Foundation Requirements and Recommendations for Elevated Homes

Hurricane Sandy Recovery Fact Sheet **May 2013**

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Many homes in New York and New Jersey damaged during Hurricane Sandy experienced flood levels that exceeded the base flood elevation (BFE). The Federal Emergency Management Agency's (FEMA) Mitigation Assessment Teams (MATs) observed several construction and foundation types in the disaster area. The assessment teams also observed narrow building lots and lots with constrained access that will pose construction challenges if those homes are required to be elevated or if owners elect to elevate them to reduce exposure to future flooding (Figure 1).

Base flood elevation (BFE): The height of the base (1-percent annual chance or 100-year) flood in relation to a specified datum.
Flood Insurance Rate Map (FIRM): an official map of a community, on which the Federal Insurance Administrator has delineated both the special hazard areas and the risk premium zones applicable to the community.
Special Flood Hazard Area (SFHA): the land in the flood plain within a community subject to a 1 percent or greater chance of flooding in any given year.

Figure 1: Homes on small, tightly spaced lots, typical throughout coastal New York and New Jersey, present access and construction challenges when being transitioned to a raised pile foundation (Rockaway, NY).

This fact sheet is intended to assist architects, builders, code officials, planners, and engineers with reconstruction and new construction to create elevated flood-resistant homes. The concepts in this fact sheet will help qualified, registered design professionals (licensed engineers or architects) determine proper site-specific foundation design recommendations when working on narrow lots and lots with constrained access. This fact sheet assumes the reader is familiar with National Flood Insurance Program (NFIP) Special Flood Hazard Area (SFHA) zone designations, including Coastal A Zones. For more information about the coastal SFHA zone designations, visit http://www.region2coastal.com/coastal-mapping-basics.

Of critical importance is how high a home must be elevated to reduce the risk of flooding. The minimum required elevation is based on the base flood elevation(BFE) shown on Flood Insurance Rate Maps (FIRMs), which are now being updated in many areas impacted by Hurricane Sandy to reflect changes to the physical, climatological, and scientific baseline that have occurred since the last maps were published. Shortly after Hurricane Sandy, FEMA issued Advisory BFEs (ABFEs) to help communities and homeowners make informed decisions as they rebuild. Additional elevation above the ABFE or Effective BFE, otherwise known as freeboard, may be required by a community.

This fact sheet includes:

- A description of basic NFIP criteria as they relate to flood insurance rates. It is financially advantageous for homeowners to renovate their homes in accordance with NFIP criteria. The first three pages of the Fact Sheet summarize some of the basic concepts about the NFIP.
- Design guidance for restoration projects involving existing elevated homes damaged by Hurricane Sandy. Many of these homes present renovation challenges because of their location on constrained building lots or the need to elevate a closed-foundation home on an open foundation. Design guidance begins on page four of this Fact Sheet.

National Flood Insurance Program Requirements

Communities that participate in the NFIP are required to adopt and enforce local regulations that apply to structures and all development located in areas mapped as SFHAs. The NFIP establishes minimum criteria and design performance requirements. These criteria specify how new structures and structures that have sustained Substantial Damage or are undergoing Substantial Improvement are to be constructed to minimize or eliminate the potential for flood damage.

Flood Insurance Rate Reform

On July 6, 2012, President Obama approved the Biggert-Waters Flood Insurance Reform Act of 2012 (BW12) which significantly changes the NFIP rating structure used to write flood insurance policies. Flood insurance premium rates are determined based on actual flood risk. “Grandfathering” and Federal flood insurance premium subsidies for many older structures will be eliminated over time. For more information about BW12, consult FEMA’s *Flood Insurance Reform Act of 2012: Impact of changes to the NFIP* (2013), available at http://www.fema.gov/library/viewRecord.do?id=7187.

Substantial Improvement / Substantial Damage

The NFIP requires that homes within mapped flood hazard areas, if determined by a community to have sustained Substantial Damage or be undergoing Substantial Improvement, be brought into full compliance with the flood provisions of current building code and local floodplain ordinances that meet or exceed the NFIP criteria. Homes that do not meet the definitions of Substantial Damage or

Designers, builders, and homeowners should consult with local building officials to determine whether local codes and regulations have more restrictive definitions and requirements, such as freeboard.

Basement: Any area of the building, including any sunken room or sunken portion of a room, having its floor below ground level (subgrade) on all sides.

Substantial Damage: Defined by the NFIP as “damage of any origin sustained by a structure whereby the cost of restoring the structure to its before-damaged condition would equal or exceed 50 percent of the market value of the structure before the damage occurred.”

Substantial Improvement: Defined by the NFIP as “any reconstruction, rehabilitation, addition, or other improvement of a structure, the cost of which equals or exceeds 50 percent of the market value of the structure before the ‘start of construction’ of the improvement. This term includes structures that have incurred ‘Substantial Damage,’ regardless of the actual repair work performed.”

Refer to FEMA P-758, Substantial Improvement / Substantial Damage Desk Reference (2010) for more information at http://www.fema.gov/library/viewRecord.do?id=4160.

Substantial Improvement are not required to be elevated. However, even if not required, homeowners should consider elevating to minimize damage in the event of a flood. Elevating homes to or above the BFE will substantially lower flood insurance premiums.

It is the community's responsibility to determine whether a building has sustained Substantial Damage or if proposed improvements are considered Substantial Improvements. The local official may ask homeowners for information about the costs to repair damaged homes and market value information based on a recent property appraisal. Other methods to estimate market value can be found in FEMA P-758, *Substantial Improvement / Substantial Damage Desk Reference* (2010). The Substantial Damage and Substantial Improvement requirements are included in community floodplain management regulations and building codes.

Know the Flood Risk before Repairing or Reconstructing the Home

Homeowners, builders, and design professionals need to know the flood risk for the location of the home in order to determine how high a home needs to be elevated. Most flooding that occurs is from either riverine or ocean sources. The first step in identifying flood risk is to determine whether a home is located within an SFHA and what BFE applies. This is done by reviewing the relevant FIRM and Flood Insurance Study (FIS), and talking to local floodplain administrators or building officials. The local official will confirm the location of the home using information from the FIRM and FIS. In addition, information on the source and type of flooding risks that could potentially affect the property, such as velocity flows, wave action, debris impact, and depth of flooding, is necessary to determine the type of foundation needed and other requirements.

FIRMs and ABFE Maps

Post-Hurricane Sandy ABFE maps are available for parts of New York and New Jersey at http://www.region2coastal.com/sandy/abfe

FIRMs for all other participating communities are available at https://msc.fema.gov and information on the publication of FIRMs is available at http://www.floodsmart.gov

Even homes elevated sufficiently to meet minimum NFIP criteria can experience flooding above the base flood. Many communities require that homes be elevated above the BFE. Consult Hurricane Sandy Recovery Advisory No. 5, *Designing for Flood Levels Above the Base Flood Elevation* (2013), for more information.

Advisory Base Flood Elevations: FEMA recommends that the best available data be used to plan for new construction and for homes that are being elevated or undergoing significant reconstruction or repair. This will ensure that all recovery construction is built stronger, safer, and less vulnerable to future flooding events.

Some communities have adopted the ABFEs issued after Hurricane Sandy. In those communities, reconstruction and repair of residential buildings that have been determined to have incurred Substantial Damage or are undergoing Substantial Improvement must be elevated to the ABFE rather than the BFEs shown on the Effective FIRM. Freeboard, which is additional elevation above the ABFE or Effective BFE, may also be required by the community.

New FIRMS. FEMA will begin to release new preliminary flood hazard information through work maps and eventually preliminary FIRMs to replace the ABFE data. Similar to the advisory data, the revised flood hazard information will be posted on FEMA's Geoplatform and http://www.Region2Coastal.com for public review and use as it becomes available. Stakeholders are encouraged to check these Web sites frequently as FEMA will replace the advisory data with the preliminary data as it is developed through the year. Preliminary FIRMs will undergo a public review period and statutory appeal period prior to being adopted by communities as the Effective FIRM. In certain locations, the new FIRMs may result in higher base flood elevations or higher risk zone designations than are shown on current FIRMs. These new base flood elevations and flood risk zones will affect the minimum building requirements.

Once the new FIRMs are published, the NFIP flood premiums will be rated using the new flood zones and BFEs. Homes elevated to the previous BFE will have flood insurance rated based on the new FIRMs and may be subject to higher premiums. Homeowners who already have elevated homes should reevaluate their risk based on the ABFEs, even if their homes had only minor damage or were not damaged during Sandy. For more information about the implications of flood insurance related to elevating a home, consult Hurricane Sandy Recovery Advisory No. 7, *Reducing Flood Risk and Flood Insurance Premiums for Existing Buildings* (2013).

Construction Types of Buildings Damaged in Hurricane Sandy

The damaged homes observed by FEMA's MATs were of several different construction types, including wood frame, masonry, and masonry veneer. Some homes had basements, some had crawlspaces, some had masonry piers, and some were slabs-on-grade. Figure 2 shows these typical foundation types. The homeowner, in conjunction with the local official and/or design professional, can decide the best course of action for a damaged home based on information from the Substantial Damage determination, the condition of the building, and an evaluation of the flood risk. Possible actions may include elevating the home, relocating it to a site outside the SFHA, or demolishing it and building a new home.

If the home can be elevated, the type of compliant foundation design that can be used is determined by the construction type, foundation type, and the flood zone in which the home is located. For example, generally the most appropriate elevation technique for frame homes is to elevate on extended foundation walls or open foundations. Techniques used for masonry homes include: 1) extend the walls of the home upward and raise the lower floor to or above the required elevation; and 2) abandon the lowest floor by converting it to a garage or storage area, and move the living area to an upper floor. In terms of foundation types, slab-on-grade homes are generally more difficult to elevate than homes on basement, crawlspace, or pier foundations. Elevating homes with basement foundations involves elevating or relocating utility equipment usually found in basements and filling in the basement.

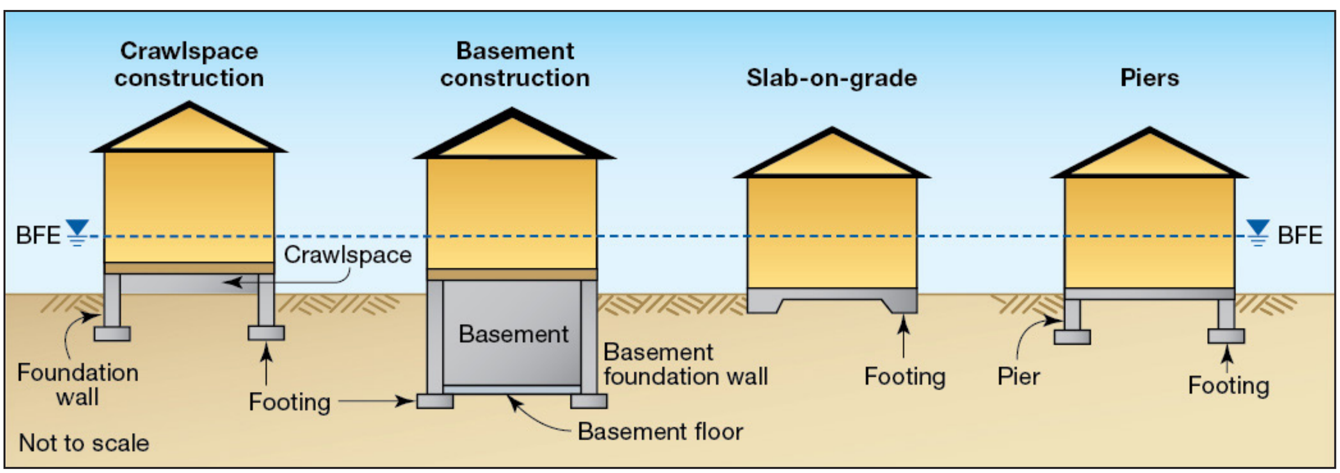

Figure 2: Types of homes observed in the disaster area.

Compliant Designs for Homes Located in Zone A

Homes located in Zone A should have foundations that comply with local floodplain management and building code requirements. Compliance with the requirements and determination of NFIP flood insurance premiums are based on the elevation of the top of the lowest floor, which is defined as the lowest floor of the lowest enclosed area including the basement. However, unfinished or flood damage-resistant areas, usable solely for parking of vehicles, building access, or storage in an area other than a basement are not considered lowest floors, provided the areas are not built so as to render the structure in violation of the applicable design requirements. For more specific information about the NFIP criteria, consult Hurricane Sandy Recovery Advisory No. 5, *Designing for Flood Levels Above the Base Flood Elevation* (2013).

All new homes and homes determined to have sustained Substantial Damage or that will be Substantially Improved must adhere to the following criteria:

- All buildings must be properly **anchored** to resist, flotation, collapse, and lateral movement.
- The **top of the lowest floor must elevated to, or above, the required elevation** (Figure 3).
- Homes can be elevated on perimeter foundation walls, or on piles, piers, or columns. If permitted by the community, elevation can also be achieved by placing fill under the structure. If the community permits fill to be placed below the BFE, the fill must be compacted and protected against **scour and erosion**. It is easiest to place fill before a home is constructed or, for existing homes, when the home is temporarily relocated.

Scour refers to a localized loss of soil, often around a foundation element due to flood flow obstruction or interaction. Scour can be determined by procedures included in FEMA P-55, Coastal Construction Manual (2011).

Erosion is the process of the gradual wearing away of land masses. Erosion estimations should be based on local historical data. These data can be obtained from local and State agencies, universities, site-specific studies, and consultation with a design professional knowledgeable about the area.

- **Basements are not permitted**. To be compliant, existing below-grade areas must be backfilled.
- Walls of enclosed areas below elevated homes must have **flood openings** that allow floodwaters to automatically equalize during an event. For more information, consult FEMA NFIP Technical Bulletin 1, *Openings in Foundation Walls and Walls of Enclosures* (2008).
- Enclosed areas below elevated buildings are permitted to be used only for **parking, building access, and storage**.
- **Utilities**, including electrical, heating, ventilation, plumbing, air-conditioning equipment (including ductwork) must be elevated above the BFE, or specifically designed to prevent water from entering or accumulating within the components during flooding.
- **Flood damage-resistant construction materials** must be used below the BFE. For more information, consult FEMA NFIP Technical Bulletin 2, *Flood Damage Resistant Materials Requirements* (2008).
- When the lowest floor is set, and again prior to final inspection, builders must obtain **elevation certificates** to document compliance. Owners need these certificates to obtain NFIP flood insurance.
- Construction of the home and other development must not result in any increase in flood levels within the community during the occurrence of the Base Flood discharge.

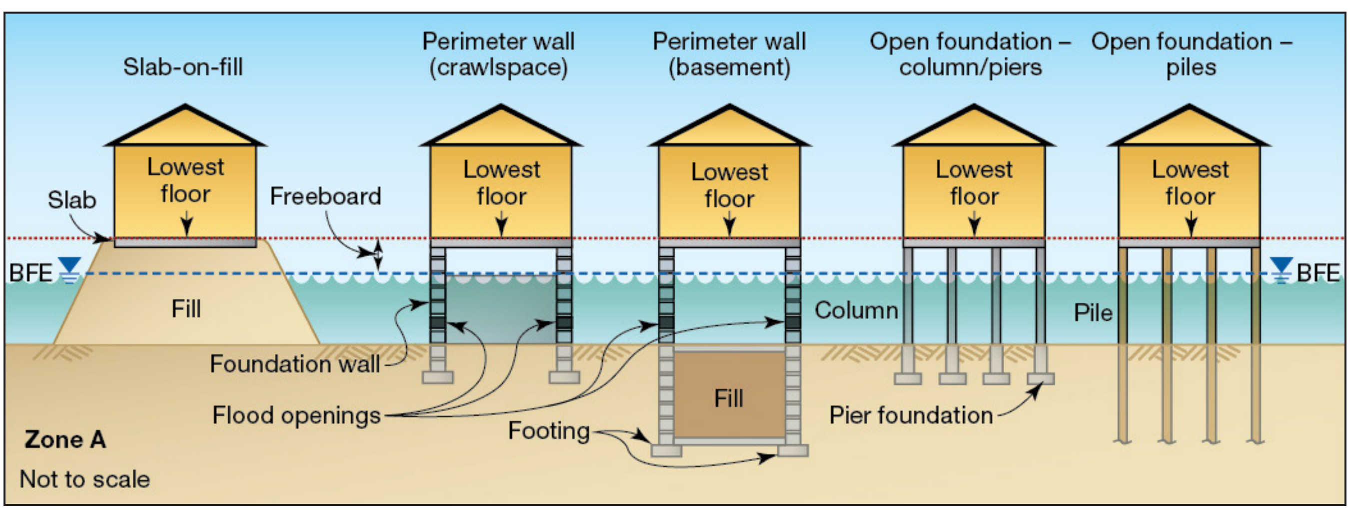

Figure 3: Examples of NFIP-compliant homes in Zone A where the top of the lowest floor is located above the BFE.

Compliant Designs for Homes Located in Zone V

The NFIP criteria, the community's floodplain management regulations, and building codes all require homes in coastal high hazard areas (Zone V) to have open foundations (piers, columns, or piles). Open foundations are required in areas subject to high-velocity wave action because the reduced surface area of the foundation reduces the hydrodynamic and breaking wave loads acting on the building and the building's vulnerability to scour and erosion. Foundation performance in areas subject to storm surge and wave loads improves significantly with a deep, open foundation. These foundations, including alternatives described in this fact sheet, are usually constructed with treated timber, concrete, or steel piles driven to a depth such that the strength of the foundation is not compromised by the erosion and scour common for coastal storm surges. Because the NFIP requires a licensed engineer or architect to design and certify foundations for buildings in Zone V, as well as many of the other factors that go into designing foundations, some decisions about types of foundation elements and connections are the responsibility of the registered design professional.

All new homes and homes determined to have sustained Substantial Damage or that will be Substantially Improved must adhere to the following criteria:

- All residential buildings must be properly **anchored**. The NFIP requires open pile or column foundations and structures attached thereto to be anchored to resist flotation, collapse, and lateral movement due to the effects of wind and water loads acting simultaneously on all building components.
- **Open foundations** (piers, pilings, or columns) are required (Figure 4). Closed foundations, such as solid masonry or concrete walls, and use of fill, are not permitted.
- **Basements are not permitted**. To be compliant, existing below-grade areas must be backfilled to or above the adjacent ground surface.
- The **bottom of the lowest horizontal structural member of the lowest floor must elevated to the required elevation.**
- Enclosed areas below elevated buildings are permitted to be used only for **parking, building access, and storage**.
- Areas below elevated buildings must be **free of obstructions**. The space below the lowest floor can be enclosed by non-supporting breakaway walls, open-wood lattice work, and insect screening intended to collapse under wind and water loads. For more information, consult FEMA NFIP Technical Bulletin 5, *Free of Obstruction Requirements for Buildings Located in Coastal High Hazard Areas* (2008).
- **Walls must be designed to break away** under base flood conditions when used to enclose areas below elevated buildings. For more information, consult FEMA NFIP Technical Bulletin 9, *Design and Construction Guidance for Breakaway Walls* (2008).
- **Flood damage-resistant construction materials** must be used below the BFE. For more information, consult FEMA NFIP Technical Bulletin 2, *Flood Damage Resistant Materials Requirements* (2008).
- **Utilities**, including electrical, heating, ventilation, plumbing, and air-conditioning equipment (including ductwork) must be elevated on platforms, which may be attached to the building above the BFE.
- When the lowest floor is set, and again prior to final inspection, builders must obtain **elevation certificates** to document compliance. Owners need these certificates to obtain NFIP flood insurance.
- The design and methods of construction must be **certified by a registered design professional** to be in accordance with an accepted standard of practice for meeting Zone V design requirements.

The current accepted standard of practice is ASCE 24, *Flood Resistant Design and Construction*. The IRC allows ASCE 24 to be used as an alternative to the Zone V requirements. FEMA recommends that designers use it when designing homes in Zone V. ASCE 24 has more detailed criteria and commentary and specifically requires foundation designs to account for **erosion and scour**, among other considerations.

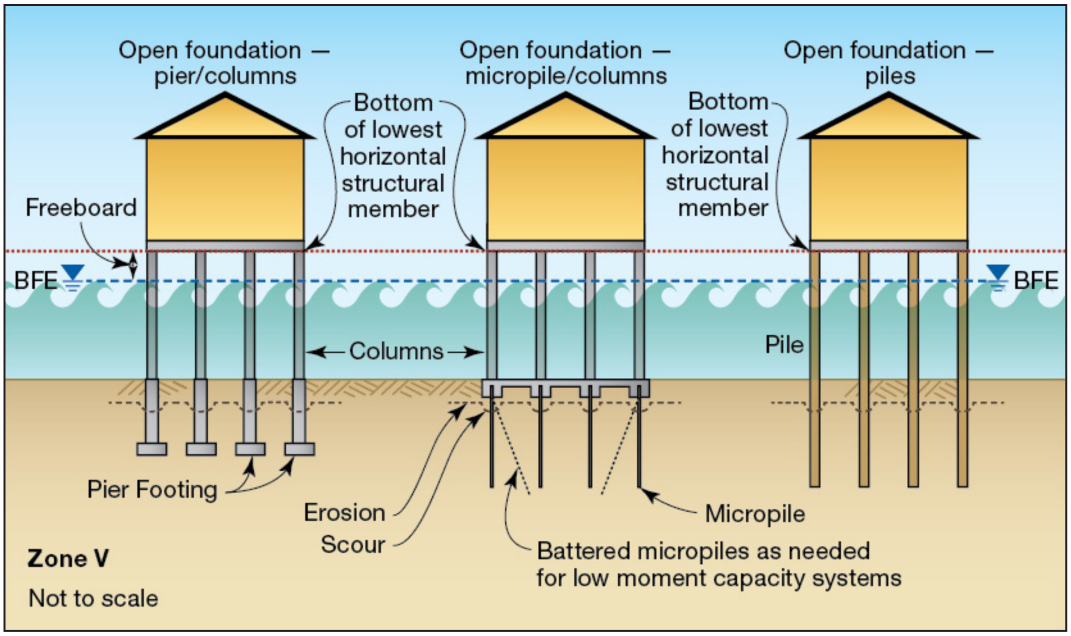

Figure 4: Examples of NFIP-compliant foundations in Zone V in which the bottom of the lowest horizontal structural member is located above the BFE.

- All new residential buildings must be **landward of the reach of mean high tide** to protect these buildings from damaging waves. Further, man-made alteration of sand dunes and mangrove stands is prohibited if potential for flood damage is increased.

Solutions for Elevated Construction on Open Foundations

Homes on small lots or with limited access require special methods to elevate-in-place (Figure 5). Small lots may not have adequate space on which to relocate a home while new foundation piles are driven. Horizontal and vertical clearances needed to elevate-in-place and drive traditional piles may also be inadequate. Alternative (non-timber pile) open foundations may be more feasible when lot size is a constraining factor.

One solution for elevating a home on a small lot is to place a system of concrete columns and construct grade beams to support the elevated home. For more information on grade beams, consult Section 10.5.6 of FEMA P-55, Coastal Construction Manual (2011).

Another option for elevating a home on a small lot, if permitted by local building codes, is to incorporate deep foundation elements, such as micropiles, into the footings to increase building support and resist the lateral and uplift loads caused by high winds, flooding, scour, or erosion. Foundation elements such as micropiles or helical piles can

Figure 5: Elevating tightly spaced homes, such as these in Breezy Point, NY, presents construction challenges.

be installed even if there are minimal horizontal or low vertical clearances, and when there are limitations on disturbance to neighboring homes.

Achieving proper open foundation designs for small lots may require owners to consult with a geotechnical engineer and a structural engineer, who may also need to work with an elevation contractor and a specialty foundation contractor. The need to protect neighboring homes and utilities also affects construction risks and costs, and will need to be considered when selecting the appropriate foundation alternative.

Pier Foundations

Pier (a type of column) foundations are typically constructed of either reinforced concrete or reinforced masonry columns. Piers are generally placed on footings to support the elevated home. Without footings, piers function as short piles and rarely have sufficient capacity to resist uplift, lateral, and gravity loads. Additionally, when exposed to lateral loads, discrete footings can rotate (Figure 6) and therefore, piers supported by discrete footings are not recommended in coastal environments.

Figure 6: Discrete pier footings undermined by erosion and scour in Mantoloking, NJ.

Piers supported with continuous concrete footings provide much greater resistance to lateral loads because the footings can act as an integrated unit to resist rotation. The integrated footing system must be steel reinforced to resist moment forces that develop at the base of the piers as a result of lateral loads on the foundation and elevated home.

Pier foundations are typically shallow due to excavation constraints and are appropriate only where there is limited potential for erosion and scour. To prevent the continuous footing system from being undermined, the foundations must extend below the maximum estimated depth for long- and short-term erosion and localized scour.

In some case, existing pier foundations may be retrofitted with grade beams to provide enhanced lateral support. See the section titled “Pile Foundations” for more information on grade beams.

Pile Foundations

Pile foundations are required in Zone V coastal environments so that waves can pass more easily under elevated homes. Traditional piles are typically constructed of treated timber, steel, or precast concrete and are driven into the ground to a depth required to resist vertical and lateral loads from gravity, wind, and flood forces. Pile foundations use the soil’s resistance to support the elevated home.

Critical aspects of a pile foundation include the pile size and spacing, installation method, embedment depth, bracing, and the connection to the elevated home. Piles that are properly sized, spaced, installed, and braced, and have adequate embedment into the soil (with consideration for erosion and scour effects) will perform properly and allow the home to remain standing and intact following a design flood event. For more information about scour and erosion, refer to section 3.1.1.2 of FEMA’s *Hurricane Ike in Texas and Louisiana: Mitigation Assessment Team Report* (2009).

Piles can be used with or without grade beams. When used without grade beams, piles extend to the lowest floor of the elevated home. Improved performance is achieved when the piles extend beyond the lowest floor to an upper floor level, although owners should check with an insurance agent to understand how the extended piles will be rated for flood insurance. Using grade beams provides resistance to rotation (also called "fixity") in the top of the embedded piles and improves stiffness of the pile foundation system against lateral loading.

When used together, piles and grade beams work together to support the elevated home and transfer vertical and lateral loads imposed on the elevated home and foundation to the ground below. Design and installation of grade beams should include the following concepts:

- Grade beam design criteria should include resisting lateral flood loads from both hydrodynamic forces and flood-borne debris impacts.
- Grade beams are to provide horizontal bracing of piers or piles and should not directly support any vertical load-carrying elements such as floor slabs. They should be designed to be self-supporting between vertical foundation members, such as piles, to account for cases when erosion and scour extend below the grade beam. According to NFIP requirements, grade beams that are structurally connected to slabs are considered to be the lowest horizontal structural member supporting the slab, which is a nonconforming use below BFE and severely increases flood insurance premiums if present.

Micropile Foundations

Foundations supported on micropiles function similarly to deep pile foundations. Micropiles are defined in the International Building Code (IBC) as 12-inch-diameter (305mm) or less, bored, grouted-in-place piles incorporating steel pipe (casing) and/or steel reinforcement. When used for new construction, traditional driven piles are typically more cost effective than micropiles. However, micropiles may be the only feasible and cost effective retrofitting solution when access is limited, horizontal or vertical clearances are limited, or when strict control of vibrations and settlement is required (Figure 7).

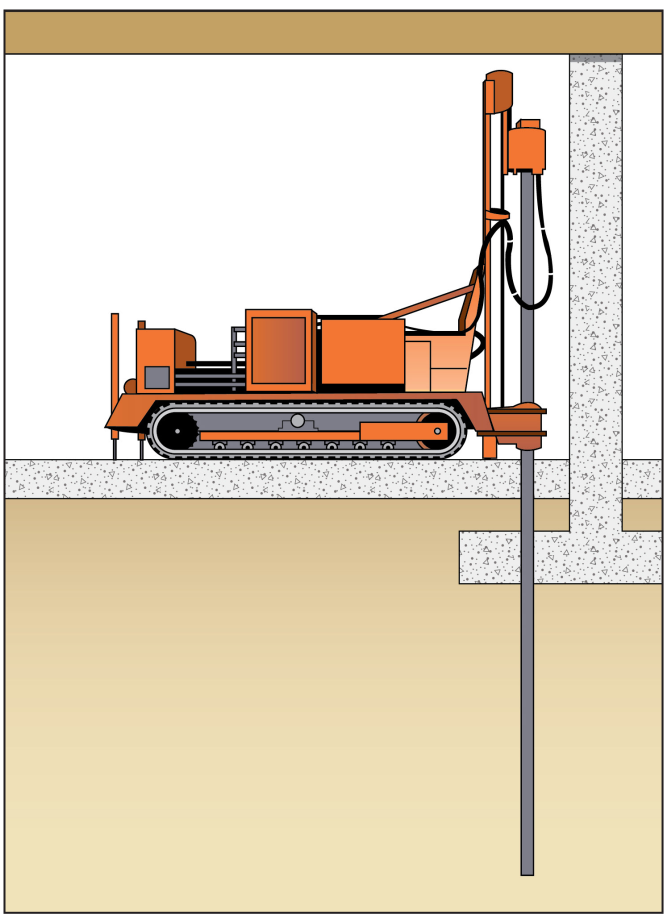

Figure 7: Example of a micropile drill rig.

Micropiles are usually smaller in diameter than traditional piles and can be designed to perform under a wide variety of soil conditions. Micropiles can be designed to resist compressive, tensile, or shear structural loads for most situations (Figure 8a). The equipment used to install these piles is compact (such as small, front-end loader attachments), and results in less disturbance and vibration to existing homes than traditional pile-driving equipment.

Current best practices, including Federal Highway Administration (FHWA) criteria described in FHWA NHI-05-039, *Micropile Design and Construction Guidelines Manual* (FHWA 2005) should be used to develop micropile design capacity. Micropiles can be used for underpinning applications, such as halting structural movement, repairing or replacing inadequate foundations, and providing scour and erosion protection, and can transfer loads to deeper, more competent bearing strata.

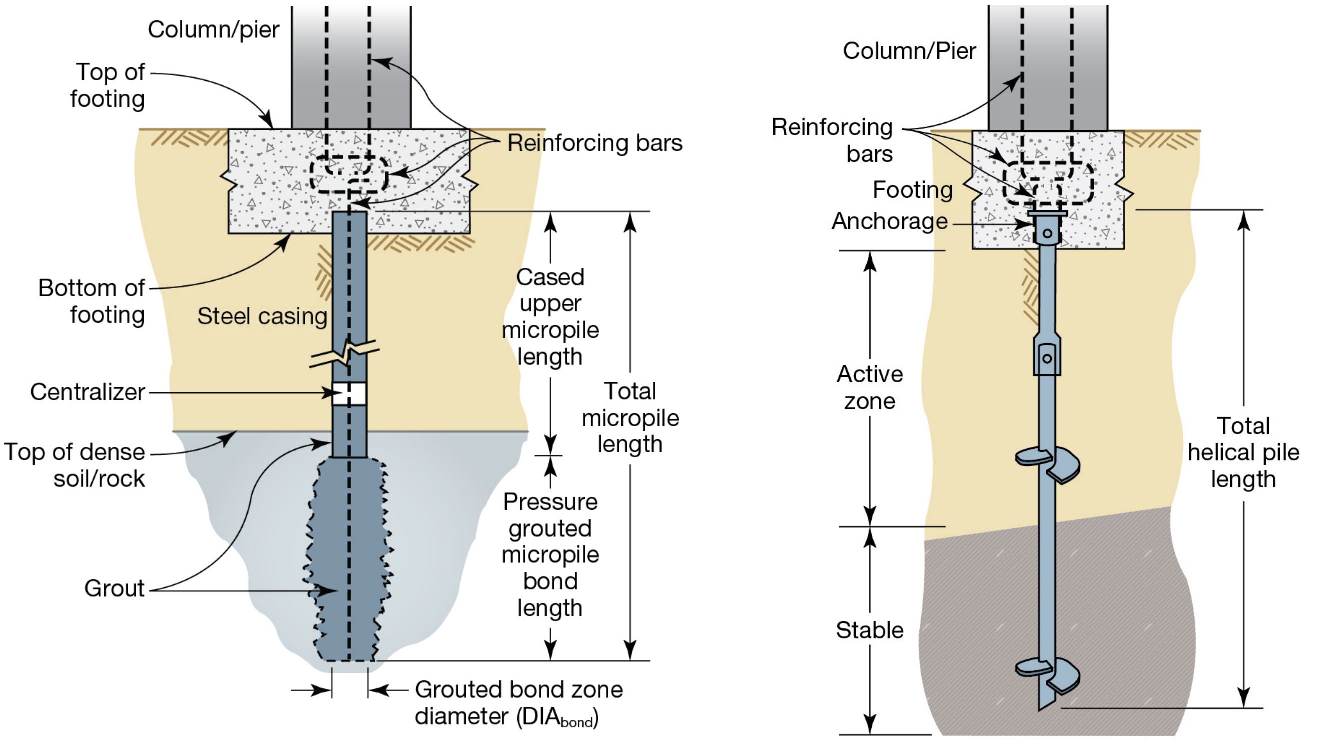

Figure 8: Example of a grouted micropile (8a) and a helical pile (8b).

With a relatively small diameter, micropiles have limited lateral capacity compared to larger traditional piles, and may require grade beams or bracing to resist lateral loads, including flood loads. The bracing must be designed to limit deflections under flood forces when exposed by scour and erosion, or under other conditions of reduced lateral soil support such as areas of soft, weak soils, soils with seismic liquefaction potential, or in areas where subsurface voids are present.

A detailed geotechnical investigation must be completed to determine the quality of the bearing soil or rock strata, whether grouting is needed to fill voids, and to select an installation method (i.e., drilling through rock or boulders vs. driving piles through soft material).

Helical piles are a type of micropile with an auger helix on the end of a slender shaft, which is drilled into the ground (Figure 8b). A helical pile is defined in the 2012 IBC as a manufactured steel, deep foundation element consisting of a central shaft and one or more helical bearing plates. Each helical bearing plate is formed into a screw thread with a uniform defined pitch.

Helical bearing plates attached to the central shaft act as the bearing surface to resist compressive forces from the elevated structure. Increased bearing capacities can be provided by using larger diameter helixes or by attaching more piles to the foundation. As with other micropiles, there is little lateral resistance provided by the helical pile itself, so resistance must be provided by a strong moment-resisting connection to the foundation. Helical piles can be a cost-effective solution to deep/open foundation requirements where access and vertical and horizontal clearances are limited.

Design Considerations

To successfully elevate a home on an open foundation, site-specific conditions must be identified. Once the site-specific conditions are identified and evaluated, a proper design can then be implemented.

Site-Specific Design Considerations for Homes Elevated on Open Foundations

Some of the site-specific factors that must be considered include soil conditions; the required elevation; the flood, wind, and seismic loads the building must be designed to resist; and whether the existing home is structurally sound enough to elevate-in-place. Table 1 presents design considerations for elevating buildings on open

Table 1: Design Considerations for Elevating Buildings on Open Foundations in Zone V (and Coastal A Zones)

Overall Category	Data Needed	Consider
State and local requirements	State and local building code requirements Local flood ordinance requirements Zoning ordinance requirements BFE or ABFE, if applicable Natural resources conservation regulations	Open foundations are required in Zone V For new homes and homes that have sustained Substantial Damage or will be Substantially Improved, open foundations including piers, columns, and piles, and micropiles may be used Elevating to (or above) the BFE/ABFE will help protect the home in future storms and reduce flood insurance costs
Structural condition of home	Structural strength of load paths. Determine whether the home is structurally strong enough to be lifted	How connections can be improved to strengthen the home
	Structural strength of the existing footings. Determine whether the footings are adequate for the proposed modification	How the footings can be strengthened or replaced
Geotechnical condition of site	Determine whether a shallow foundation is feasible	Piers/Columns are appropriate for shallow foundations
	Determine whether a deep foundation is required	Piles, piers/columns and micropiles are appropriate for deep foundations
	Predicted flood conditions, including the effects of scour and long-term erosion	Piling and Pier/Column foundations with footings and grade beams can be designed to withstand 3-foot wave loads, but may fail if erosion and scour undermine the foundation Micropile foundations may not be able to withstand lateral loads when exposed by scour and erosion
	Elevation of the water table	Grade beams can be elevated above the water table, but the pile or pier/column must be designed to resist cantilever action, moments, and deflection at the top. Deeper embedment may be necessary
	Potential for exposure to water or salt-laden air	Provide corrosion protection if needed Anchors should be galvanized or grouted underground to mitigate corrosion Where there are corrosive soils or a shallow variable groundwater table and the micropile is subject to increased corrosion, micropiles should be fully grouted
Access, horizontal and vertical clearance on the lot	Availability of access for large construction equipment to the lot or possibility of temporarily relocating the home	Traditional driven-pile foundations are often preferred if there is enough room to temporarily move the home while the new open foundation is constructed.
	Adequacy of horizontal and vertical clearances and access	Pile-driving technologies are available depending on site constraints, including low-head-room rigs or hammers, to elevate the home in place. These technologies are typically associated with micropiles When buildings are very close together, excavating to construct columns/piers with spread footings or grade beams could adversely affect neighboring buildings When buildings are very close together, lifting beams may not have required clearance for installation
Basements and crawlspaces	Presence of a basement or crawlspace	Basements must be filled in if NFIP compliance is required or desired Existing basement or crawl space walls must be analyzed to determine if additional reinforcement is required to resist design loads associated with elevating the building, as well as the loads of the design level event
Utilities	Presence of utilities located below the BFE/ABFE; utilities include mechanical, electrical, and plumbing (MEP) and heating, ventilation and air conditioning (HVAC) equipment	Utilities and their controls should be elevated above the BFE/ABFE

foundations. Once all of this information has been evaluated, the design professional will be able to prepare cost estimates to determine which foundation design is the best value. Table 2 presents relative costs and a number of considerations associated with elevating homes on different foundation types.

Table 2: Comparison of Relative Costs and Considerations Associated with Elevating Homes on Alternative Open Foundations in Tight, Narrow Lots

<table>
<tr><th colspan="2">Consideration</th><th>Column/Pier Foundation</th><th>Traditional Pile Foundation</th><th>Micropile Foundation</th></tr>
<tr><td colspan="2">Requires moving home off footprint</td><td>No</td><td>Yes</td><td>No</td></tr>
<tr><td colspan="2">Elevate-in-place</td><td>Yes</td><td>No</td><td>Yes</td></tr>
<tr><td colspan="2">Impacts to neighboring properties</td><td>Medium to High</td><td>High</td><td>Low</td></tr>
<tr><td rowspan="3">Cost</td><td>Foundation</td><td>$</td><td>$$$</td><td>$$</td></tr>
<tr><td>Foundation connection</td><td>$$</td><td>$</td><td>$$</td></tr>
<tr><td>Elevation</td><td>$$</td><td>$$$</td><td>$$</td></tr>
<tr><td colspan="2">Ease of installation</td><td>Yes</td><td>Maybe</td><td>Yes</td></tr>
<tr><td colspan="2">Design basis</td><td>IBC[1]/ASCE 24/FEMA P-55[2]</td><td>IBC[1]/ASCE 24/FEMA P-55[2]</td><td>IBC[1]/ASCE 24/ FEMA P-55[2]/FHWA NHI-05-039[3]</td></tr>
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1 IBC, International Building Code
2 *Coastal Construction Manual* (2011)
3 *Micropile Design and Construction Guidelines Manual* (2005)

Open Foundation and Elevation Design Process

The design process for elevating homes on open foundations is shown in Figure 9.

Pile design: Pile design requires some additional steps.

- Remove existing structure to allow access for pile-driving equipment
- Determine pile depth based on pile load and soil strata
- Determine pile spacing based on pile capacity, building loads, and span capacity of the building and grade beams
- Achieve lateral capacity by increasing the number of piles or by properly connecting batter piles/anchors to the piles and footings with a pile cap
- Design the new access to the building and utility extensions

Micropile installation: Contractor qualifications should be specified prior to bidding elevation projects. Qualifications should include prior experience, bonding/insurance, licensure, and familiarity with local construction and soil types. To ensure the foundation is installed properly, micropile installation should be supervised by an experienced contractor who has recently completed similar projects in similar soils. Geotechnical conditions can vary greatly across one property and an experienced contractor will be able to make field decisions when obstructions, refusal, voids, soft soils, and other unanticipated subsurface conditions are encountered. To be successful, micropiles must be installed with an adequate embedment and must be able to resist the load capacity. Load testing of piles is recommended to verify design calculations and the adequacy

1. Perform a field investigation and data review
2. Determine whether the home can be elevated
3. Determine applicable codes and local floodplain requirements
4. Establish uplift, lateral, gravity, and seismic loads
5. Estimate the lifting load of the house
6. Identify the best location for the principal lift beams, lateral support beams, and framing lumber and evaluate their adequacy
7. Determine whether the building can withstand design forces (uplift, lateral, gravity, seismic)
8. Design connections to enable load paths to adequately carry the expected design loads to the ground
9. Analyze the existing foundation strength and engineering parameters
10. Design the foundation, pile/pier connections, and grade beam to adequately carry the expected design loads
11. Obtain all required permits and approvals
12. Ensure all utility hook-ups are designed (plumbing, phone, electrical, cable, and mechanical)

Figure 9: 12-step design process for elevating homes.

of a contractor's installation methods. Regardless of the resistance measured during installation or through load testing, the minimum embedment depth specified by the design professional must be satisfied for the pile to perform as designed.

Useful Links and Resources

Publications

- ASCE (American Society of Civil Engineers). ASCE 24, *Flood Resistant Design and Construction.*
- ASCE. ASCE 7, *Minimum Design Loads for Buildings and Other Structures.*

FEMA (Federal Emergency Management Agency). 2008. FEMA NFIP Technical Bulletin 1, *Openings in Foundation Walls and Walls of Enclosures.* Available at http://www.fema.gov/library/viewRecord.do?id=1579.

FEMA. 2008. FEMA NFIP Technical Bulletin 2, *Flood Damage Resistant Materials Requirements.* Available at http://www.fema.gov/library/viewRecord.do?id=1580.

FEMA. 2008. FEMA NFIP Technical Bulletin 5, *Free of Obstruction Requirements.* Available at http://www.fema.gov/library/viewRecord.do?id=1718.

FEMA. 2008. FEMA NFIP Technical Bulletin 9, *Design and Construction Guidance for Breakaway Walls.* Available at http://www.fema.gov/library/viewRecord.do?id=1722.

FEMA. 2009. *Homeowner's Guide to Retrofitting.* FEMA P-312. Available at http://www.fema.gov/library/viewRecord.do?id=1420.

FEMA. 2009. *Hurricane Ike in Texas and Louisiana: Mitigation Assessment Team Report.* Available at https://www.fema.gov/library/viewRecord.do?id=3577.

FEMA. 2009. Hurricane Ike Recovery Advisories. Available at http://www.fema.gov/library/viewRecord.do?id=3539.

FEMA. 2009. *Recommended Residential Construction for Coastal Areas Building on Strong and Safe Foundations.* FEMA P-550. Available at http://www.fema.gov/library/viewRecord.do?id=1853.

FEMA. 2010. *Substantial Improvement / Substantial Damage Desk Reference.* FEMA P-758. Available at http://www.fema.gov/library/viewRecord.do?id=4160.

FEMA. 2011. *Coastal Construction Manual.* FEMA P-55. Available at http://www.fema.gov/library/viewRecord.do?fromSearch=fromsearch&id=1671.

FEMA. 2012. *Changes in the Flood Insurance Program: Preliminary Considerations for Rebuilding.* Available at http://www.dec.ny.gov/docs/water_pdf/fpmfemacfip.pdf

FEMA. 2012. *Comparison of Select NFIP and Building Code Requirements for Special Flood Hazard Areas.* FEMA Quick Reference Guide. Available at http://www.fema.gov/library/viewRecord.do?id=5701.

FEMA. 2012. *Engineering Principles and Practices of Retrofitting Floodprone Residential Structures.* FEMA P-259. Available at http://www.fema.gov/library/viewRecord.do?id=1645.

FEMA. 2013. *Flood Insurance Reform Act of 2012: Impact of changes to the NFIP.* Available at http://www.fema.gov/library/viewRecord.do?id=7187.

FEMA. 2013. Hurricane Sandy Recovery Advisories and Fact Sheets Available from http://www.fema.gov/building-science/hurricane-sandy-building-science-activities-resources.

- Hurricane Sandy Recovery Advisory No. 1, *Improving Connections in Elevated Coastal Residential Buildings*
- Hurricane Sandy Recovery Advisory No. 3, *Restoring Mechanical, Electrical and Plumbing Systems in Non-Substantially Damaged Residential Buildings*
- Hurricane Sandy Recovery Advisory No. 5, *Designing for Flood Levels Above the Base Flood Elevation.*
- Hurricane Sandy Recovery Advisory No. 7, *Reducing Flood Risk and Flood Insurance Premiums for Existing Buildings.*
- FEMA *Hurricane Sandy Mitigation Assessment Report.*

FHWA (Federal Highway Administration). 2005. *Micropile Design and Construction Guidelines Manual,* FHWA NHI-05-039.

ICC (International Code Council). 2012. International Building Code. Country Club Hills, IL.

ICC. 2012. International Residential Code for One- and Two-Family Dwellings. Country Club Hills, IL.

Web Sites

Deep Foundation Institute, http://www.dfi.org/default.asp

International Association of Certified Home Inspectors, house raising, http://www.nachi.org/house-raising.htm

International Association of Structural Movers, http://www.iasm.org/index.html

Information on FEMA FIRMs, www.msc.gov and www.floodsmart.gov

Post-Hurricane Sandy ABFE maps for parts of New York and New Jersey, www.region2coastal.com/sandy/abfe

For more information, see the FEMA Building Science Frequently Asked Questions website at http://www.fema.gov/frequently-asked-questions.

If you have any additional questions on FEMA Building Science Publications, contact the helpline at FEMA-Buildingsciencehelp@fema.dhs.gov or 866-927-2104.

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