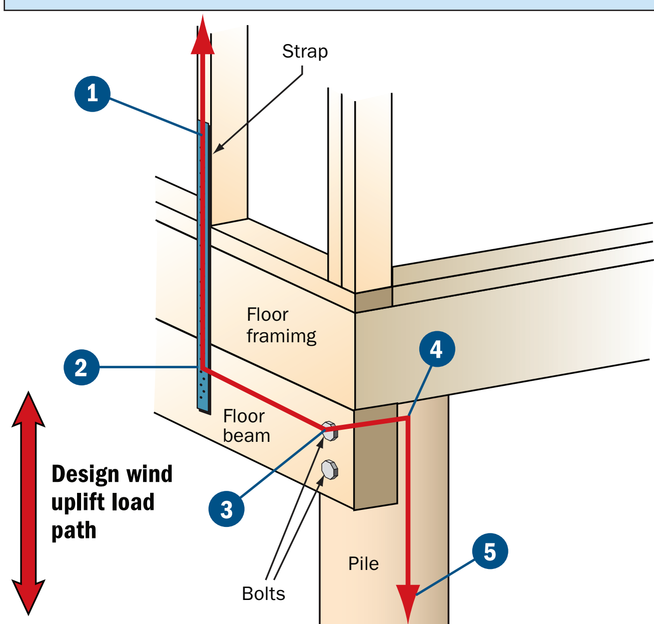
LINK 4
The accumulated uplift force is transferred from the main floor beams to the pile foundation with special brackets or bolts (see Fact Sheet No. 3.3). Note: Some of this load is offset by the weight of the building.

Note: Horizontal load paths transferring shear from upper stories to the ground must also be analyzed.

If a connection fails, an alternative load path will form. If the members and connections in the new load path have inadequate resistance, progressive failure can occur. Loads must be routed around openings, such as windows and doors. Accumulated loads on headers are transferred to the studs on the sides of the opening.



Load path around a window opening.



Load path through a pile connection.

Load paths can be complex through a connection. It is important that each link within the connection be strong enough to transfer the full design load.

The detail at left shows a typical floor-to-pile connection. Uplift loads are transferred through the joint in the following order.

1. from upper story to strap
2. from strap to floor beam
3. from floor beam to bolts
4. from bolts to pile
5. from pile to ground

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Masonry Details

HOME BUILDER'S GUIDE TO COASTAL CONSTRUCTION — Technical Fact Sheet No. 4.2

Purpose: *To highlight several important details for masonry construction in coastal areas.*

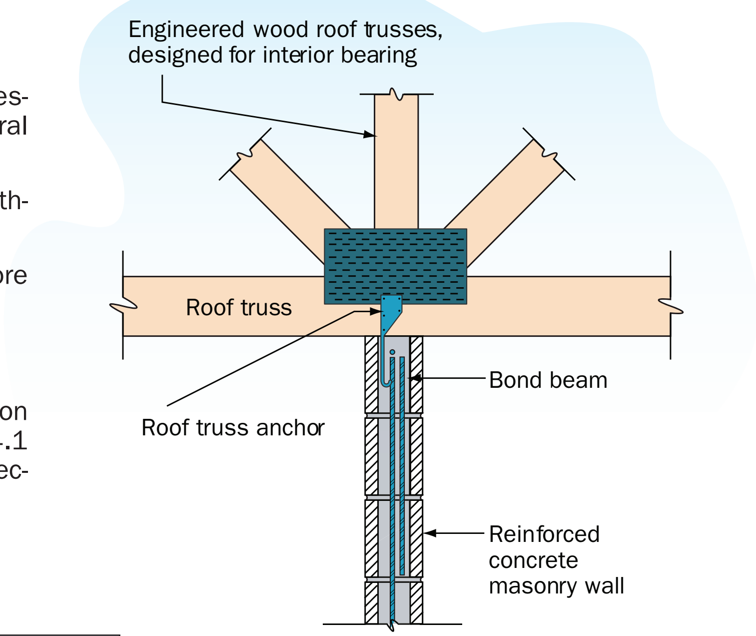
Key Issues

- Continuous, properly connected load paths are essential because of the higher vertical and lateral loads on coastal structures.
- Building materials must be durable enough to withstand the coastal environment.
- Masonry reinforcement requirements are more stringent in coastal areas.

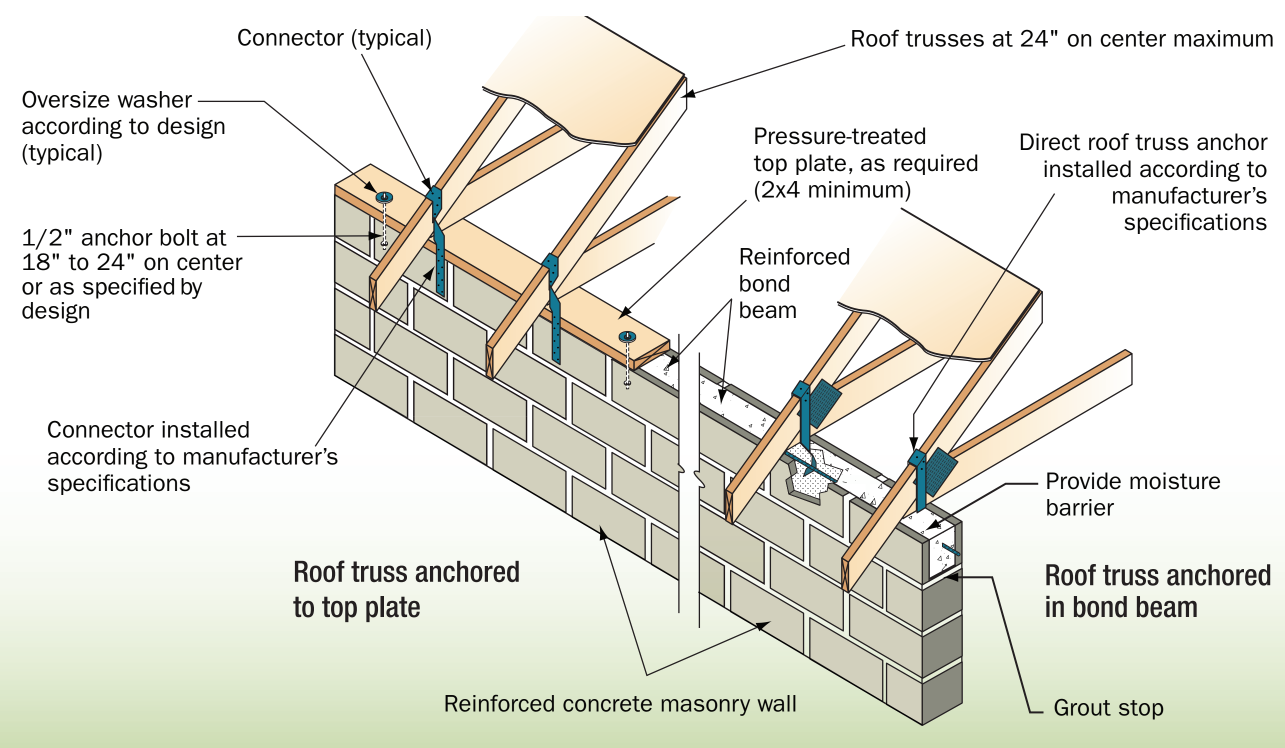
Load Paths

A properly connected load path from roof to foundation is crucial in coastal areas (see Fact Sheets Nos. 4.1 and 4.3). The following details show important connections for a typical masonry home.

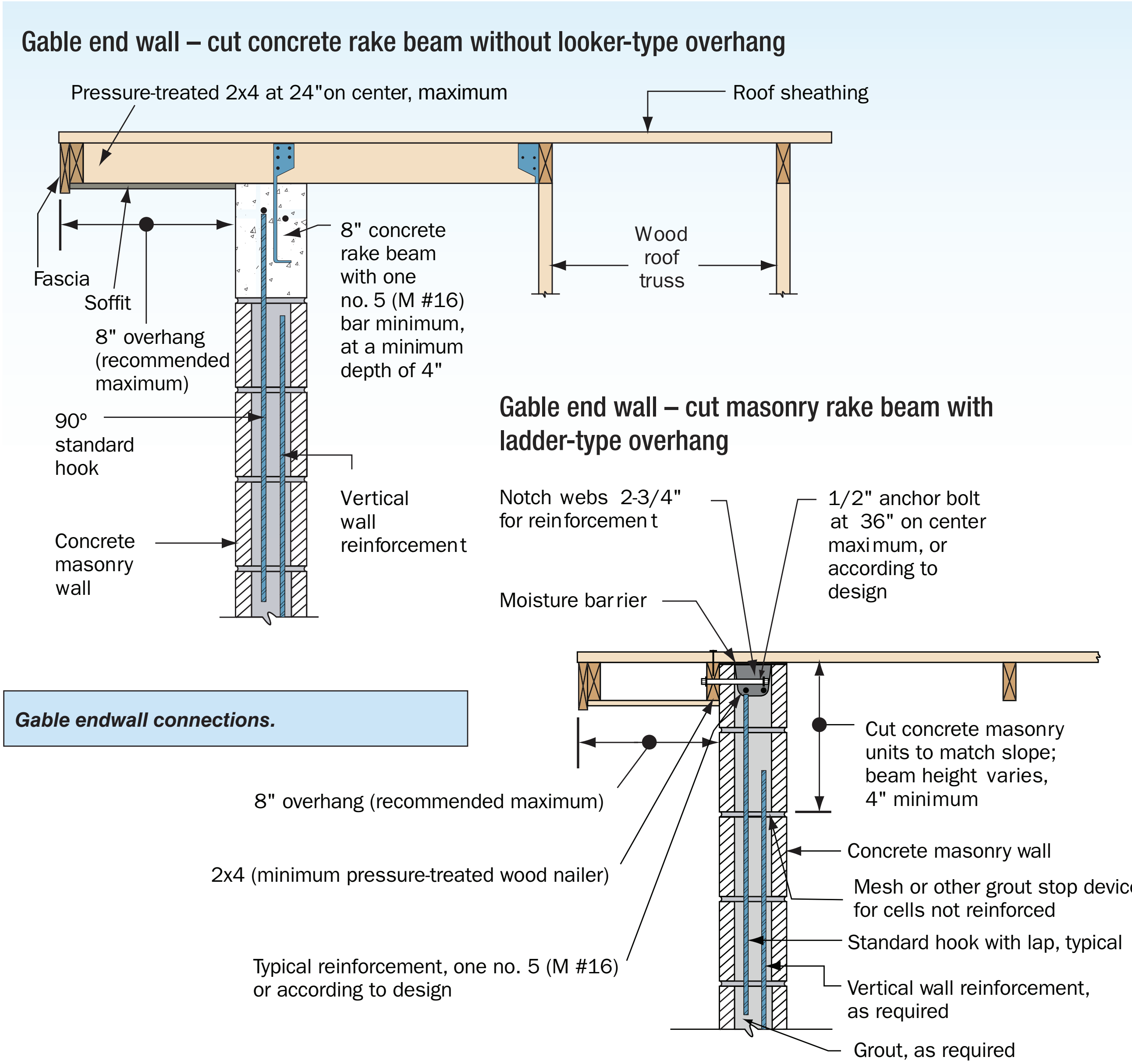
Roof framing to interior masonry wall



Roof framing to masonry wall



LOAD PATHS 4

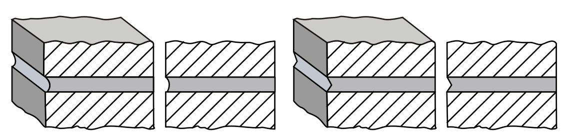


Gable endwall connections.

Durability – High winds and salt-laden air can damage masonry construction. The entry of moisture into large cracks can lead to corrosion of the reinforcement and subsequent cracking and spalling. Moisture resistance is highly dependent on the materials and quality of construction.

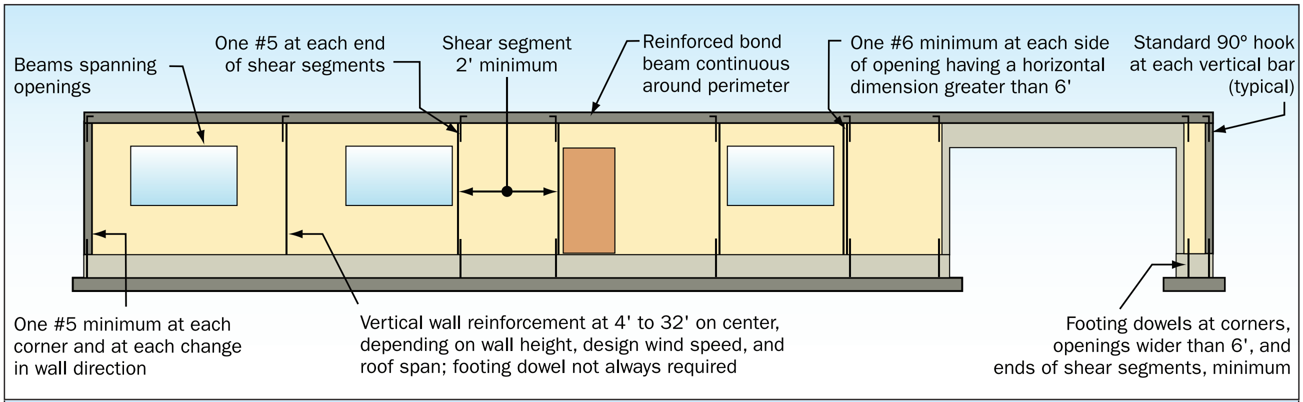
Quality depends on:

- **Proper storage of material –** Keep stored materials covered and off the ground.
- **Proper batching –** Mortar and grout must be properly batched to yield the required strength.
- **Good workmanship –** Head and bed joints must be well mortared and well tooled. Concave joints and V-joints provide the best moisture protection (see detail above). All block walls should be laid with full mortar coverage on horizontal and vertical face shells. Block should be laid using a "double butter" technique for spreading mortar head joints. This practice provides for mortar-to-mortar contact as two blocks are laid together in the wall and prevents hairline cracking in the head joint.



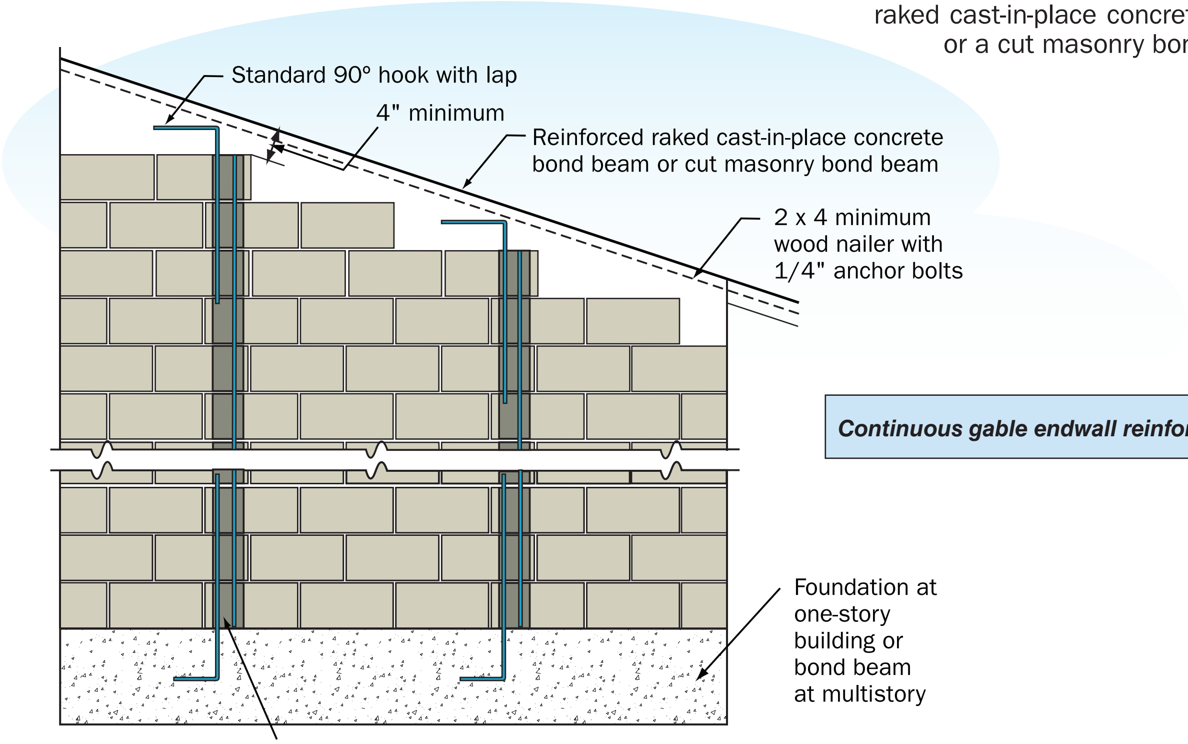
- **Protection of work in progress –** Keep work in progress protected from rain. During inclement weather, the tops of unfinished walls should be covered at the end of the workday. The cover should extend 2 feet down both sides of the masonry and be securely held in place. Immediately after the completion of the walls, the wall cap should be installed to prevent excessive amounts of water from directly entering the masonry.

Reinforcement: Masonry must be reinforced according to the building plans. Coastal homes will typically require more reinforcing than inland homes. The following figure shows typical reinforcement requirements for a coastal home.



Masonry reinforcement.

Gable Ends: Because of their exposure, gable ends are more prone to damage than are hipped roofs unless the joint in conventional construction at the top of the endwall and the bottom of the gable is laterally supported for both inward and outward forces. The figure at right shows a construction method that uses continuous masonry from the floor to the roof diaphragm with a raked cast-in-place concrete bond beam or a cut masonry bond beam.



Continuous gable endwall reinforcement.

LOAD PATHS 4

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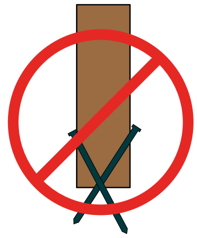
Use of Connectors and Brackets

HOME BUILDER'S GUIDE TO COASTAL CONSTRUCTION Technical Fact Sheet No. 4.3

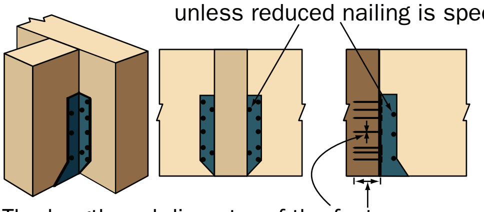
Purpose: *To highlight important building connections and illustrate the proper use of various types of connection hardware.*

Key Issues

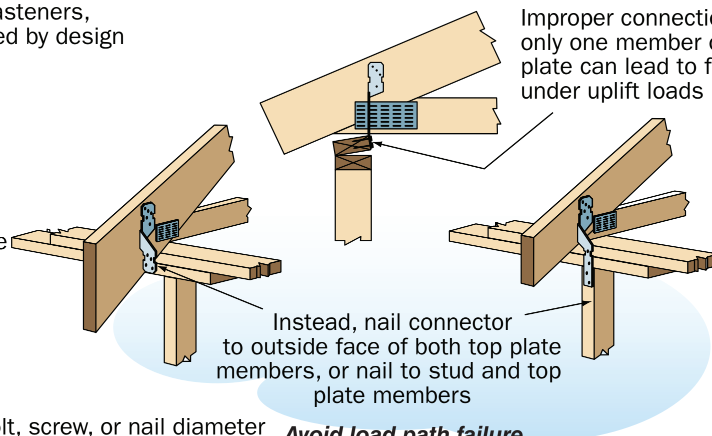


Never rely on toe-nailing for uplift connections in high-wind areas

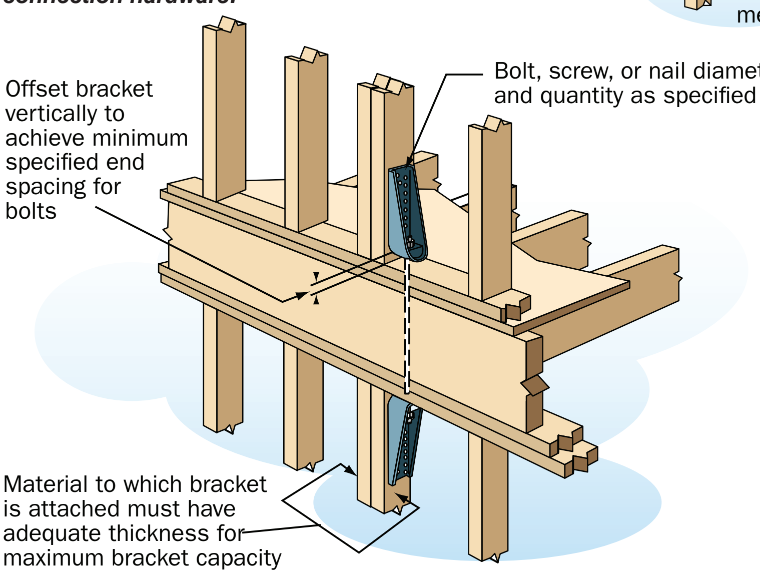
- In high-wind regions, special hardware is used for most framing connections. Toe-nailing is not an acceptable method for resisting uplift loads in high-wind regions.
- Hardware must be installed according to the manufacturer's or engineer's specifications.
- The correct number of the specified fasteners (length and diameter) must be used with connection hardware.
- Avoid cross-grain tension in connections.
- Metal hardware must be adequately protected from corrosion (see NFIP Technical Bulletin 8-96).
- Connections must provide a continuous load path (see Fact Sheet No. 4.1).



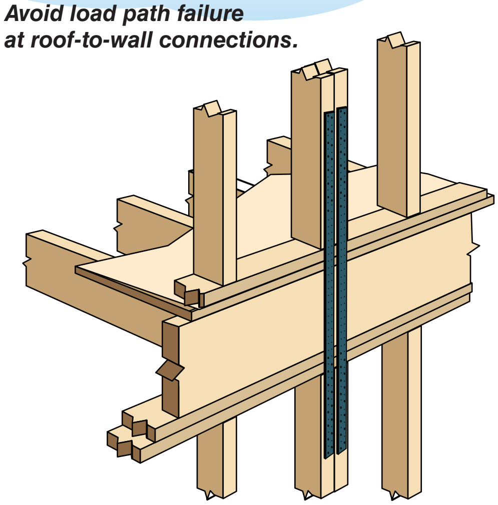
Proper fasteners must be used with connection hardware.



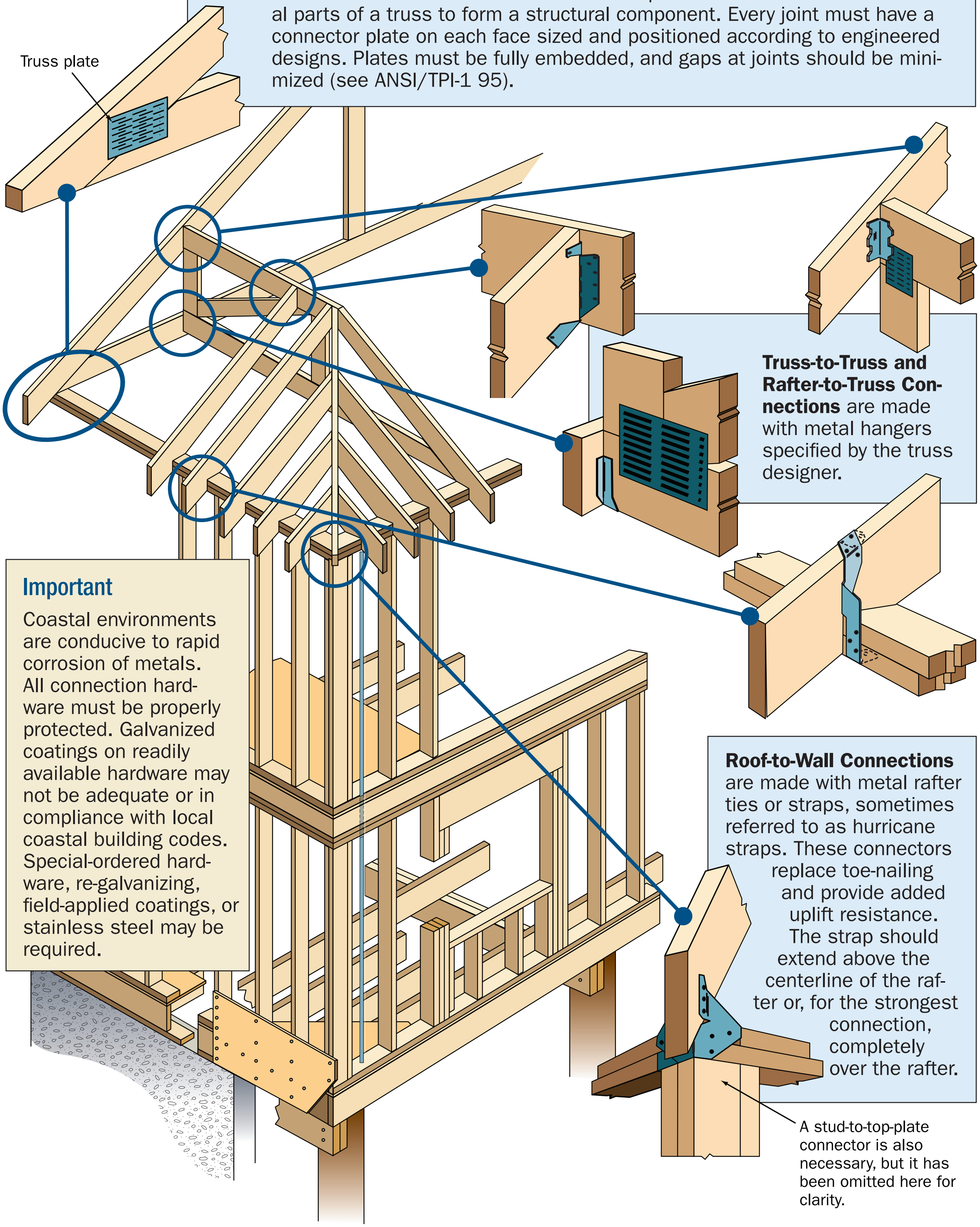
Avoid load path failure at roof-to-wall connections.



Proper bracket connection.



Proper strap connection.



Truss Member Connections are made with metal plates that connect the individual parts of a truss to form a structural component. Every joint must have a connector plate on each face sized and positioned according to engineered designs. Plates must be fully embedded, and gaps at joints should be minimized (see ANSI/TPI-1 95).

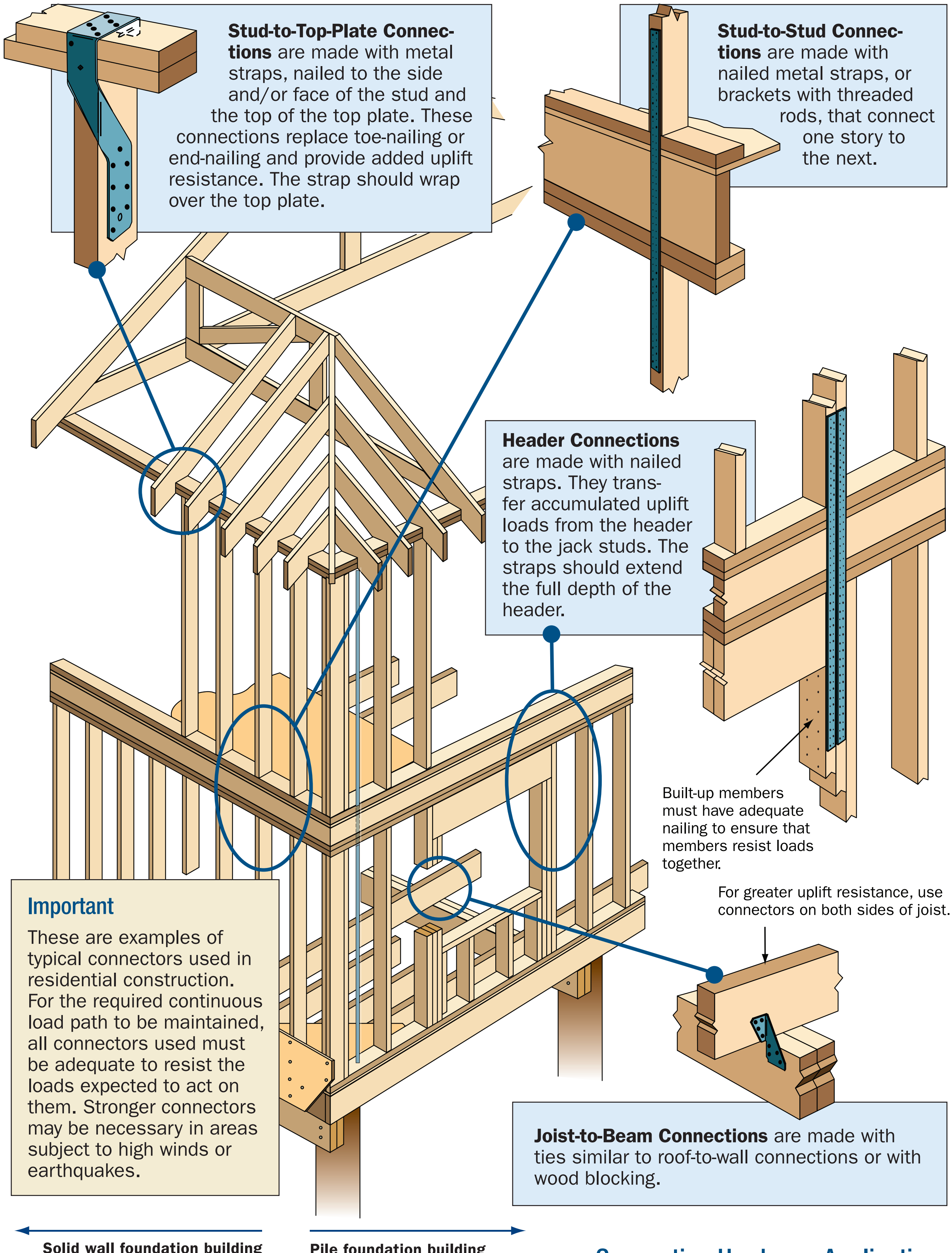
Truss-to-Truss and Rafter-to-Truss Connections are made with metal hangers specified by the truss designer.

Important

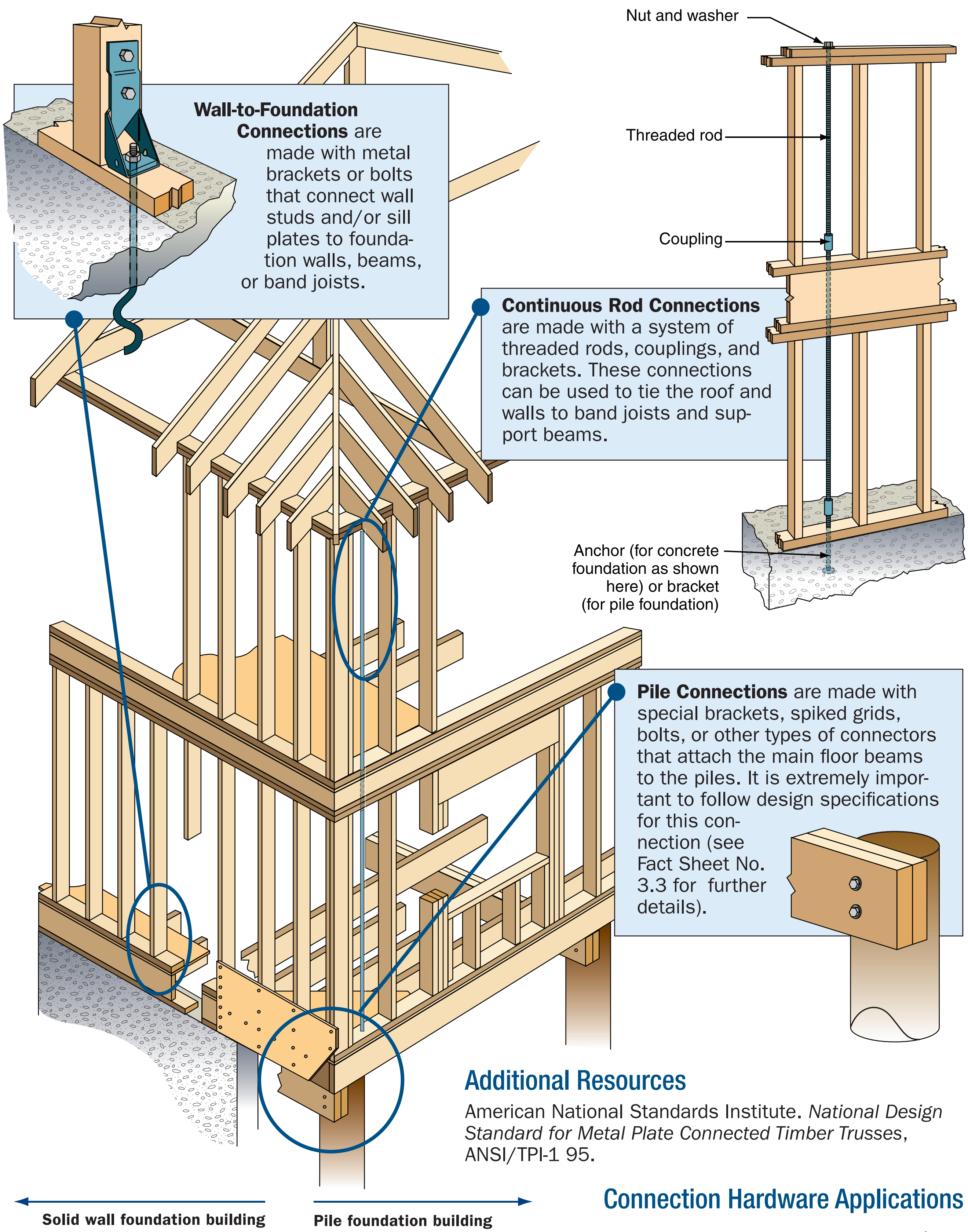
Coastal environments are conducive to rapid corrosion of metals. All connection hardware must be properly protected. Galvanized coatings on readily available hardware may not be adequate or in compliance with local coastal building codes. Special-ordered hardware, re-galvanizing, field-applied coatings, or stainless steel may be required.

Roof-to-Wall Connections are made with metal rafter ties or straps, sometimes referred to as hurricane straps. These connectors replace toe-nailing and provide added uplift resistance. The strap should extend above the centerline of the rafter or, for the strongest connection, completely over the rafter.

Connection Hardware Applications



Connection Hardware Applications



Additional Resources

American National Standards Institute. *National Design Standard for Metal Plate Connected Timber Trusses*, ANSI/TPI-1 95.

Connection Hardware Applications

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Housewrap

Purpose: *To explain the function of housewrap, examine its attributes, and address common problems associated with its use.*

Key Issues

- Housewrap has two functions: to prevent airflow through a wall and to stop (and drain) liquid water that has penetrated through the exterior finish.
- Housewrap is not a vapor retarder. It is designed to allow water vapor to pass through.
- The choice to use housewrap or building paper depends on the climate and on specifier or owner preference. Both materials can provide adequate protection.
- Housewrap ***must*** be installed properly or it could be more detrimental than beneficial.

Proper installation, especially in lapping, is the key to successful housewrap use.

Purpose of Housewrap

Housewrap serves as a dual-purpose weather barrier. It not only minimizes the flow of air in and out of a house, but also stops liquid water and acts as a drainage plane. Housewrap is not a vapor retarder. The unique characteristic of housewrap is that it allows water vapor to pass through it while blocking liquid water. This permits moist humid air to escape from the inside of the home, while preventing outside liquid water (rain) from entering the home.

When Should Housewrap Be Used?

Almost all exterior finishes allow at least some water penetration. If this water continually soaks the wall sheathing and framing members, problems such as dryrot and mold growth could occur. Housewrap stops water that passes through the siding and allows it to drain away from the structural members. In humid climates with heavy rainfall, housewrap is recommended to prevent water damage to the framing. Use in dryer climates may not be as critical, since materials are allowed to adequately dry, although housewrap also prevents air movement through the wall cavity, which is beneficial for insulating purposes.

Housewrap or Building Paper?

To answer this question, it is important to know what attributes are most important for a particular climate. Five attributes associated with secondary weather barriers are:

- **Air permeability –** ability to allow air to pass through
- **Vapor permeability –** ability to allow water vapor (gaseous water) to pass through
- **Water resistance –** ability to prevent liquid water from passing through
- **Repels moisture –** ability to prevent moisture absorption
- **Durability –** resistance to tearing and deterioration

As shown in the following table, the climate where the house is located determines the importance of the attribute.

Product Attribute Rating		Poor – Fair – Good – Excellent	
Attribute	When it is Important	Product Performance	
		Building Paper	Housewrap
Air Permeability	Windy and cold climates	Fair	Good
Vapor Permeability	Hot, humid climates	Fair	Good
Water Resistance	Windy and rainy climates	Good	Excellent
Repels Moisture	High rainfall	Good	Good
Durability	Windy, with possible extended exposure	Fair	Good
Cost	Owner preference	Excellent	Fair

In general, housewrap is a good choice for coastal homes.

Installing Housewrap

No matter what product is used (housewrap or building paper), neither will work effectively if not installed correctly. In fact, installing housewrap incorrectly could do more harm than not using it at all. Housewrap is often thought of and installed as if it were an air retarder alone. A housewrap will channel water and collect it whether the installer intends it to or not. This can lead to serious water damage if the housewrap is installed in a manner that does not allow the channeled water out of the wall system. The following are tips for successful installation of housewrap:

- Follow manufacturers' instructions.
- Plan the job so that housewrap is applied before windows and doors are installed.
- Proper lapping is the key – the upper layer should always be lapped over the lower layer.
- Weatherboard-lap horizontal joints at least 6 inches.
- Lap vertical joints 6 to 12 inches (depending on potential wind-driven rain conditions).
- Use 1-inch minimum staples or roofing nails spaced 12 to 18 inches on center throughout.
- Tape joints with housewrap tape.
- Allow drainage at the bottom of the siding.
- Extend housewrap over the sill plate and foundation joint.
- Install housewrap such that water will never be allowed to flow to the inside of the wrap.
- Avoid complicated details in the design stage to prevent water intrusion problems.
- When sealant is required:
  - use backing rods as needed,
  - use sealant that is compatible with the climate,
  - use sealant that is compatible with the materials it is being applied to,
  - surfaces should be clean (free of dirt and loose material), and
  - discuss maintenance with the homeowner.

Avoid These Common Problems

- **Incomplete wrapping**

  Gable ends are often left unwrapped, leaving a seam at the low end of the gable. This method works to prevent air intrusion, but water that gets past the siding will run down the unwrapped gable end and get behind the housewrap at the seam. Also, it is common for builders to pre-wrap a wall before standing it. If this is done, the band joist is left unwrapped. Wrap the band joist by inserting a strip 6 to 12 inches underneath the bottom edge of the wall wrap. In addition, outside corners are often missed.

- **Improper lapping**

  This often occurs because the housewrap is thought of as an air retarder alone. When applying the housewrap, keep in mind that it will be used as a vertical drainage plane, just like the siding.

- **Improper integration with flashing around doors and windows** – See Fact Sheet No. 6.1.
- **Relying on caulking or self-sticking tape to address improper lapping**

Sealant can and will deteriorate over time. A lapping mistake corrected with sealant will have a limited time of effectiveness. If the homeowner does not perform the required maintenance, serious water damage could occur when the sealant eventually fails. ***Therefore, do not rely on sealant or tape to correct lapping errors.***

WALL SYSTEMS 5

Developed in association with the National Association of Home Builders Research Center

Roof-to-Wall and Deck-to-Wall Flashing

HOME BUILDER'S GUIDE TO COASTAL CONSTRUCTION — Technical Fact Sheet No. 5.2

Purpose: *To emphasize the importance of proper roof and deck flashing, and to provide typical and enhanced flashing techniques for coastal homes.*

Key Issues

- Poor performance of flashing and subsequent water intrusion is a ***common problem*** for coastal homes.
- ***Enhanced flashing techniques are recommended*** in areas that frequently experience high winds and driving rain.
- ***Water penetration*** at deck ledgers can cause ***wood dry rot and corrosion of connectors*** leading to ***deck collapse.***

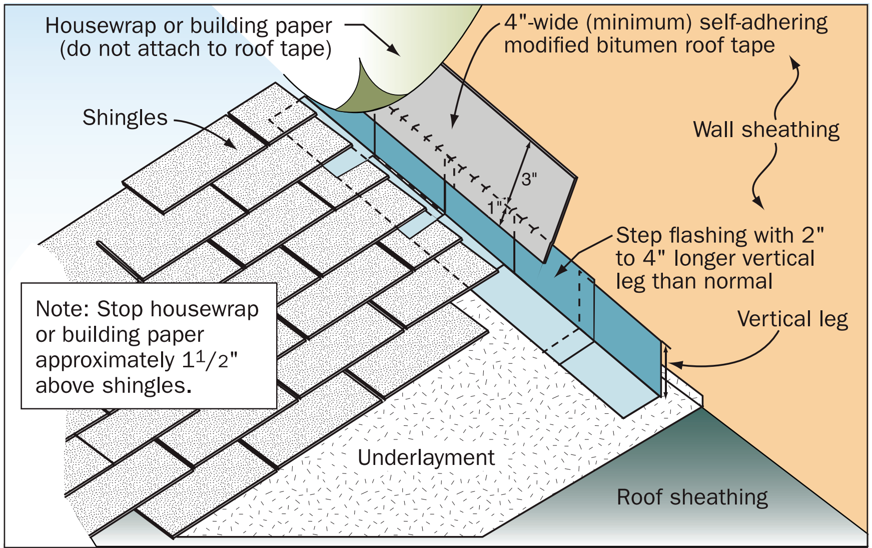

Figure 1. Roof/wall flashing detail.

Roof and Deck Flashing Recommendations for Coastal Areas

- ***Always*** lap flashing and other moisture barriers properly.
- Use increased lap lengths for added protection.
- Do not rely on sealant as a substitute for proper lapping.
- Use fasteners that are compatible with or of the same type of metal as the flashing material.
- Use flashing cement at joints to help secure flashing.
- At roof-to-wall intersections (see Figure 1):
  - Use step flashing that has a 2- to 4-inch-longer vertical leg than normal.
  - Tape the top of step flashing with 4-inch-wide (minimum) self-adhering modified bitumen roof tape.
  - Do not seal housewrap or building paper to step flashing.
- For deck flashing:
  - Follow proper installation sequence to prevent water penetration at deck ledger (see Figure 2).
  - Leave gap between first deck board and flashing to allow for drainage (see Figure 3).
  - Use spacer behind ledger to provide gap for drainage (see Figure 3).
  - Use stainless steel deck connection hardware.

See Fact Sheet Nos. 7.2 and 7.3 for rake and eave details.

WALL SYSTEMS 5

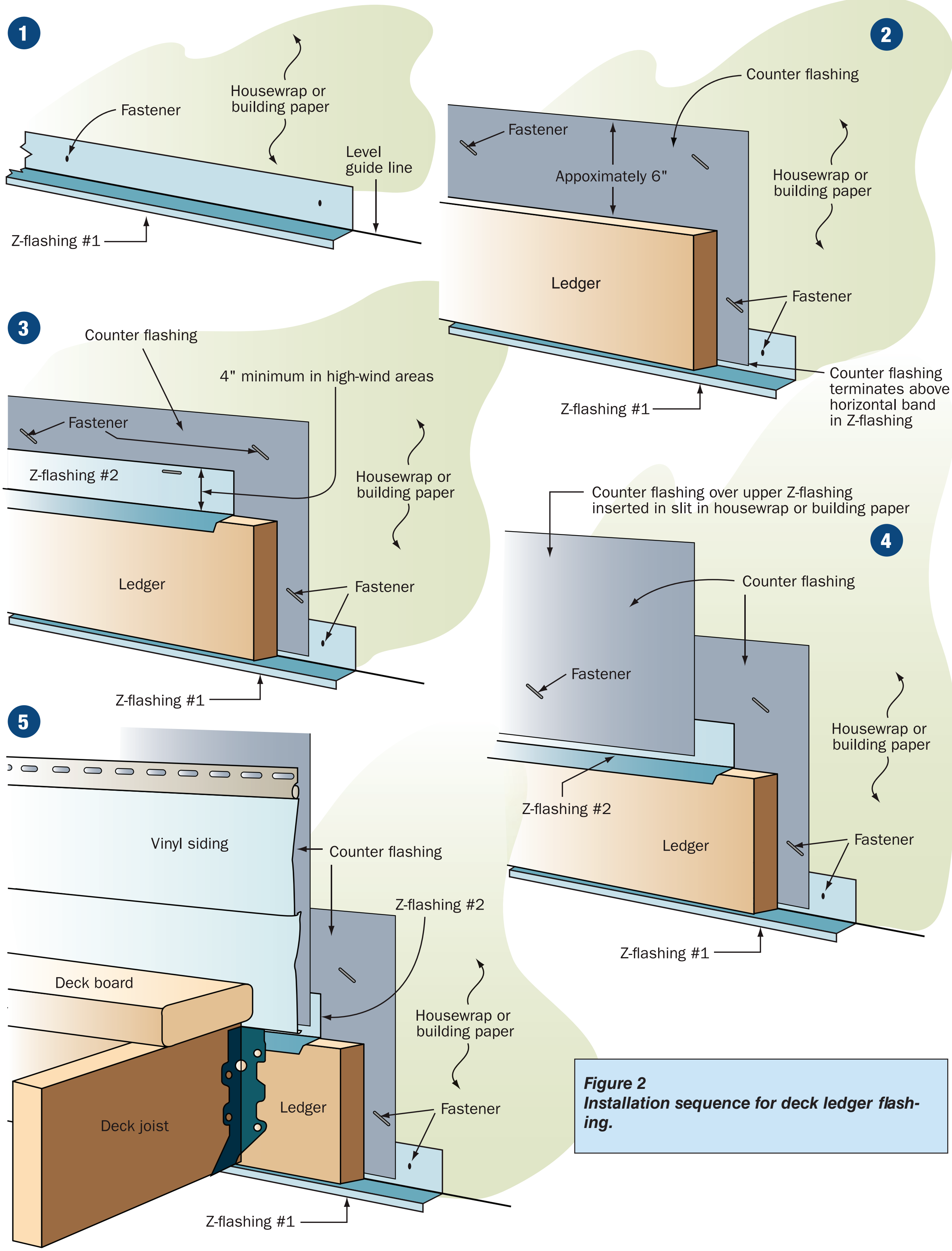

Figure 2
Installation sequence for deck ledger flashing.

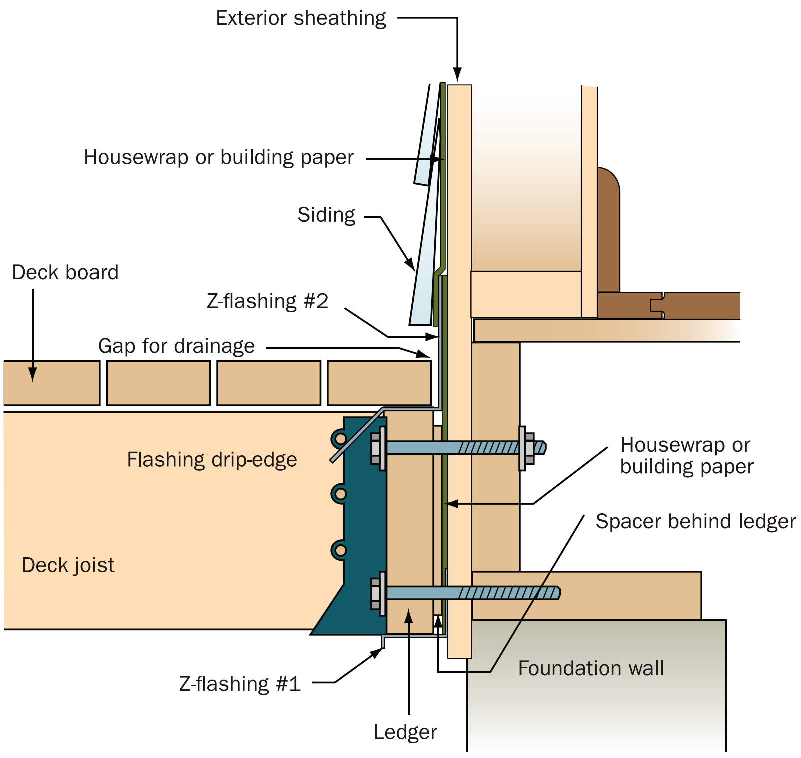

Figure 3 Deck ledger flashing.

Developed in association with the National Association of Home Builders Research Center

Siding Installation in High-Wind Regions

HOME BUILDER'S GUIDE TO COASTAL CONSTRUCTION — Technical Fact Sheet No. 5.3

Purpose: *To provide basic design and installation tips for various types of siding that will enhance wind resistance in high-wind regions (i.e., greater than 90 miles per hour [mph] basic [gust design] wind speed)[1].*

Key Issues

- Siding is frequently blown off walls of residential and non-residential buildings during hurricanes. Also, wind-driven rain is frequently blown into wall cavities (even when the siding itself is not blown off). Guidance for achieving successful wind performance is presented in the following.
- To avoid wind-driven rain penetration into wall cavities, an effective moisture barrier (housewrap or building paper) is needed. For further information on moisture barriers, see Fact Sheet No. 1.9, Moisture Barrier Systems. For further information on housewrap, see Fact Sheet No. 5.1, Housewrap.
- Always follow manufacturer's installation instructions and local building code requirements.
- Use products that are suitable for a coastal environment. Many manufacturers do not rate their products in a way that makes it easy to determine whether the product will be adequate for the coastal environment. Use only siding products where the supplier can provide specific information on product performance in coastal or high-wind environments.
- For buildings located within 3,000 feet of the ocean line, stainless steel fasteners are recommended.
- Avoid using dissimilar metals together.
- The installation details for starting the first (lowest) course of lap siding can be critical. Loss of siding often begins at the lowest course and proceeds up the wall (Figures 4 and 12). This is particularly important for elevated buildings, where the wind blows under the building as well as against the sides.
- When applying new siding over existing siding, use shims or install a solid backing to create a uniform, flat surface on which to apply the siding, and avoid creating gaps or projections that could catch the wind.
- Coastal buildings require more maintenance than inland buildings. This maintenance requirement needs to be considered in both the selection and installation of siding.

Moisture barrier (also known as a water-resistive barrier): In the context of residential walls, the moisture barrier is either housewrap or building paper (felt). The moisture barrier occurs between the wall sheathing and the siding. It is a dual-purpose layer that sheds water that gets through the siding and limits air flow through the wall. When properly sealed, housewrap is considered an air barrier. Although building paper provides some resistance to air flow, it is not considered an air barrier. Moisture barriers shed water, but they allow water vapor to pass through them.

For further guidance on principles, materials, and procedures for the design and construction of walls to make them resistant to water intrusion, see American Society for Testing and Materials (ASTM) E 2266, *Standard Guide for Design and Construction of Low-Rise Frame Building Wall Systems to Resist Water Intrusion*.

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1 The 90 mph speed is based on ASCE 7-05. If ASCE 7-10 is being used, the equivalent wind speed is 116 mph for Risk Category II buildings.

Vinyl Siding

Vinyl siding can be used successfully in a coastal environment if properly designed and installed.

Windload Resistance

Vinyl siding is required by the International Building Code (IBC) and the International Residential Code (IRC) to comply with ASTM D 3679, *Standard Specification for Rigid Poly (Vinyl Chloride)* (PVC) Siding. Both the IBC and IRC require static pressure testing over solid wall surfaces capable of independently resisting the design wind pressures to approximate loading conditions that occur in 110-mph wind zone areas for a building up to 30 feet in height in Exposure B.[2] Most vinyl siding has also been tested for higher wind pressures and can be used in locations with a higher basic wind speed, greater building height, more open exposure, or some combination of these. While vinyl siding wind pressure ratings found in most product literature are based on tests of the vinyl over an approved sheathing capable of independently resisting the design wind pressures, methods of installation that rely on a combination of wind resistance provided by exterior wall sheathing, vinyl siding, and interior wall sheathing are available for some applications. The design wind pressure or wind speed for which these products are rated, as well as requirements for sheathing behind the vinyl siding are available from product literature, installation instructions, or listings of agencies such as the International Code Council (ICC) Evaluation Service.

- For design wind speeds greater than 110 mph per ASCE 7-05, or 139 mph per ASCE 7-10, or, building heights greater than 30 feet, or Exposure C, choose a siding product rated for those conditions or higher. The manufacturer's product literature or installation instructions should specify the fastener type, size and spacing, and any other installation details such as requirements for the sheathing materials behind the vinyl siding needed to achieve this rating.
- Products that have been rated for high winds typically have an enhanced nailing hem and are sometimes made from thicker vinyl (Figure 1). Thick, rigid panels provide greater wind resistance, withstand dents, and lie flatter and straighter against the wall. Optimum panel thickness should be 0.040 to 0.048 inches, depending on style and design. Thinner gauge vinyl works well for stable climates; thicker gauge vinyl is recommended for areas with high winds and high temperature changes.
- Position nails in the center of the nailing slot (Figure 2). To allow for thermal movement of the siding, do not drive the head of the nail tight against the nail hem (unless the hem has been specifically designed for this). Allow approximately 1/32 inch (which is about the thickness of a dime) clearance between the fastener head and the siding panel (Figure 3).
- Drive nails straight and level to prevent distortion and buckling in the panel.
- Do not caulk the panels where they meet the receiver of inside corners, outside corners, or J-trim. Do not caulk the overlap joints.
- Do not face-nail or staple through the siding.

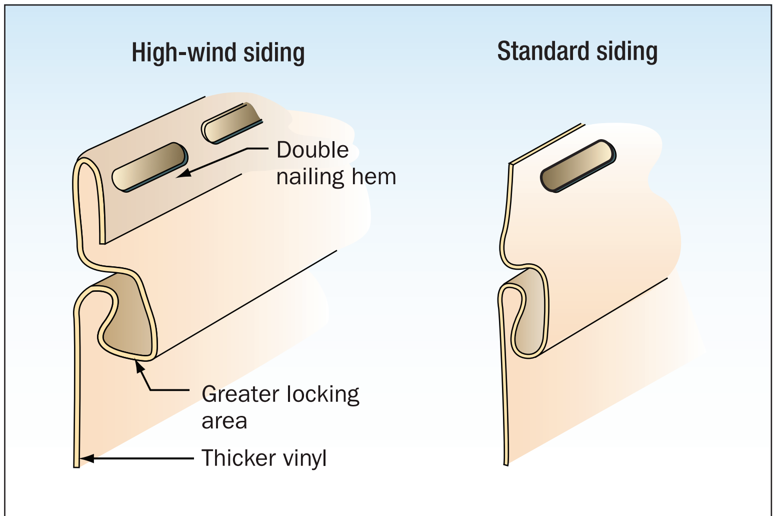

Figure 1. Features of typical high-wind siding and standard siding.

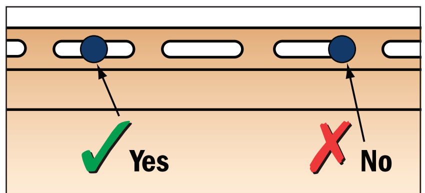

Figure 2. Proper and improper fastener locations.

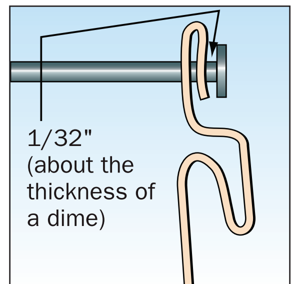

Figure 3. Allow 1/32" clearance between the fastener head and the siding panel.

2 The 110 mph wind speed is based on ASCE 7-05. If ASCE 7-10 is used, the equivalent wind speed is 139 mph for Risk Category II buildings.

- Use aluminum, galvanized steel, or other corrosion-resistant nails when installing vinyl siding. Aluminum trim pieces require aluminum or stainless steel fasteners.
- Nail heads should be 5/16 inch minimum in diameter. Shank should be 1/8 inch in diameter.
- Use the manufacturer-specified starter strip to lock in the first course; do not substitute other accessories such as a J-channel or utility trim (Figure 4) unless specified by the manufacturer. If the manufacturer specifies a particular strip for high-wind applications, use it. Make sure that the starter strip is designed to positively lock the panel, rather than just hooking over a bulge in the strip; field test the interlock before proceeding with the installation. Make sure that every course of siding is positively locked into the previous course (Figure 5). Push the panel up into the lock from the bottom before nailing rather than pulling from the top. Do not attempt to align siding courses with adjacent walls by installing some courses loosely.
- Make sure that adjacent panels overlap properly, about half the length of the notch at the end of the panel, or approximately 1 inch. Make sure the overlap is not cupped or gapped, which is caused by pulling up or pushing down on the siding while nailing. Reinstall any panels that have this problem.
- Use utility trim under windows or anywhere the top nail hem needs to be cut from siding to fit around an obstacle. Be sure to punch snap-locks into the siding to lock into the utility trim. Do not overlap siding panels directly beneath a window (Figure 6).
- At gable end walls, it is recommended that vinyl siding be installed over approved sheathing capable of independently resisting the full design wind pressures rather than over plastic foam sheathing or combinations of exterior foam sheathing and interior gable end sheathing except as provided for in the IRC Section R703.11.2. Figure 7 depicts the vulnerability of siding on gable end walls not properly sheathed with approved materials capable of independently resisting the full design wind pressures.
- Install vinyl siding in accordance with manufacturer's installation instructions and local building code requirements. Ensure product rating is appropriate for the intended application.
- It is recommended that vinyl siding installers be certified under the VSI Certified Installer Program sponsored by the Vinyl Siding Institute.

Figure 4. Utility trim was substituted for the starter strip and the bottom lock was cut off the siding. Siding was able to pull loose under wind pressure.

Figure 5. The siding panel was not properly locked into the panel below.

Figure 6. Proper detailing around windows and other obstacles is important. Use utility trim, punch snap-locks into siding, and do not overlap directly beneath a window.

Wood Siding

- Use decay-resistant wood such as redwood, cedar, or cypress. See the Sustainable Design section regarding certified wood.
- To improve longevity of paint, back-prime wood siding before installation.
- Carefully follow manufacturer's detailing instructions to prevent excessive water intrusion behind the siding.
- For attachment recommendations, see *Natural Wood Siding: Selection, Installation and Finishing*, published by the Western Wood Products Association.

This publication recommends an air gap between the moisture barrier and the backside of the siding to promote drainage and ventilation. Such a wall configuration is referred to as a rain screen wall. See the text box on page 5.

- Follow the installation details shown in Figures 8a and 8b. (Note: Although these details do not show a rain screen, inclusion of vertical furring strips to create a rain screen is recommended.)

***Figure 7.** The vinyl siding at this gable was installed over plastic foam insulation. Without wood sheathing, the wind pressures on the vinyl are increased. Also, if the siding blows away, the foam insulation is very vulnerable to blow-off. With loss of the foam insulation, wind-driven rain can freely enter the attic, saturate the ceiling insulation, and cause collapse of the ceiling.*

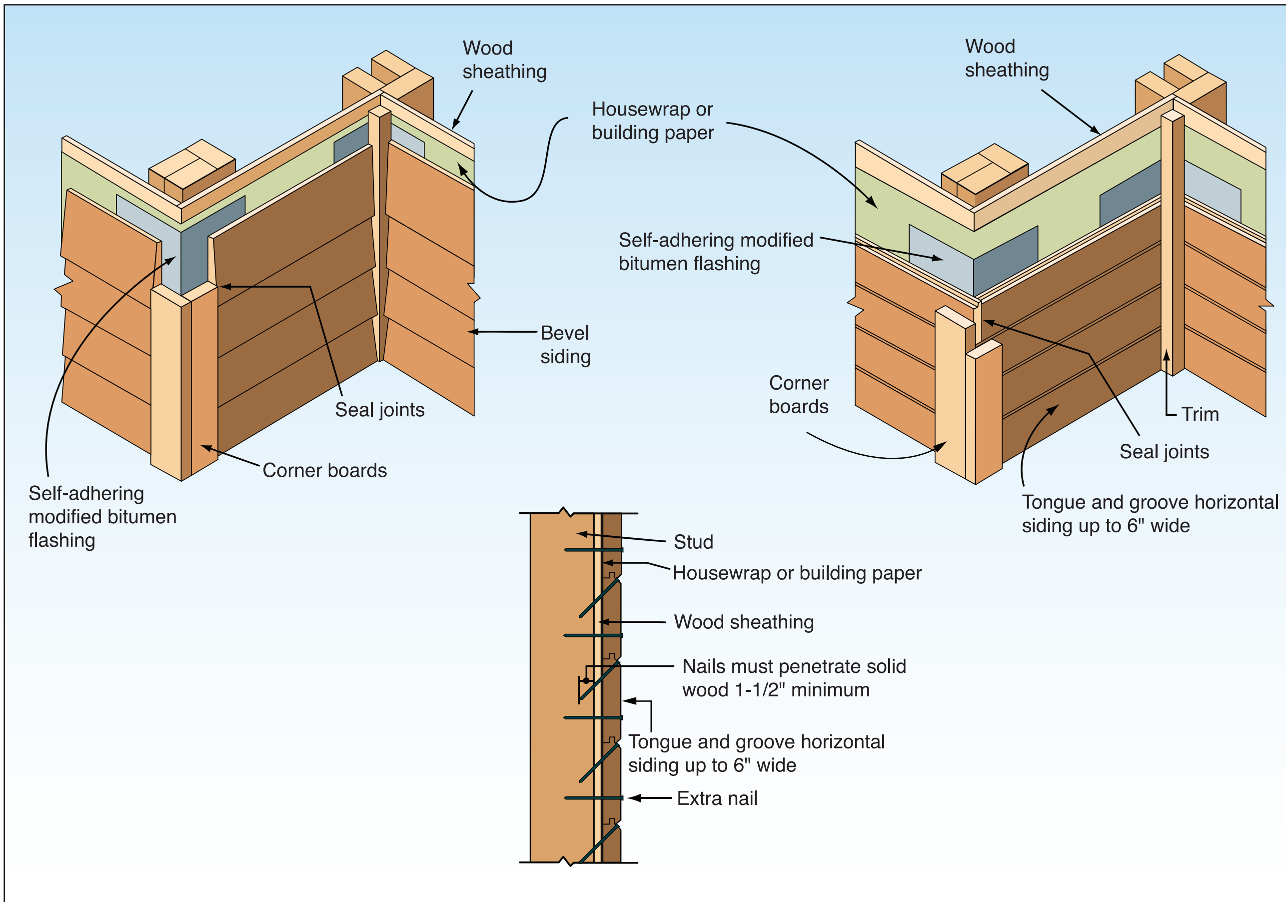

***Figure 8a.** Wood siding installation details.*

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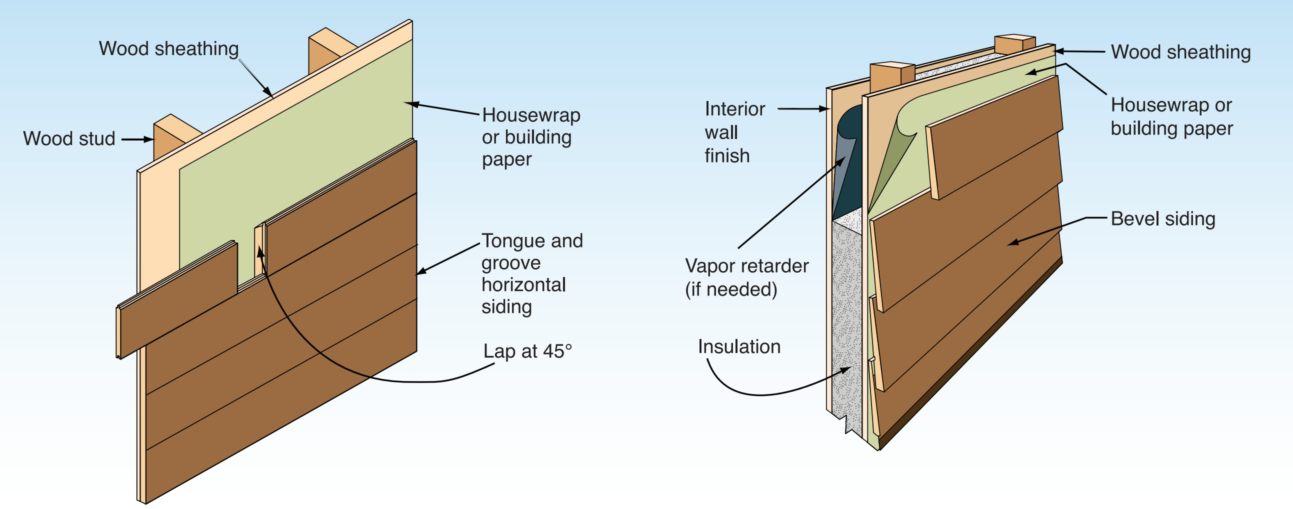

Figure 8b. Wood siding installation details.

Pressure-equalized rain screen wall system

In areas that experience frequent wind-driven rain and areas susceptible to high winds, it is recommended that a rain screen design be considered when specifying wood or fiber cement siding. (Typical vinyl siding products inherently provide air cavities behind the siding that facilitate drainage. Therefore, incorporation of vertical furring strips is normally not applicable to this type of wall covering.) A rain screen design is accomplished by installing suitable vertical furring strips between the moisture barrier and siding material (see Figure 9). The cavity facilitates drainage of water from the space between the moisture barrier and backside of the siding and it facilitates drying of the siding and moisture barrier.

Furring strip attachment: For 1 by 2 inches furring strips, tack strips in place and use siding nails that are 3/4 inch longer than would be required if there were no strips (to maintain the minimally required siding nail penetration into the studs). For thicker furring strips, an engineered attachment is recommended.

At the bottom of the wall, the cavity should be open to allow water drainage. However, the opening should be screened to avoid insect entry.

At the wall/soffit juncture, the top of the cavity can open into the attic space to provide inlet air ventilation, thereby, eliminating soffit vents and their susceptibility to wind-driven rain entry. If the rain screen cavity vent path is used instead of soffit vents, the depth of the cavity needs to be engineered to ensure that it provides sufficient air flow to ventilate the attic.

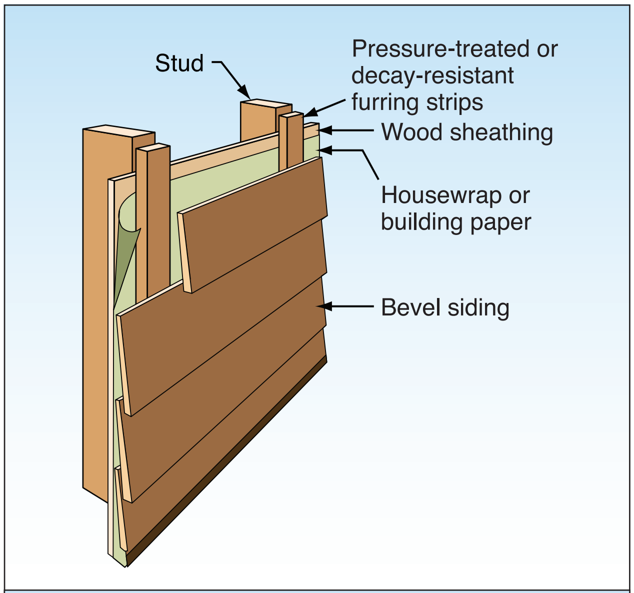

Figure 9. Pressure-equalized rain screen system.

Fiber Cement Siding

- Installation procedures are similar to those for wood siding, but require specialized cutting blades and safety precautions because of the dust produced during cutting with power tools. Manufacturer's installation recommendations should be strictly adhered to, and particular attention paid to the painting and finishing recommendations for a high-quality installation.
- Always seal field-cut ends according to the manufacturer's instructions. Properly gap the intersection between siding edges and other building components and fill the gap with sealant.

- Always consult and follow the manufacturer's installation requirements for the needed wind speed rating or design pressure (refer to the manufacturer's building code compliance evaluation report). Observe the manufacturer's fastener specifications, including fastener type and size, spacing, and penetration requirements. Do not over drive or under drive.
- At gable end walls, it is recommended that fiber cement siding be installed over wood sheathing rather than over plastic foam sheathing.
- Keep blind nails between 3/4 and 1-inch from the top edge of the panel (Figure 10). Be sure to drive nails at least 3/8 inch from butt ends, or use manufacturer-specified joiners.
- Face nailing (Figure 11) instead of blind nailing is recommended where the basic (design) wind speed is 100 mph or greater. If the local building code or manufacturer specifies face nailing at a lower wind speed, install accordingly.
- Do not leave the underside of the first course exposed or extending beyond the underlying material (Figure 12). Consider the use of a trim board to close off the underside of the first course.

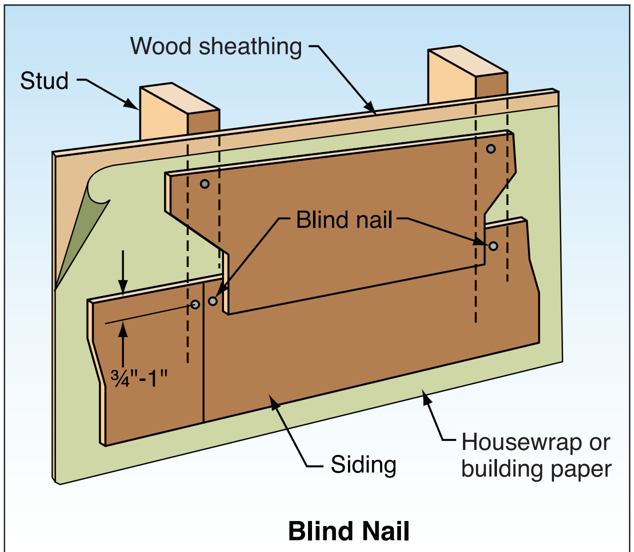

Figure 10. Blind nailing.

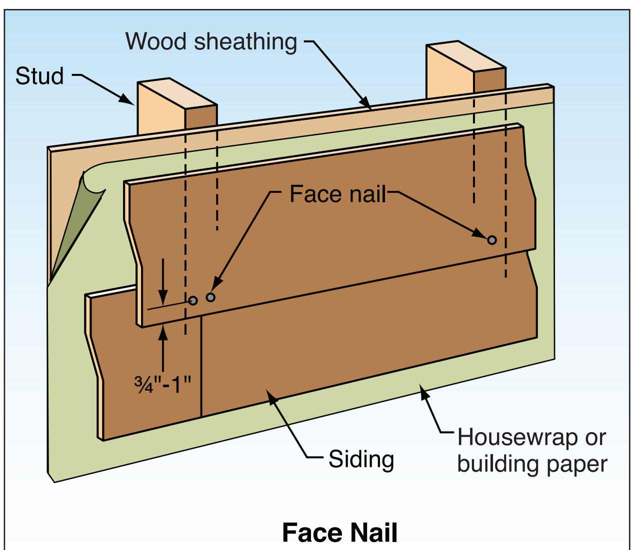

Figure 11. Face nailing.

Figure 12. Blind nailed siding installed with exposed gap at bottom (red circle) is vulnerable to failure.

Sustainable Design

Material selection for sustainable sources and durability

For wood products, it is best to select material that has been certified by a recognized program such as the American Tree Farm System® (ATFS), the Forest Stewardship Council (FSC) or the Sustainable Forestry Initiative® (SFI). Not only do these programs verify that wood is harvested in a more responsible fashion, but they also verify that the use of chemicals and genetic engineering of these products is avoided.

The following publications discuss sustainable aspects of vinyl siding:

A Dozen Things You Might Not Know That Make Vinyl Siding Green (available online at http://vinylsiding.org/greenpaper/090710_Latest_Revised_Green_paper.pdf).

Siding with the Environment (available online at http://www.vinylsiding.org/publications/final_Enviro_single_pg.pdf).

Energy Conservation and Air Barriers

Uncontrolled air leakage through the building envelope is often overlooked. The U.S. Department of Energy estimates that 40 percent of the cost of heating or cooling the average American home is lost due to uncontrolled air leakage. In warmer climates, it is a lower percentage of loss. An air barrier system can reduce the heating, ventilation, and cooling (HVAC) system size, resulting in reduced energy use and demand.

Uncontrolled air leakage can also contribute to premature deterioration of building materials, mold and moisture problems, poor indoor air quality, and compromised occupant comfort. When uncontrolled air flows through the building envelope, water vapor moves with it. Controlling the movement of moisture by air infiltration requires controlling the air pathways and/or the driving force.

To effectively control air leakage through the building envelope, an effective air barrier is required. To be effective, it needs to be continuous; therefore, air barrier joints need to be sealed and the barrier needs to be sealed at penetrations through it. The Air Barrier Association of America recommends that materials used as a component of a building envelope air barrier be tested to have an air infiltration rate of less than 0.004 cubic feet per minute (cfm)/square foot, assemblies of materials that form the air barrier be tested to have an air infiltration rate of less than 0.04 cfm/square foot, and the whole building exterior enclosure have an air infiltration rate of less than 0.4 cfm/square foot.

Air barrier: A component installed to provide a continuous barrier to the movement of air through the building envelope. Housewrap is a common air barrier material for residential walls. Although very resistant to airflow, housewrap is very vapor permeable and therefore is not suitable for use as a vapor retarder.

Vapor retarder: A component installed to resist diffusion of water vapor and provide a continuous barrier to movement of air through the building envelope. Polyethylene is a common vapor retarder material for residential walls. To determine whether or not a vapor retarder is needed, refer to the appropriate provisions of Chapter 14 of the 2009 IBC or Chapter 6 of the 2009 IRC. Also refer to the Moisture Control section of the NRCA Roofing and Waterproofing Manual, published by the National Roofing Contractors Association (NRCA) (http://www.nrca.net).

ASTM E 1677, *Standard Specification for an Air Retarder (AR) Material or System for Low-Rise Framed Building Walls:* This specification covers the minimum performance and acceptance criteria for an air barrier material or system for framed walls of low-rise buildings with the service life of the building wall in mind. The provisions contained in this specification are intended to allow the user to design the wall performance criteria and increase air barrier specifications to accommodate a particular climate location, function, or design of the intended building.

Air Barrier Systems Installed Behind Siding

Housewrap is the most common air barrier material for residential walls. To be effective, it is critical that the joints between sheets of housewrap be sealed as recommended by the manufacturer, and penetrations (other than fasteners) should also be sealed. At transitions between the housewrap and door and window frame, use of self-adhering modified bitumen flashing tape is recommended.

An air barrier should be installed over a rigid material, or it will not function properly. It also needs to be restrained from pulling off of the wall under negative wind pressures. For walls, wood sheathing serves as a suitable substrate, and the siding (or furring strips in a rain screen wall system) provide sufficient restraint for the air barrier.

At the base of the wall, the wall air barrier should be sealed to the foundation wall. If the house is elevated on piles, the wall barrier should be sealed to an air barrier installed at the plane of the floor.

If the building has a ventilated attic, at the top of the wall, the wall air barrier should be sealed to an air barrier that is installed at the plane of the ceiling.

If the building has an unventilated attic or no attic, at the top of the wall, the wall air barrier should be sealed to an air barrier that is installed at the plane of the roof (the roof air barrier may be the roof membrane itself or a separate air barrier element).

Siding Maintenance

For all siding products, it is very important to periodically inspect and maintain the product especially in a coastal environment. This includes recoating on a scheduled maintenance plan that is necessary according to the manufacturer's instructions and a periodic check of the sealant to ensure its durability. Check the sealant for its proper resiliency and that it is still in place. Sealant should be replaced before it reaches the end of its service life.

Additional Resources

American Tree Farm System®, ATFS (http://www.treefarmsystem.org/index.shtml).

Forest Stewardship Council, FSC (http://www.fsc-info.org)

International Code Council. International Building Code. 2009. (http://www.iccsafe.org)

International Code Council. International Residential Code. 2009. (http://www.iccsafe.org)

Sustainable Forestry Initiative® Program, SFI (http://www.sfiprogram.org)

Vinyl Siding Institute, VSI (http://www.vinylsiding.org)

Developed in association with the National Association of Home Builders Research Center

Attachment of Brick Veneer in High-Wind Regions

HOME BUILDER'S GUIDE TO COASTAL CONSTRUCTION — Technical Fact Sheet No. 5.4

Purpose: *To recommend practices for installing brick veneer that will enhance wind resistance in high-wind regions (i.e., greater than 90-miles per hour [mph] basic [gust design] wind speed).[1]*

Key Issues

- When not adequately attached, brick veneer is frequently blown off walls of residential and non-residential buildings during hurricanes (Figure 1). When brick veneer fails, wind-driven water can enter and damage buildings, and building occupants can be vulnerable to injury from windborne debris (particularly if walls are sheathed with plastic foam insulation or wood fiberboard instead of wood panels). Pedestrians in the vicinity of damaged walls can also be vulnerable to injury from falling veneer (Figure 2).
- Common failure modes include tie (anchor) corrosion (Figure 3), tie fastener pull-out (Figure 4), failure of masons to embed ties into the mortar (Figure 5), and poor bonding between ties and mortar and mortar of poor quality (Figure 6).
- Ties are often installed before brick laying begins. When this is done, ties are often improperly placed above or below the mortar joints. When misaligned, the ties must be angled up or down in order for the ties to be embedded into the mortar joints (Figure 7). Misalignment not only reduces embedment depth, but also reduces the effectiveness of the ties because wind forces do not act parallel to the ties themselves.
- Corrugated ties typically used in residential veneer construction provide little resistance to compressive loads. Use of compression struts would likely be beneficial, but off-the-shelf devices do not currently exist. Two-piece adjustable ties (Figure 8) provide significantly greater compressive strength than corrugated ties and are, therefore, recommended. However, if corrugated ties are used, it is recommended that they be installed as shown in Figures 9 and 10 in order to enhance their wind performance.

1 The 90 mph speed is based on ASCE 7-05. If ASCE 7-10 is being used, the equivalent wind speed trigger is 115 mph for Risk Category II buildings.

Figure 1. Failed brick veneer over plywood. Many of the ties are still attached to the substrate, but several of the tie fasteners pulled out of the substrate and the ties are embedded in the collapsed veneer. Estimated wind speed: 107 miles per hour (peak gust, Exposure C, at 33 feet).

Figure 2. The upper portion of the brick veneer at this apartment building collapsed. Pedestrian and vehicular traffic in the vicinity of the damaged wall are vulnerable to injury and damage if remaining portions of the wall were to collapse during subsequent storms.

Figure 3. Significant tie corrosion caused the brick at a fire station to fail, even though the building is not near the coast. Note that metal is missing for half of the width of the tie at two locations (red arrows). The left end of the tie was still embedded into a concrete masonry unit back-up wall. The right end is where the tie failed in tension, thus leaving a portion of the tie embedded in the collapsed brick.

Figure 4. This tie remained embedded in the mortar joint while the smooth-shank nail pulled out from the stud.

Figure 5. These four ties were never embedded into the mortar joint.

- Buildings that experience veneer damage typically do not comply with current building codes. Building code requirements for brick veneer have changed over the years. Model codes prior to 1995 permitted brick veneer in any location, with no wind speed restrictions. Also, some older model codes allowed brick veneers to be anchored with fewer ties than what is required by today's standards.

The Masonry Society's (TMS) 402/American Concrete Institute 530/American Society of Civil Engineers (ASCE) 5 *Building Code Requirements and Specifications for Masonry Structures* (TMS 402) is the current masonry standard referenced by model building codes. The 2009 International Residential Code (IRC) and the 2009 International Building Code (IBC) references the 2008 edition of TMS 402, which is the latest edition.

TMS 402 addresses brick veneer in two manners: rational design and a prescriptive approach. Nearly all brick veneer in residential and low-rise construction follows the prescriptive approach. The first edition of TMS 402 limited the use of prescriptive design to areas with a basic wind speed of 110 mph or less. The 2008 edition of TMS 402 extended the prescriptive requirements to include a basic wind speed of 130 mph, but limits the veneer wall area per tie that can be anchored with veneer ties to 70 percent of that allowed in lower wind speed regions. The 2008 edition requires rational design approaches in locations where the basic wind speeds exceed 130 mph.

Some noteworthy distinctions exist in the requirements for anchored brick veneer between the 2005 and the 2008 editions of TMS 402. For lower wind speed regions (110 mph and below), TMS 402-05 limited the vertical spacing of ties to 18 inches; the 2008 edition allows vertical ties to be spaced up to 25 inches, provided the wall area of veneer anchored per tie does not exceed 2.67 square feet. In TMS's high-wind regions (over 110 mph and up to 130 mph), both editions of the code limit vertical spacing to 18 inches. TMS 402-08 also limits the space between veneer anchored with corrugated ties and the wall sheathing to 1 inch. This is to avoid compression failures in the corrugated ties when they are exposed to positive pressures.

- The following Brick Industry Association (BIA) Technical Notes provide guidance on brick veneer: Technical Notes 28 – Anchored Brick Veneer, Wood Frame Construction; Technical Notes 28B – Brick Veneer/Steel Stud Walls; and Technical Notes 44B – Wall Ties. Although these Technical Notes provide attachment recommendations, the recommendations are inadequate because they are not specific for high-wind regions.