

Foundations in Coastal Areas



FEMA



HOME BUILDER'S GUIDE TO COASTAL CONSTRUCTION FEMA 499/August 2005 Technical Fact Sheet No. 11

Purpose: To describe foundation types suitable for coastal environments.

Key Issues

- Foundations in coastal areas must elevate buildings above the Base Flood Elevation (BFE), while withstanding flood forces, high winds, scour and erosion, and floating debris.
- Foundations used for inland construction are generally not suitable for coastal construction.
- Deeply embedded pile or column foundations are required for many coastal areas; in other coastal areas, they are recommended – instead of solid wall, crawlspace, slab, or other shallow foundations that can be undermined easily. ("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. 27).



Storm surge and waves overtopping a barrier island during Hurricane Frederic.

Foundation Design Criteria

All foundations for buildings in flood hazard areas must be constructed with flood-damage-resistant materials (see Fact Sheet No. 8) and must do two things in addition to meeting the requirements for conventional construction: (1) elevate the building above the 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 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 – it is required by the National Flood Insurance Program (NFIP) in V zones (even when the ground elevation lies above the BFE) and is recommended for coastal A zones. However, even a deeply embedded open pile foundation will not prevent eventual undermining and loss due to long-term erosion (see Fact Sheet No. 7).

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 by the *Home Builder's Guide to Coastal Construction* for A zones in coastal areas.

Fill – Because fill is susceptible to erosion, it is **prohibited as a means of providing structural support to buildings in V zones** and must **not** be used as a means of elevating buildings in **any other coastal area subject to erosion, waves, or fast-moving water.**

Slab-on-Grade – Slab-on-grade foundations are also susceptible to erosion and are therefore **prohibited in V zones**. They also are **not recommended for A zones in coastal areas**. (Note that parking slabs are often permitted below elevated buildings, but are themselves susceptible to undermining and collapse.)

Crawlspace – Crawlspace foundations are **prohibited in V zones** and are **not recommended for A zones in coastal areas**. They are susceptible to erosion when the footing depth is inadequate to prevent undermining. Crawlspace walls are also vulnerable to wave attack. 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 Sheet Nos. 15 and 27).

Stemwall – Stemwall foundations are similar to crawlspace foundations in construction, but the interior space that would otherwise form the crawlspace is often backfilled with gravel that supports a floor slab. Stemwall foundations have been observed to perform better during storms than many crawlspace and pier foundations. However, the building code may limit stemwall height to just a few feet. Flood openings are not required in a backfilled stemwall foundation. Stemwall foundations are **prohibited in V zones** but are **recommended in A zones subject to limited wave action**, as long as embedment of the wall is sufficient to resist erosion and scour.

Solid Foundation Walls – Solid foundation walls are **prohibited by the NFIP in V zones** and are not recommended for **A zones 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 Sheet Nos. 15 and 27.



Pier (column) failures: footings undermined and columns separated from footings.



Building failure caused by undermining of slab-on-grade foundation during Hurricane Fran.



Failure of crawlspace foundation undermined by scour.

Pier (column) – Pier foundations are **recommended for A zones 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 if materials and workmanship are not first rate. Fact Sheet No. 14 provides guidance on how to determine whether pier foundations are appropriate, and how to design and construct them.

Pile – Pile foundations are **recommended for V zones and many A zones in coastal areas**. 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 Sheet Nos. 12 and 13). Pile foundations with **inadequate embedment** will lead to **building collapse**. **Inadequately sized** piles are **vulnerable to breakage by waves and debris**.

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. 7), moving the building when it is threatened, or (where permitted and economically feasible) controlling erosion through slope stabilization and structural protection.



Pile failures led to collapse of floor of elevated building.



Insufficient pile embedment and failure of connections at tops of piles allowed elevated building to be floated off its foundation.



House undermined by bluff erosion. Photograph by Lesley Ewing. Courtesy of California Coastal Commission.

Foundations in V Zones With Ground Elevations Above the BFE

In some instances, coastal areas will be mapped on an NFIP Flood Insurance Rate Map (FIRM) as V zones, but will have dunes or bluffs with ground elevations above the BFE shown on the FIRM. **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.