Improving Connections in Elevated Coastal Residential Buildings

FEMA

HURRICANE SANDY RECOVERY ADVISORY *RA1, February 2013*

Purpose and Intended Audience

FEMA post-disaster assessment teams observed residential buildings damaged during Hurricane Sandy that had inadequate connections between the elevated floor and the pile foundation (Figure 1). This Recovery Advisory describes how to improve connections attaching elevated floors to pile foundations. The improved connection details herein are no substitute for properly elevating a building above the base flood elevation (BFE). Even properly elevated homes may experience an event greater than the base flood. The improved connection details presented in this advisory will reduce potential damage from future wind events and provide added resistance against flood-related structural failure in the event that flood levels exceed the elevated height of the floor. Readers of this Recovery Advisory should consult Hurricane Sandy Recovery Advisory No. 5, *Designing for Flood Levels Above the Base Flood Elevation After Hurricane Sandy*, on properly elevating buildings.

Figure 1: Building with insufficient connectors (red circle) washed off its pile foundation when elevated floor-to-pile connectors failed. Stronger connectors were used on the house in the background (Ortley Beach, NJ).

Although the information in this Recovery Advisory is most useful for new construction, the same concepts can be applied to retrofits of existing construction. The intended audience for this Recovery Advisory is builders, architects, and engineers. This Recovery Advisory uses the concept of load paths. Readers unfamiliar with load paths can find an overview in FEMA P-499, *Home Builder's Guide to Coastal Construction*, Category 4 – Load Paths technical fact sheets (refer to Table 1).

Key Issues:

1. Inadequate connections between structural building elements can lead to failure during a flood or high-wind event.
2. The connection between an elevated floor and a pile foundation must be designed to withstand both uplift and lateral loads (Figure 2).
3. Connectors for elevated floor-to-pile foundation elements are often exposed to salt water and must be protected from corrosion. Connectors should be inspected regularly and replaced as needed.

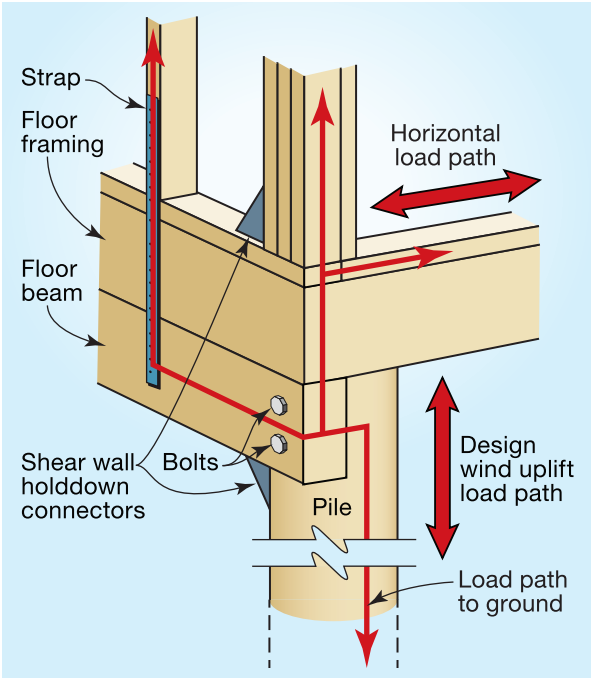


Figure 2: Example load paths through a floor-to-pile foundation connection

This Recovery Advisory Addresses:

- Strengthening elevated floor-to-pile foundation connections
- Protecting metal connectors and brackets from corrosion
- Resources for strengthening connections

Strengthening Elevated Floor-to-Pile Foundation Connections

The FEMA assessment teams deployed after Hurricane Sandy observed damaged connections between elevated floors and pile foundations. These inadequate connections were subjected to flood levels that exceeded the top of the foundation, and these loads exceeded the capacity of the connections. As a result, the buildings experienced simultaneous uplift and lateral loads during the storm and were pushed off their foundations.

As shown in Figure 1, the inadequate connectors failed, resulting in complete separation of the building from the foundation (foreground), while homes with more substantial connectors secured the building to the foundation (background). It was also observed that elevated floor-to-pile foundation connections that were attached near the top edge of the beam with fasteners driven inline with the wood grain resulted in the beam splitting along the grain as shown in Figure 3.

Figure 3: Building with connectors nailed along the grain in the upper edge of the wood beam resulted in the beam splitting (Beach Haven, NJ).

Building Codes

Model building codes do not have standard details to guide the connection of an elevated floor to a pile foundation. These connections are typically designed to resist high-wind forces and, in some cases, seismic forces (lateral loads) or to meet standard practice for connecting and bracing wood members. They are not typically designed to resist uplift from flood-induced buoyancy forces. Strengthening these connections will reduce the likelihood of a building separating from its foundation if flood levels exceed the top of the foundation or wave loads impact the floor system.

While the details presented in this advisory address better floor-to-pile foundation connections, prior to beginning any new construction or retrofit project it is important to consult the local building code to verify that all elements of the building project, not just the foundation connections, will be compliant.

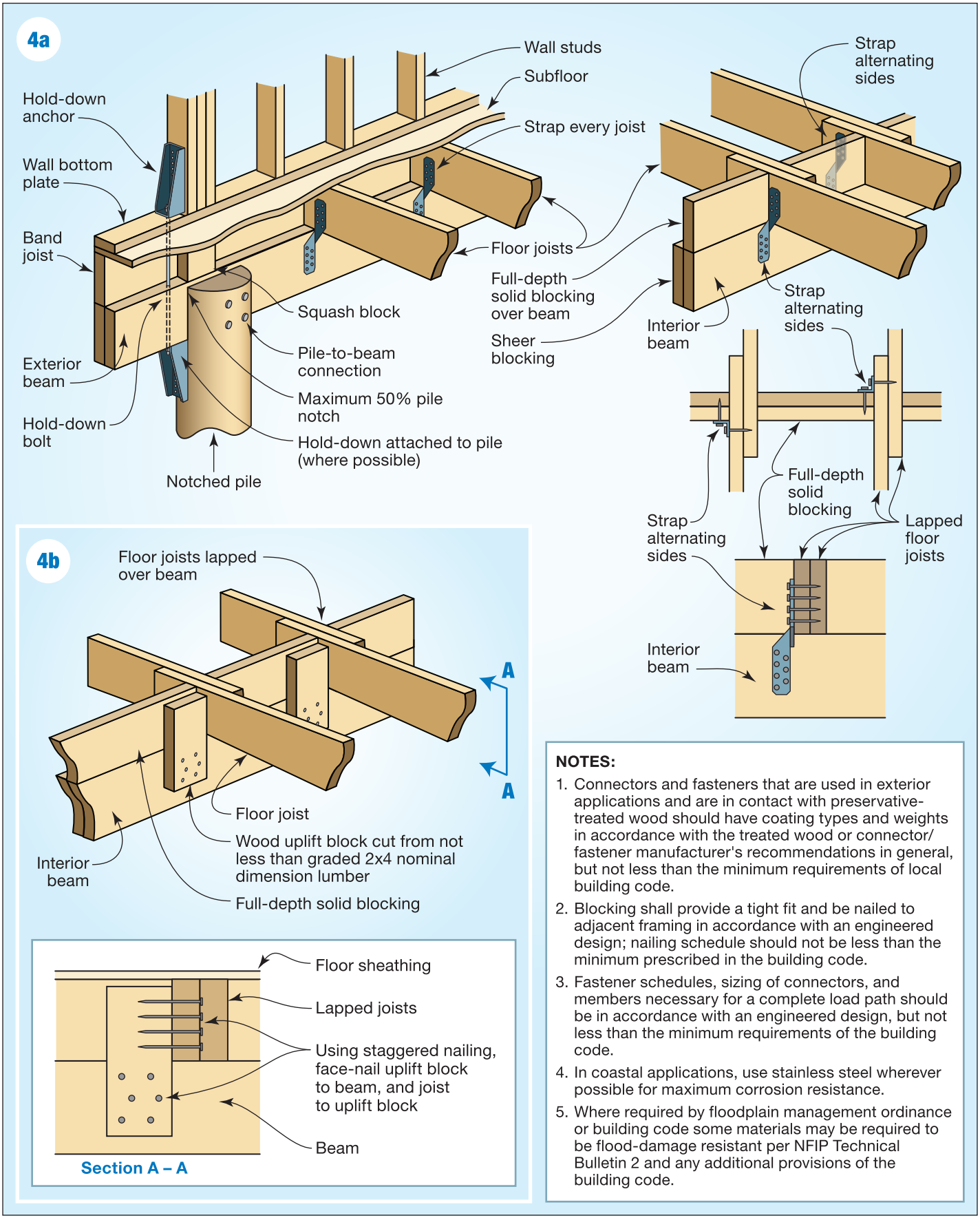
Details of Strengthening Elevated Floor-to-Pile Foundation Connections

Figure 4 shows details for strengthening the connection of an elevated floor-to-pile foundation. The connections are strengthened by:

- Using full-depth solid blocking between joists to brace joists and provide shear resistance
- Using connectors that extend to (or beyond) the mid height of the beam and joist to provide uplift resistance
- Attaching hold-down connectors directly to the pile

Figure 4a illustrates strengthened connections using a combination of metal connectors and full-depth solid blocking between joists. Figure 4b illustrates strengthened connections by using full-depth solid blocking between joists and wood uplift blocks. Both of these methods, when used as part of an engineered design, can address both uplift and lateral loading from flood and wind loads.

To achieve the full-strength capacity of the connection, the connectors need to be secured with fasteners of the suitable size, length, and material specified by the manufacturer.



NOTES:

1. Connectors and fasteners that are used in exterior applications and are in contact with preservative-treated wood should have coating types and weights in accordance with the treated wood or connector/fastener manufacturer's recommendations in general, but not less than the minimum requirements of local building code.
2. Blocking shall provide a tight fit and be nailed to adjacent framing in accordance with an engineered design; nailing schedule should not be less than the minimum prescribed in the building code.
3. Fastener schedules, sizing of connectors, and members necessary for a complete load path should be in accordance with an engineered design, but not less than the minimum requirements of the building code.
4. In coastal applications, use stainless steel wherever possible for maximum corrosion resistance.
5. Where required by floodplain management ordinance or building code some materials may be required to be flood-damage resistant per NFIP Technical Bulletin 2 and any additional provisions of the building code.

Figure 4. Detail of an elevated floor-to-pile connection using metal connectors and full-depth solid blocking (4a); detail of an elevated floor-to-pile connection using wood uplift blocking and full-depth solid blocking (4b).

Protecting Metal Connectors and Brackets from Corrosion

Metal connectors and fasteners must be adequately protected from corrosion to retain their design capacity. Metal corrosion is most pronounced in coastal buildings within 3,000 feet of the ocean and should be considered a potential issue in all coastal areas (Figure 5).

Minimizing corrosion should be an objective when selecting new connectors. Most often, corrosion resistance can be achieved by using connectors and fasteners that are hot-dip, zinc-coated galvanized steel or stainless steel; see notes above in Figure 4. It is important to verify with the connector manufacturer that the treated wood, fasteners, and connectors are compatible and will not result in an increased rate of corrosion when brought into contact with each other. For example, galvanized fasteners (nails/screws) should be used with galvanized connectors, and stainless steel fasteners should be used with stainless steel connectors. Connections assembled with a mixture of materials will accelerate corrosion if the different metals come into contact with each other. For more information on corrosion protection, see FEMA Technical Bulletin 8, *Corrosion Protection for Metal Connectors in Coastal Areas for Structures Located in Special Flood Hazard Areas in Accordance with the National Flood Insurance Program* (FEMA, 1996).

Figure 5. Corroded connectors (red circles) and lack of blocking between joists meant there is no longer a continuous load path providing uplift and shear transfer to foundation piles (Fire Island, NY).

Deteriorated connectors should be replaced. Existing fasteners not yet corroded can be protected by applying corrosion-resistant paints such as zinc or epoxy-polyamide. However, the effectiveness of an applied paint is not completely predictable because its effectiveness is not necessarily correlated to paint thickness, and it is only effective on the painted areas. Unpainted areas and hard-to-reach portions of the connectors and fasteners will remain susceptible to corrosion.

Metal connectors and fasteners, and protective coating if used, should always be installed in accordance with the manufacturers' or engineers' specifications.

Resources and Useful Links

- ICC (International Code Council). 2012. International Building Code. Country Club Hills, IL. The ICC offers a free viewer that shows the codes at http://www.iccsafe.org/content/pages/freeresources.aspx
- ICC. 2012. *International Residential Code for One- and Two-Family Dwellings.* Country Club Hills, IL.
- FEMA. 1996. *Corrosion Protection for Metal Connectors in Coastal Areas for Structures Located in Special Flood Hazard Areas in Accordance with the National Flood Insurance Program*. Technical Bulletin 8. Available at http://www.fema.gov/library/viewRecord.do?id=1721
- FEMA. 2013. Hurricane Sandy Recovery Advisory No. 5, *Designing for Flood Levels Above the Base Flood Elevation After Hurricane Sandy.* Washington, DC.
- American Wood Council. *Wood Frame Construction Manual.* Leesburg, VA.

The FEMA Region II Web page provides useful information and links for disaster survivors and recovering communities including available FEMA assistance and recovery initiatives. Please refer to http://www.region2coastal.com.

The connection between an elevated floor and a pile foundation is only one of many connections that must be strong enough to transfer loads without failing. Other connections are equally important for reducing the likelihood of damage for high winds or floods. Table 1 lists FEMA documents that have information related to load path connections in residential buildings. Although these resources may not have sufficient information to size specific connections, they will introduce readers to the concepts necessary to properly anchor a coastal building. All of the documents listed in Table 1 can be downloaded from the publications section of the FEMA Building Science Web site: http://www.fema.gov/building-science-publications.

Table 1: FEMA Resources for Connection Information

Resource Title	Connections and Fasteners	Wood-Frame Construction	Masonry Construction	Foundations	Walls and Roofs
FEMA P-499, *Home Builder's Guide to Coastal Construction* (2010)					
Fact Sheet 1.1: Coastal Building Success and Failures		✔	✔	✔	✔
Fact Sheet 1.2: Summary of Coastal Construction Requirements and Recommendations		✔	✔	✔	✔
Fact Sheet 1.5: V Zone Design and Construction Certificate		✔	✔	✔	
Fact Sheet 1.6: Designing for Flood Levels Above the BFE		✔	✔	✔	
Fact Sheet 1.7: Coastal Building Materials	✔	✔	✔	✔	✔
Fact Sheet 1.8: Alternative Construction Materials		✔	✔	✔	✔
Fact Sheet 3.1: Foundations in Coastal Areas		✔	✔	✔	
Fact Sheet 3.2: Pile Installation	✔	✔		✔	
Fact Sheet 3.3: Wood-Pile-to-Beam Connections	✔	✔		✔	
Fact Sheet 3.4: Reinforced Masonry Pier Construction	✔	✔	✔	✔	
Fact Sheet 3.5: Foundation Walls		✔	✔	✔	
Fact Sheet 4.1: Load Paths	✔	✔	✔	✔	✔
Fact Sheet 4.2: Masonry Details	✔		✔	✔	✔
Fact Sheet 4.3: Use of Connectors and Brackets	✔	✔		✔	✔
Fact Sheet 8.1: Enclosures and Breakaway Walls	✔	✔	✔	✔	
Fact Sheet 9.1: Repairs, Remodeling, Additions and Retrofitting (Flood)	✔	✔	✔	✔	✔
Fact Sheet 9.2: Repairs, Remodeling, Additions and Retrofitting (Wind)	✔	✔	✔	✔	✔
Technical Bulletin 2: Flood Damage-Resistant Materials Requirements (2008)	✔	✔	✔	✔	✔
Technical Bulletin 5: Free-of-Obstruction Requirements (2008)		✔	✔	✔	
Technical Bulletin 8: Corrosion Protection for Metal Connectors in Coastal Areas (1996)	✔				
Technical Bulletin 9: Design and Construction Guidance for Breakaway Walls (2008)		✔	✔	✔	
Technical Bulletin 11: Crawlspace Construction for Buildings Located in Special Flood Hazard Areas (2001)		✔	✔	✔	
FEMA P-55, *Coastal Construction Manual* (2011)	✔	✔	✔	✔	✔
FEMA P-762, *Local Officials Guide for Coastal Construction* (2009)	✔	✔	✔	✔	✔
FEMA P-804, *Wind Retrofit Guide for Residential Buildings* (2010)	✔	✔	✔	✔	✔

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

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