Recommendations

3.1 Building Foundation Systems

3.1.1 Piling Embedment for Structural Support

It is critical that coastal foundations be designed to survive the anticipated amount of erosion and scour. Erosion and scour combine to impact coastal piling foundations in three distinct ways. First, in the absence of cross-bracing, the loss of soil adjacent to a thin vertical foundation member results in a longer unsupported length. The increase in unsupported length allows for greater deflection of the vertical member. Second, the loss of soil adjacent to pilings leaves less soil to counteract lateral loads applied to the pilings by the structure above, the velocity flow of the storm surge, wave action, and debris impact. Third, pilings, which rely on friction between the piling and the adjacent soil to transfer loads into the ground, lose some of the resisting friction when the adjacent soil is eroded and scoured. The loss of friction reduces the ability of the piling to resist uplift loads from wind.

For the concerns discussed above to be adequately addressed, designs of coastal foundation systems must account for the conditions expected to occur during the base flood (100-year flood) and long-term erosion for the life of the building. The following documents offer guidance to designers of coastal foundations:

- The ASCE standard *ASCE 7-95, Minimum Design Loads Building and Other Structures.* The 1995 version of this standard includes, for the first time, criteria for determining flood loads (Chapter 5) and for combining flood and other loads to determine combined load factors (Chapter 2) for buildings that experience simultaneous wind and flood loads. This standard is available from ASCE. Portions, if not the whole standard, may well be incorporated by the model building code organizations into future versions of model building codes. This standard also meets, or exceeds, the minimum requirements of the NFIP for determining loads.
- The ASCE standard *Flood Resistant Design and Construction Practices.* This standard is currently in development and should be completed in 1997. It will be available from ASCE. This new standard will provide descriptive as well as prescriptive requirements regarding the design and construction of buildings that are to be located in floodprone areas. The draft of this standard presents the recommendations of some of the Nation's leading experts in coastal construction and meets or exceeds the minimum requirements of the NFIP.
- FEMA's *Coastal Construction Manual* (FEMA 55). This document provides further guidance on coastal foundation systems. It recommends that pilings be embedded to a depth of -10 feet m.s.l.
- FEMA's Technical Bulletin No. 5, *Free of Obstruction Requirements for Buildings Located in Coastal High Hazard Areas.* This document provides information on NFIP-compliant design and construction practices that can prevent damage to coastal buildings caused by below-building obstructions.

The BPAT recommends that in the absence of State or local requirements based on detailed engineering studies or the historical performance of coastal buildings subjected to base flood conditions, pilings for structures in areas subject to erosion and scour be embedded to -10 feet m.s.l. In areas with terminating strata that inhibit erosion and scour, and areas with rocky shorelines, foundation systems with shallower depths may be justified.

The findings of the W-C study suggest that in coastal areas of North Carolina where the ground elevations are at or below 11 feet m.s.l. the current requirements of the State Building Code regarding piling embedment depth may have been adequate to prevent foundation failure during Hurricane Fran. However, given the limitations of that study (as discussed in Appendix C), and the anticipated revisions to BFEs for North Carolina coastal communities as discussed in Section 2.10 of this report, it may be appropriate for the state to consider the need for piling embedment depth requirements more stringent than those in its current Code. These issues are discussed below.

All of the structures tested by W-C were located where the ground elevation was 11 feet m.s.l. or less. To meet the applicable code requirement, the pilings for these structures had to be embedded to a minimum of -5 feet m.s.l. In areas where the grade is greater than 11 feet m.s.l., pilings will meet the State Code if they are embedded 16 feet below average original grade. As a result, the bottoms of the pilings in these areas will be above -5 feet m.s.l. This embedment depth may not be sufficient for structures built on or directly behind frontal dunes, where extensive erosion and scour can cause the loss of the entire dune or remove so much of it that piling support becomes inadequate. There are areas within the state where this situation can occur. For structures in these areas, the state may want to consider revising the Code to require that piling embedment depth be -5 feet m.s.l. or 16 feet below grade, whichever is greater.

As noted in Section 2.10, FEMA is preparing revised FIRMs for several North Carolina communities affected by Hurricane Fran. Because the revised FIRMs are expected to include BFEs higher than those shown on the current FIRMs, new structures and substantially damaged structures that are reconstructed will have to be elevated higher to meet minimum NFIP requirements. As a result, these structures may be subject to different wind and flood loads than structures built previously, when lower elevation requirements applied, and increased piling embedment may be necessary.

In addition, the findings of the W-C study suggest that the State of North Carolina needs to emphasize the importance of inspection and code enforcement to ensure that all structure pilings meet current and any future Code requirements.

3.1.2 Piling Foundations for Decks, Porches, and Roof Overhangs

The design criteria for vertical foundation members for building extensions such as porches, decks, and roof overhangs must be equal to those for the foundation system of the main structure.

Oceanfront Residential Buildings

The vertical foundation members for decks, porches, and roof overhangs must be designed and constructed to maintain their ability to support the structure above. These building extensions are often on the ocean side of oceanfront structures, where they are exposed to amounts of storm surge, velocity flow, wave action, vertical erosion, and localized scour at least as great as those that affect the main structure. The foundation requirements for these building extensions should never be less stringent than those for the building itself. Because of the damage caused to the main structure when building extensions collapse and the debris they generate once they collapse, they should not be considered sacrificial. The only exceptions would be stairways and narrow walkways required for building access.

In areas subject to erosion and scour, embedment of vertical foundation members for building extensions should be based on a depth related m.s.l., not a depth below existing grade.

The BPAT recommends that in these areas, the requirements applied to the main building support system also be applied to the piling foundations for decks, porches, and roof overhangs. This recommendation is based on the observed performance of coastal buildings in many hurricanes, including Hurricane Fran

Landward Residential Buildings

In landward areas also, vertical foundation supports for building extensions such as decks, porches, and roof overhangs should meet the same requirements applied to the main building support system. In areas not subject to erosion but subject to localized scour, embedment of these foundation members may be based on a depth related to existing grade. From the observed performance of landward coastal buildings and building extensions, the continued use of an embedment depth of 8 feet is recommended for all vertical foundation members.

3.1.3 Grade of Lumber Used for Timber Pilings and Cross-Bracing

The requirements of the North Carolina State Building Code regarding the quality of wood materials used in the construction of residential building foundations, including wood piles and dimensional lumber, are set forth in Section R-309 of the Code. Section R-309 specifically addresses protection against decay. It states that all pressure-treated wood foundation members must bear the quality mark of a quality control inspection agency for pressure-treated wood that has been approved by the State Building Code Council. It does not contain any explicit requirements regarding grades of lumber used for vertical foundation members or cross bracing. Contractors and inspectors must therefore depend on their judgment in determining acceptable grades of lumber for these applications. To help avoid situations in which foundation strength is compromised by the use of lower-quality wood materials (as depicted in Figure 2-20), the State should consider amending the Code to include prescriptive language regarding the grade of wood materials used for vertical members and cross bracing in structure foundations.

3.1.4 Proper Elevation of Coastal Buildings

Buildings constructed in Coastal High Hazard Areas (V zones — as shown on NFIP FIRMs) must be elevated so that the lowest horizontal structural member of the lowest floor is at or above the BFE and the area below the building is free of obstructions. These requirements are intended to allow velocity flows and waves to pass freely under the building. When a building in a V zone meets these requirements, its lowest floor is usually 12 inches or more above BFE, because of the thickness of the floor diaphragm and the supporting beams. FIRMs for coastal communities usually show A zones landward of V zones. In A zones, a building's lowest floor must be elevated to or above the BFE, and areas below the BFE may contain obstructions. In B, C, and X zones, no elevation requirements apply.

The practice of elevating buildings on open foundations and ensuring that the lowest horizontal structure member is above the BFE was widely used in A, B, C, and X zones on the barrier islands impacted by Hurricane Fran Homes in these zones were often elevated 8 to 9 feet on embedded piling foundations to allow below-building parking and storage This practice undoubtedly resulted in much lower damages than would have occurred if the lowest floors of these homes had been elevated to the BFE in A zones and not elevated in B, C, and X zones. The practice of requiring V zone construction standards in coastal A zones exceeds NFIP minimum requirements. Coastal A zones subjected to velocity flow and wave action are not distinguished from other A zones on FIRMs. Communities on barrier islands may want to consider adopting stricter standards in areas of known high coastal hazard, whether or not they are currently identified as V zones.

A building elevated so that its lowest floor is above BFE can qualify for an extremely favorable flood insurance rate. Rates for buildings in both Zone A and Zone V are lowered incrementally for each 1-foot increase in the height of the lowest floor above the BFE, up to a maximum of 4 feet. For buildings at this height, the rate reduction is 33 percent in Zone A and 60 percent in Zone V. Rate reductions are justified because a building that exceeds the minimum elevation requirements generally has a low risk of being significantly damaged by flooding. Therefore, in the design process for a new building, elevating above the BFE is well worth considering. Local insurance agents can provide information concerning the flood insurance rates associated with elevating above the BFE.

3.1.5 Cross-Bracing Below Elevated Buildings

Whenever possible, piling foundations should be designed to withstand simultaneous wind and flood loads without the use of cross-bracing. Alternatives to cross-bracing that may provide the necessary stability include incorporating a structural, unroofed deck into the building design to increase the building footprint; using pilings that are larger, longer, or both; and reducing piling spacing. When cross-bracing is necessary, its use should be minimized to the extent possible, especially where it would be perpendicular to velocity flow, wave action, and debris impact. Whenever cross-bracing is used, regardless of its orientation, it must be designed to withstand the anticipated wind and flood loads.

3.1.6 Solid Perimeter Masonry Foundation Walls Supported on a Continuous Footing

The use of solid perimeter foundation walls in coastal flood hazard areas should be scrutinized carefully. Since these foundations create large obstructions to velocity flow and are usually backfilled with the native sandy material, they are extremely susceptible to extensive localized scour. This condition was observed to have occurred even in overwash areas where accretion of sand occurred. Scour occurred where the velocity flow was disrupted at the seaward face of the obstruction and where the flow reconverged at the landward face of the obstruction.

Only where an engineering analysis of potential scour has been completed by a professional engineer should coastal communities consider allowing solid perimeter wall foundation systems in landward areas subject to high-velocity flow. Engineering solutions to this problem could include backfilling the foundation excavation with soil that is resistant to scour and installing the footing at a depth that is below the expected depth of scour (see Figure 3-1). The preferred solution is to construct piling foundations in landward areas subject to high-velocity flow. Of course, solid perimeter walls should never be used in oceanfront areas and are not permitted in V Zones.

3.1.7 Manufactured (Mobile) Home and Permanently Installed RV Foundations

Manufactured (mobile) homes and permanently installed RVs are usually supported on dry-stack masonry foundations. When manufactured homes and RVs are installed, steps should be taken to protect them from the damage caused by foundation collapse due to scour, anchor strap failure due to corrosion, and anchor strap pullout due to the use of the wrong size or type of anchor.

Protecting the foundation from localized scour requires either controlling scour or providing a foundation that extends to a depth that is below the expected depth of scour. For example, controlling scour may involve excavating the area under the footprint of the home and replacing the excavated soil with a non-scourable soil or installing a geotextile fabric beneath the home. If a fabric is installed, it must be keyed-in around the edges so that the scour will not undercut the

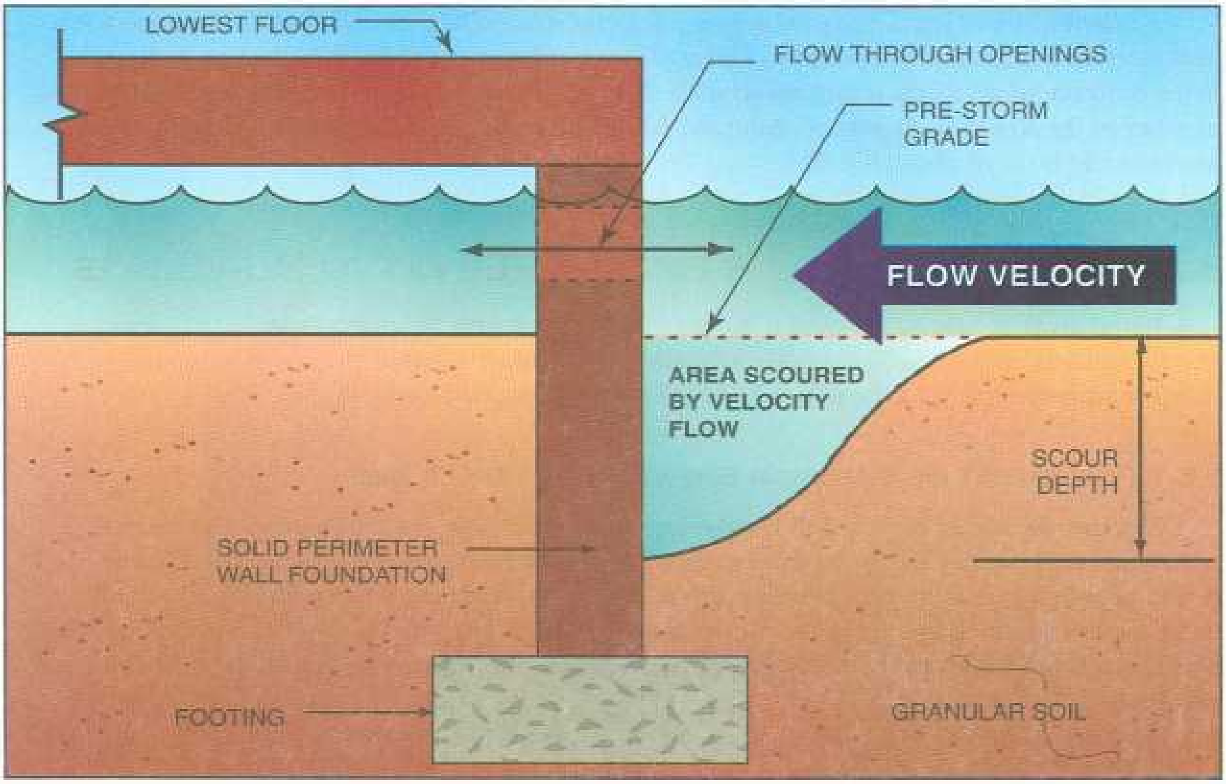

Figure 3-1 *Deepening foundation to account for scour.*

fabric. Providing a deep foundation can be done at minimal expense. A power-driven auger can be used to drill holes to a depth that exceeds the depth of the scour. The augured holes should be at least 1 foot in diameter and should exceed the expected scour depth by at least 1 foot. The deep foundation can consist of a wood post or cast-in-place concrete footing.

Metal straps used to tie down manufactured homes and RVs can become loose over time. In coastal areas, metal straps are also subject to higher rates of corrosion. Loose or corroded straps exposed to the loads imposed by high winds and flood waters are prone to failure, which can lead to damage to the foundation and home. It is critical that straps be checked periodically for both proper tension and corrosion. Checks for tension should be made frequently throughout the hurricane season and are especially important after high-wind events. All loose straps should be tightened according to the manufacturer's specifications. Straps that show visible signs of corrosion should be replaced. In coastal areas, metal straps have been shown to exhibit signs of corrosion after 3 to 5 years of exposure.

Pullout of anchors to soil saturation can be minimized through the use of the proper size and type of anchor. Anchors used in sandy soils prone to saturation by flood waters must either be long enough that the helical plates extend to a depth below the saturated soil, into soil that can resist anchor pullout, or be designed to work properly in saturated soil. In coastal areas subject to high-velocity flow that have loose to medium-dense sands and other granular soils, anchors should be at least 4 feet long and 3/4 inch in diameter and should have helical plates at least 6 inches in diameter. Major anchor manufacturers provide guidelines for selecting and installing the appropriate anchor according to the size of the home, the soil type at the installation site, and other conditions that can affect anchor performance. The manufacturer's specifications and recommendations should always be followed in the selection and installation of anchors.

To minimize the impact of tidal surge on manufactured homes and their foundations, it is recommended that in all Special Flood Hazard Areas subject to coastal flooding, including A zones, manufactured homes be elevated such that the bottom of the lowest horizontal structural member of the lowest floor is at or above the BFE. This means that the bottoms of the chassis I-beams would be at or above the BFE.

3.2 Breakaway Walls Below Elevated Buildings

When an area below an elevated building is enclosed with breakaway wall panels, special care should be taken to ensure that the placement and attachment of the panels does not interfere with the ability of the panels to break away when acted on by flood forces.

3.2.1 Placement of Exterior Sheathing Over Pilings

Exterior sheathing attached to breakaway wall panels must not extend over the vertical foundation members. This also applies to wire mesh used in exterior stucco systems. There should be a free and clear joint between the panels and vertical foundation members so that unnecessary lateral loads are not transferred to the foundation (see Figures 3-2 and 3-3). FEMA's *Coastal Construction Manual* provides guidance on how to fabricate wood-frame, metal-frame, and masonry breakaway panels.

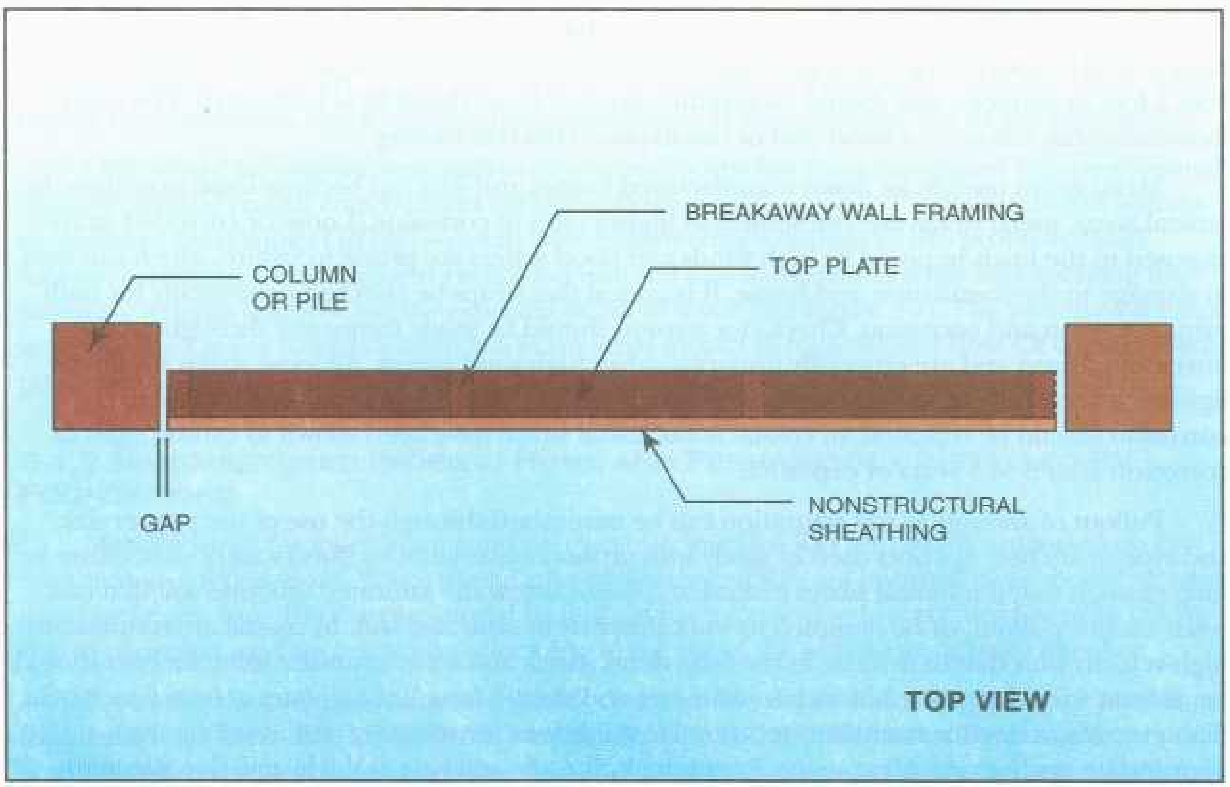

Figure 3-2 Recommended practice for breakaway wall sheathing.

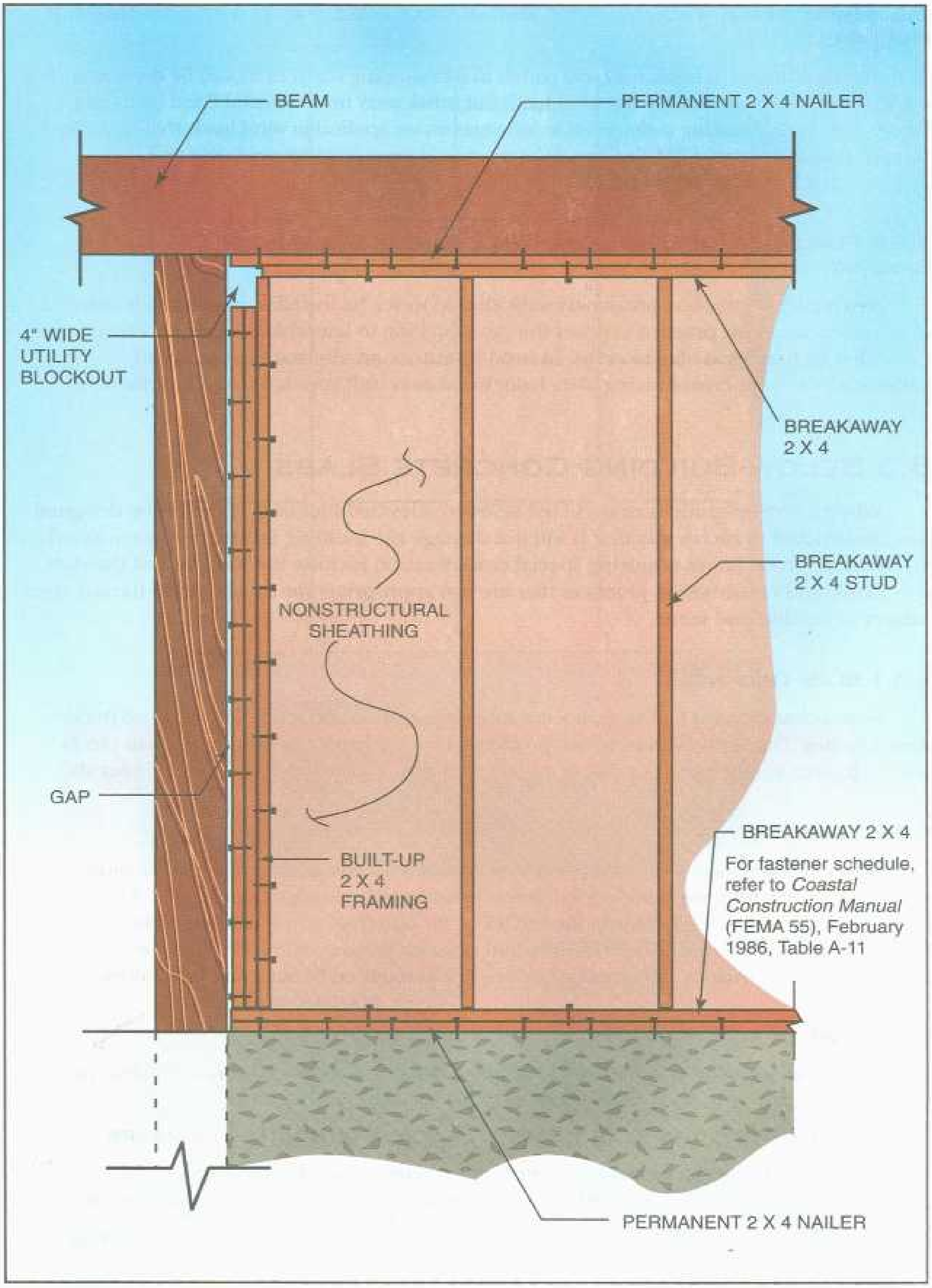

Figure 3-3 *Recommended breakaway wall attachment.*

3.2.2 Improper Attachment of Breakaway Wall Panels to Foundation Members

The attachment of breakaway wall panels to surrounding surfaces should be done in such a way that the panels will safely resist wind loads but break away under coastal flood loads (see Figure 3-3). Local building codes provide information on applicable wind loads that building components must resist. FEMA's *Coastal Construction Manual* provides guidance on how to properly attach breakaway wall panels.

3.2.3 Placement of Breakaway Wall Panels Seaward of Cross-Bracing

As a matter of practice, breakaway walls should never be installed immediately seaward of cross-bracing. This practice exposes the cross-bracing to lateral loads that far exceed those that 2x bracing is able to resist. In most instances, an alternative is to install latticework or move cross-bracing away from breakaway wall panels, into an interior area.

3.3 Below-Building Concrete Slabs

When a slab-on-grade is constructed below an elevated building, it should be designed and constructed in such a way that it will not damage the building foundation when acted on by flood forces. Issues requiring special consideration include the thickness of the slab, slab joints, and construction practices that are not appropriate for coastal flood hazard areas subject to erosion and scour.

3.3.1 Slab Thickness

Slabs below elevated buildings in areas subject to erosion and scour should be no thicker then 4 inches. Thicker slabs present two problems: they are harder to break into small pieces and each piece weighs more per unit of surface area than a same-sized piece of a thinner slab.

3.3.2 Slab Joints

Of the three types of joints described in Section 2.5.2, contraction joints are the most important for ensuring the frangibility of below-building slabs. As shown in Figure 3-4, contraction joints should be cut into the surface of the slab from piling to piling in both directions across the entire slab. Expansion and isolation joints should be installed as appropriate in accordance with standard practice or as required by State and local codes.

3.3.3 Wire Mesh

Wire mesh retards the ability of the slab to break apart and therefore should not be used.

3.3.4 Connecting the Slab to the Vertical Foundation Members

Slabs should never be connected to vertical foundations members when the slab is underlain by granular soil in areas subject to erosion and scour. This practice unnecessarily threatens the stability of the foundation system of elevated buildings.

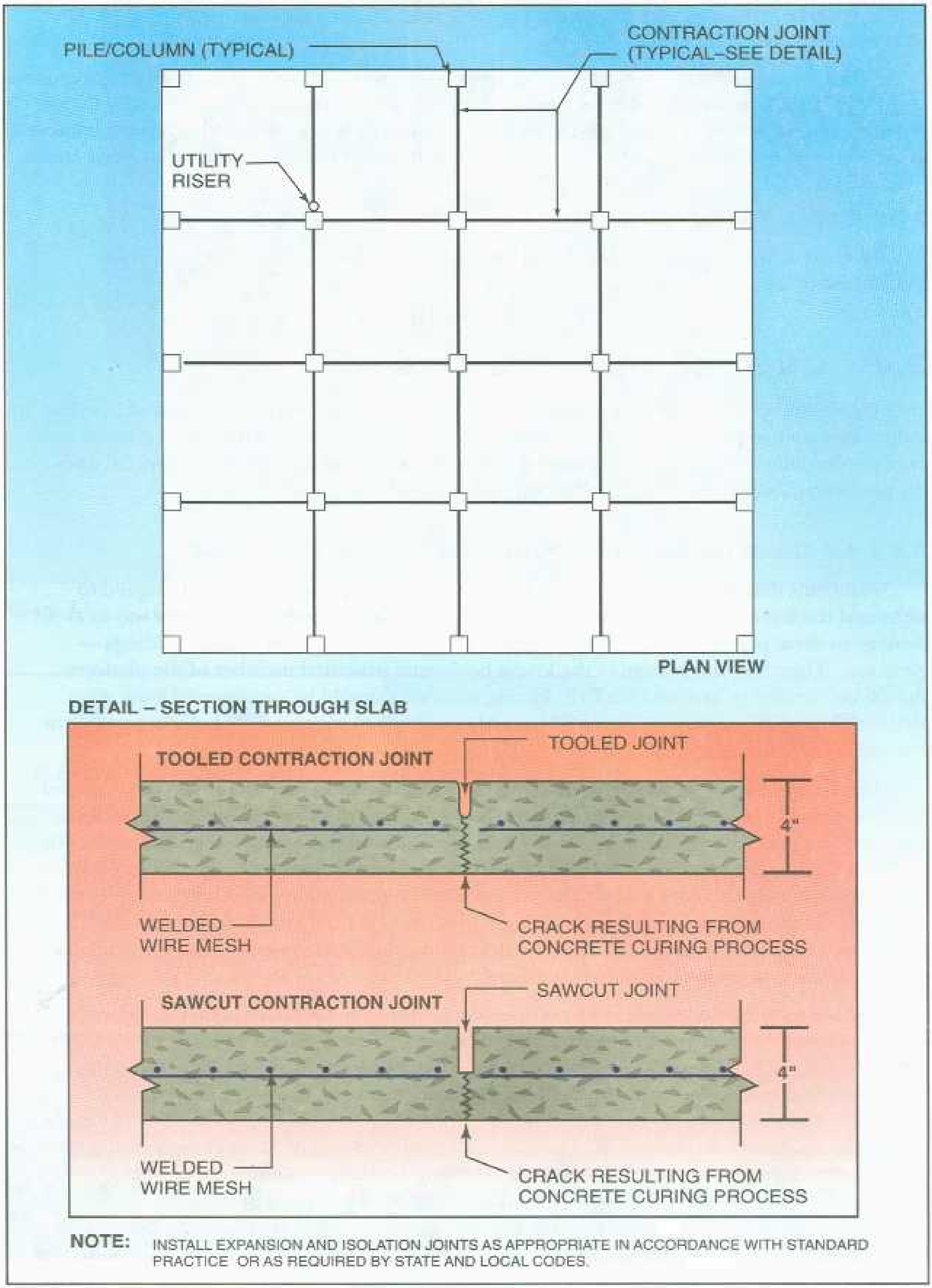

Figure 3-4 *Recommended contraction joint layout for frangible slab-on-grade below elevated building.*

3.3.5 Casting Concrete Grade Beams and Slabs-On-Grade Monolithically

Grade beams and slabs-on-grade should never be cast monolithically in areas subject to erosion and scour. In these areas, grade beams must be designed to be self-supporting (to account for the loss of supporting soil from erosion and scour) and to withstand velocity flow and debris impact as well as stiffen the foundation system. All slabs-on-grade must designed to act separately from grade beams.

3.3.6 Concrete Collars

In areas subject to erosion and scour, concrete collars should not be placed around foundation pilings.

3.4 On-Site Utility Systems

On-site utilities need to be installed with much greater attention to the effects of flooding. In some cases, such as placement of electrical meters, installation will need to be coordinated with local public utility companies. Installation of other items, such as septic systems, may fall under the purview of local or State health departments.

3.4.1 Air Conditioner / Heat Pump Compressor Platforms

Platforms that support air conditioner / heat pump compressors must be designed to withstand the forces associated with the base flood. In a coastal floodplain, the best way to avoid damage to these platforms is to employ the method used for the protection of buildings — elevation. Therefore the bottom of the lowest horizontal structural member of the platform should be elevated to or above the BFE. Ideally, platforms should be cantilevered from an elevated floor diaphragm (see Figure 3-5). An alternative is to support the platform partially or completely on pilings (see Figure 3-6).

Platforms designed and constructed with vertical foundation members must be protected from localized scour and, in oceanfront areas, protected from erosion so that the foundation members can resist the velocity flow, wave action, and debris impact found in coastal areas. When a vertical foundation member looses it ability to support the platform, the platform collapses, becoming waterborne debris that is then carried into the structure or nearby structure. Because of the cost of the compressor (often $2,000 and up), the potential loss of habitability when the compressor is rendered inoperable, and the debris that platforms generate once they collapse, these platforms cannot be considered sacrificial.

Vertical foundation members for compressor platforms in landward areas should meet the same requirements as the main building support system. In areas subject to scour, embedment of these foundation members should be based on a depth related to existing grade. From the observed performance of oceanfront buildings, an embedment depth of -10 feet m.s.l. is recommended for all vertical foundation members for oceanfront buildings. From the observed performance of landward coastal buildings, an embedment depth of 8 feet below existing grade is recommended for platform vertical foundation members. These recommendations are considered prudent in the absence of specific State and local requirements.

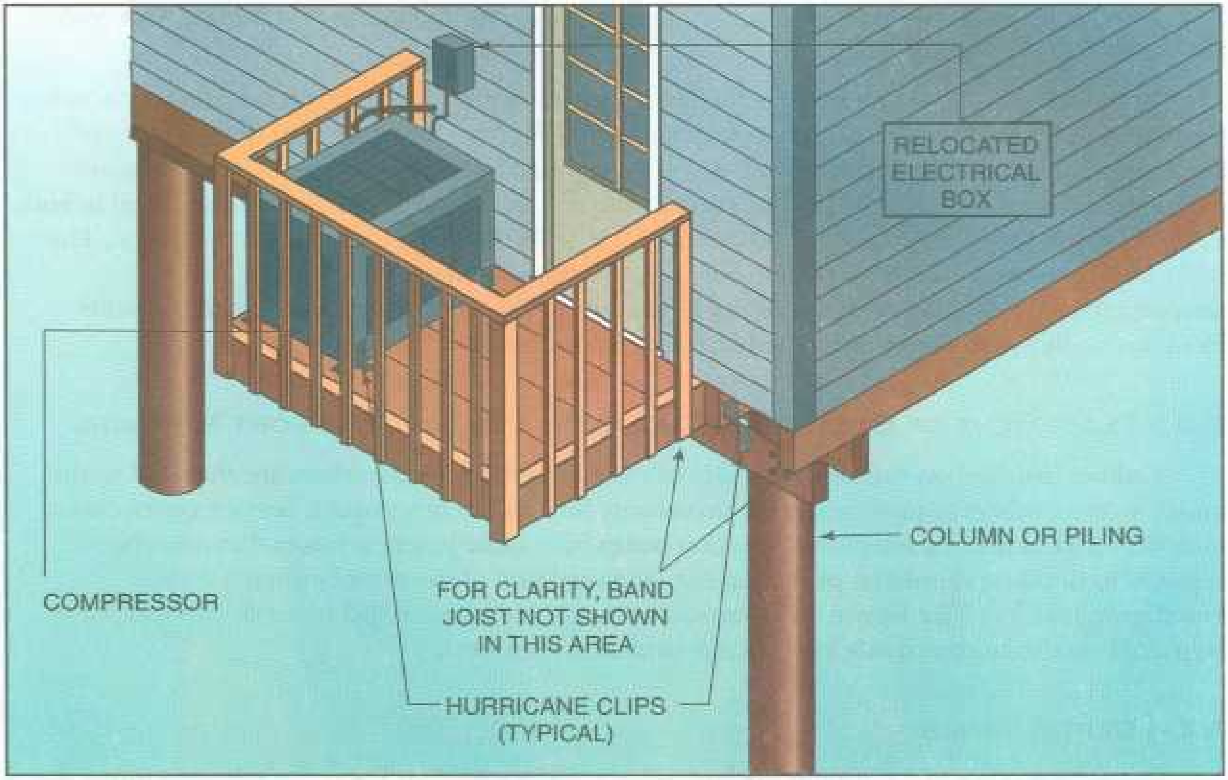

Figure 3-5 *Cantilevered mechanical platform.*

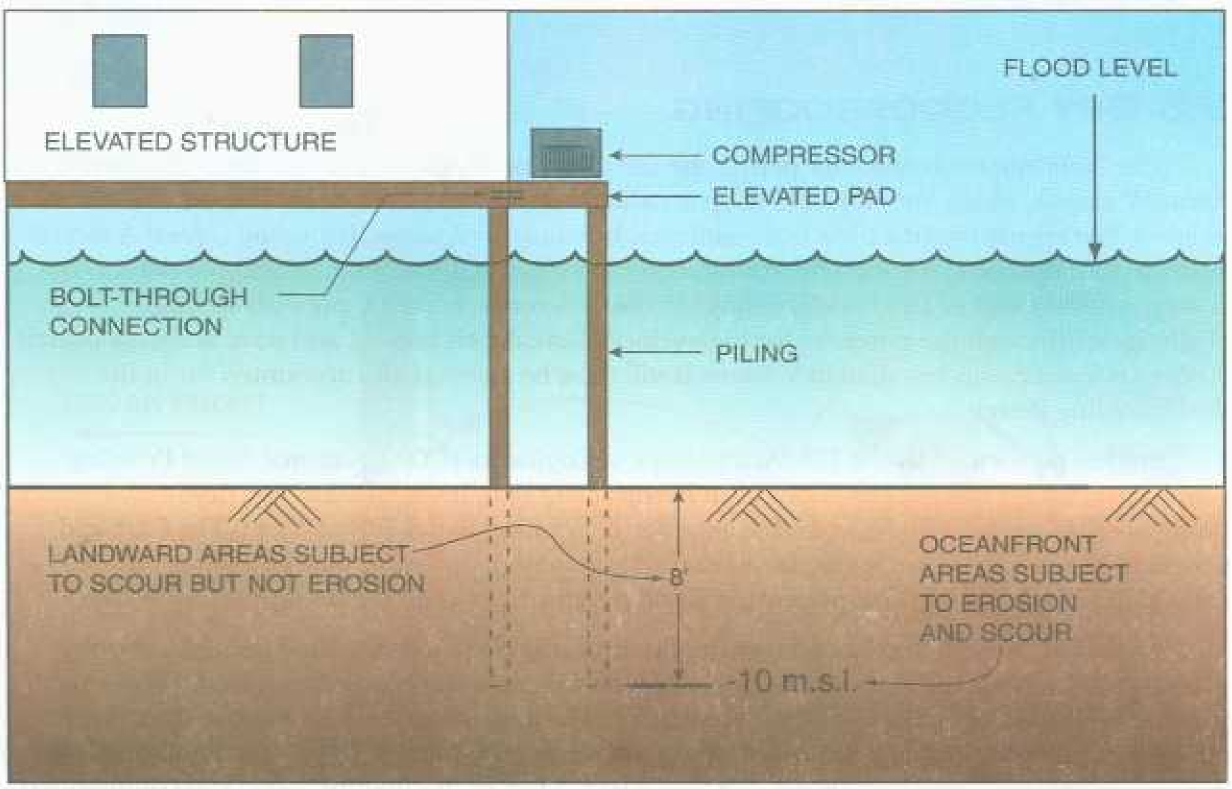

Figure 3-6 *Mechanical platform supported by pilings.*

3.4.2 Placement of Utilities on, Through, or Adjacent to Breakaway Wall Panels

Utility services should never be placed in a such a manner that they can be damaged when a breakaway wall panel breaks away or in such a way that they will interfere with the function of the breakaway panels. As noted in Section 2.6, the BPAT observed numerous types of utility system components mounted on or adjacent to breakaway wall panels. This practice is unacceptable and almost always results in the utility components being severely damaged during a hurricane. The BPAT also observed utility lines penetrating breakaway wall panels. This practice is also unacceptable. When it becomes necessary to extend these lines through a wall panel, a utility blockout, as shown in Figure 3-3, should be built into the wall.

3.4.3 Placement of Utilities Adjacent to Vertical Support Members

Utilities installed on the landward side of vertical foundation members are shielded by the foundation members against damage from velocity flow and debris impact. Service connections such as electrical meters, telephone junction boxes, and cable junction boxes that must be exposed to flooding should be placed on the landward side of the most landward vertical foundation member (see Figure 3-7). Vertical utilities such as sewer and water risers should also be placed on the landward side of vertical foundation members.

3.4.4 Septic Tanks

Septic tanks should be installed as far landward as practical and permitted by the authority having jurisdiction. Before septic tanks are installed, local and State Health Departments having regulatory control should be consulted concerning whether such tanks are permissible and how and where they should be installed.

3.5 Dry Floodproofing

The NFIP regulations do not permit the use of dry floodproofing in Coastal High Hazard Areas (V zones), which are subject to deep flooding, high-velocity flow, debris impact, and wave heights. The regulations do allow nonresidential buildings in A zones, including coastal A zones, to be dry floodproofed through the construction of walls that are substantially impervious to the passage of flood waters. Dry floodproofing in coastal A zones, however, presents special challenges. Although the potential for high-velocity flow, debris impact, and wave action in coastal A zones is significantly less than in V zones, it still must be assessed and accounted for in the dry floodproofing design.

Studies performed by the U.S. Army Corps of Engineers (COE) National Flood Proofing Committee, found in the COE publication *Floodproofing Tests*, 1988, indicate that dry floodproofing can be used in areas that experience flooding to a depth of 3 feet. The COE did not study coastal effects, including wave action. Wave action, especially waves breaking on the vertical dry floodproofing components, will add significant loads to the floodproofing system.

Therefore, it is recommended that dry floodproofing be used in coastal floodplains only where the stillwater depth is no more than 2 feet above grade during the base flood. Where the stillwater depth is 2 feet, the wave crest elevation will be approximately 1 foot above the stillwater elevation, and wave breaking and overtopping will reach even higher. To protect a building from wave overtopping where the stillwater depth is 2 feet, 4 feet of dry floodproofing is recommended (see Figure 3-8). In no case should the increase in floodproofing height be used to compensate for higher stillwater depths without a detailed engineering analysis.

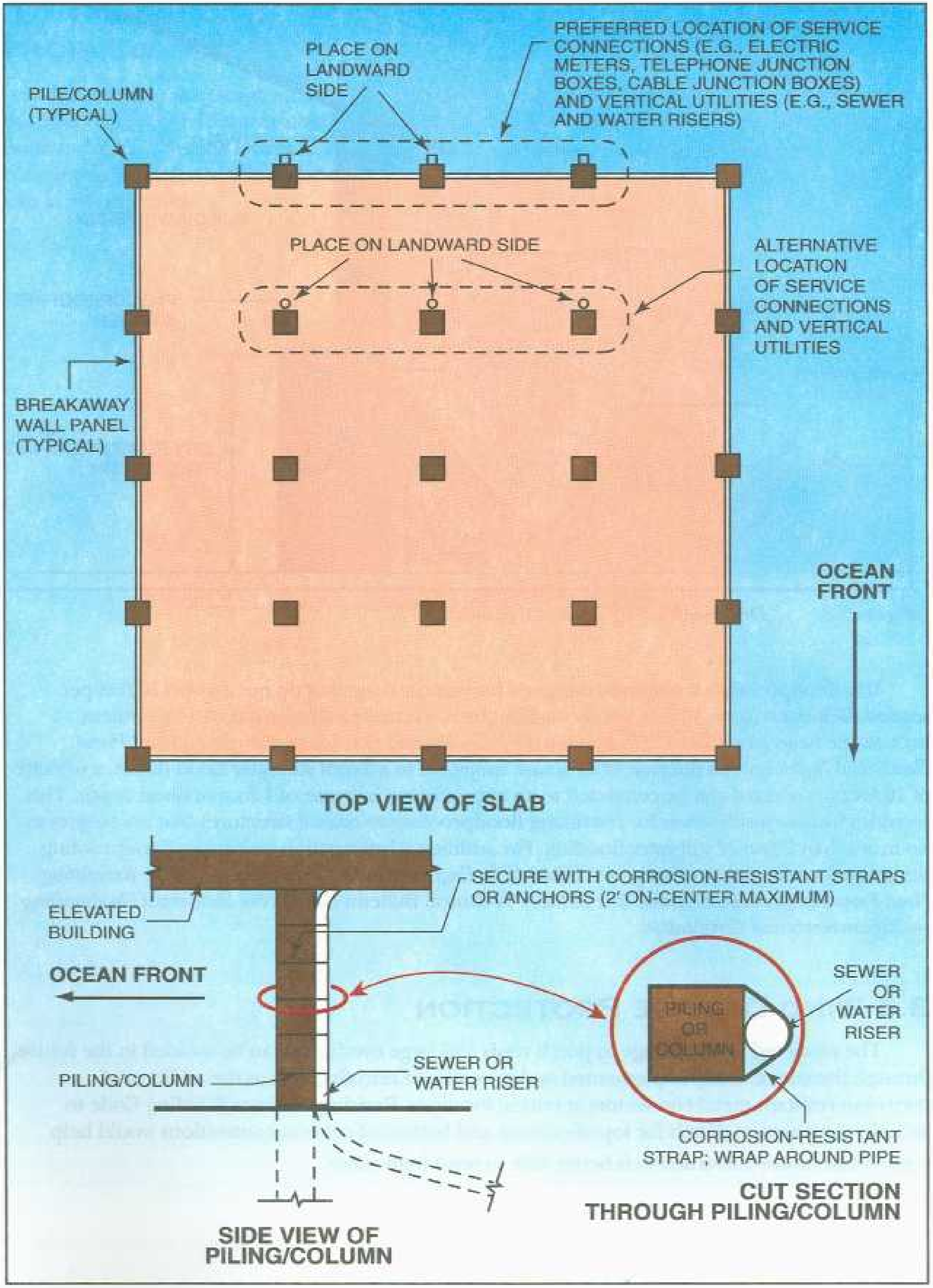

Figure 3-7 Proper location of utilities.

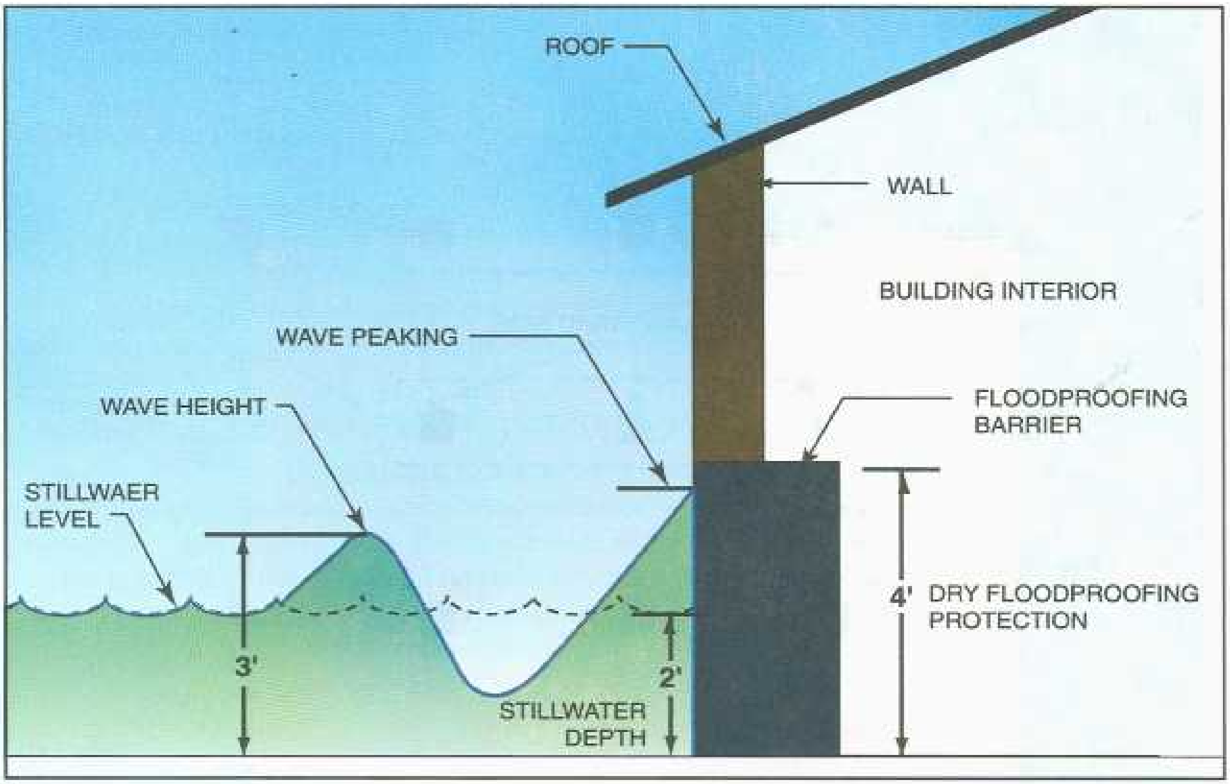

Figure 3-8 Dry floodproofing in coastal A zones.

Dry floodproofing is normally designed for velocity flows that do not exceed 10 feet per second. Velocities up to 10 feet per second can be converted to an approximate equivalent hydrostatic head (see FEMA 259: *Engineering Principles and Practices for Retrofitting Flood Prone Residential Buildings*). In the case of structure subjected to a 2-foot stillwater flood depth, a velocity of 10 feet per second can be converted to an approximate increase of 1 foot of flood depth. This provides further justification for restricting floodproofing to coastal structures that are subject to no more than 2 feet of stillwater flooding. For additional information on proper floodproofing design and construction criteria, see FEMA 259, *Engineering Principles and Practices for Retrofitting Flood-Prone Residential Structures*, and FEMA's Technical Bulletin No. 3, *Non-Residential Floodproofing — Requirements and Certification.*

3.6 Wind Damage Protection

The observed wind damage to porch roofs and large overhangs can be avoided in the future through the use of easily implemented and inexpensive retrofits, such as the addition of corrosion-resistant metal connectors at critical locations. Revising the State Building Code to include construction details for top-of-column and bottom-of-column connections would help ensure that future construction is better able to resist high winds.

3.7 Protection of Metal Structural Components from Corrosion

Maintaining the design strength of all structural components is critical. Any loss of strength can lead to structural failure during subsequent hurricanes. FEMA recently issued NFIP Technical Bulletin No. 8, *Corrosion Protection for Metal Connectors in Coastal Areas,* which provides guidance concerning the selection, installation, and maintenance of metal connectors such as truss plates and hurricane straps.