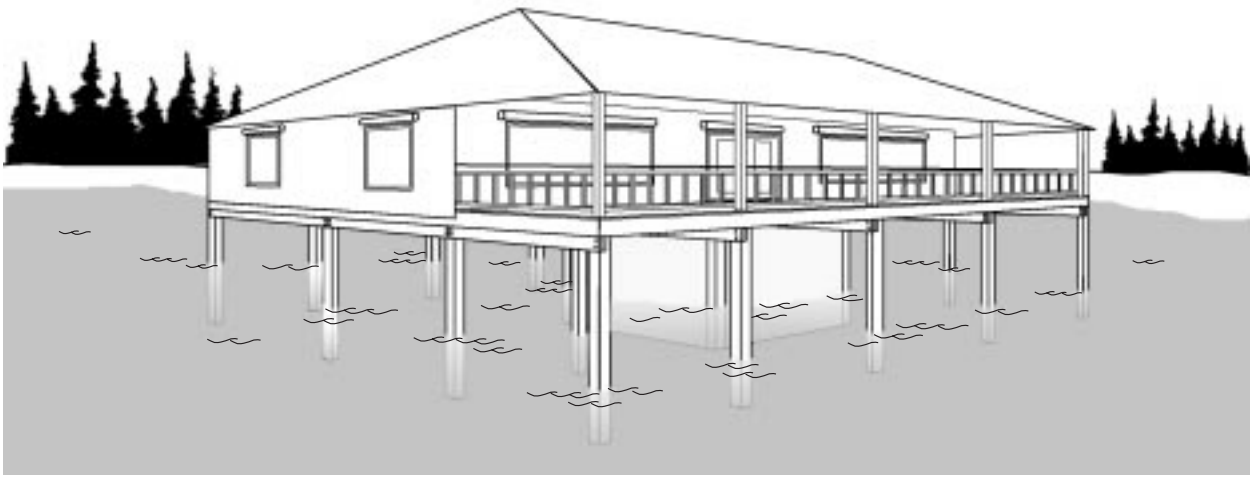
Technical Bulletin 9-99

Design and Construction Guidance for Breakaway Walls Below Elevated Coastal Buildings

in accordance with the

National Flood Insurance Program



FEDERAL EMERGENCY MANAGEMENT AGENCY
MITIGATION DIRECTORATE

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Key Word/Subject Index

This index allows the user to locate key words and subjects in this Technical Bulletin. The Technical Bulletin User's Guide (printed separately) provides references to key words and subjects throughout the Technical Bulletins. For definitions of selected terms, refer to the Glossary at the end of this bulletin.

Any comments on the Technical Bulletins should be directed to:

Federal Emergency Management Agency
Mitigation Directorate
Program Policy and Assessment Branch
500 C Street, SW.
Washington, DC 20472

Technical Bulletin 9-99 replaces Technical Bulletin 85-3 (draft), *Breakaway Walls*.

Wave design on cover based on the Japanese print *The Great Wave Off Kanagawa*, by Katsushika Hokusai (1760 – 1849), Asiatic Museum of Fine Arts, Boston.

TECHNICAL BULLETIN 9-99

Design and Construction Guidance for Breakaway Walls Below Elevated Coastal Buildings in accordance with the National Flood Insurance Program

Introduction

In Coastal High Hazard Areas (Zones V, VE, and V1-30), the National Flood Insurance Program (NFIP) regulations require that communities participating in the program adopt floodplain management ordinances or laws requiring that all new and substantially improved buildings be elevated to or above the base flood elevation (BFE) on foundations consisting of piles, posts, piers, or columns. These open foundations must be designed to allow waves and water moving at high velocity to flow beneath the building. Local ordinances or laws adopted by participating communities must further require that the area below the lowest floor of the elevated building be left free of obstructions. Walls or other obstructions below the elevated building can significantly increase the potential for flood damage to the elevated building by increasing the surface area subject to wave impact and velocity flow during a coastal storm.

Although obstructions are prohibited, the area below the lowest floor of an elevated building in a Coastal High Hazard Area may be enclosed with open wood latticework, insect screening, or non-supporting "breakaway" walls (see Figure 1). However, each of these must be designed and constructed to collapse under wind and water loads without causing collapse, displacement, or other structural damage to the elevated portion of the building or supporting foundation system. In addition, like all other construction in the Special Flood Hazard Area, any enclosure below the lowest floor of an elevated building must be built with flood-resistant materials and with methods and practices that minimize flood damage. Furthermore, the area below the lowest floor of the elevated building may be used only for parking, building access, or storage.

Specific design requirements are included in the NFIP regulations for breakaway walls. More recent research on breakaway walls performed for the Federal Emergency Management Agency (FEMA) and the National Science Foundation by North Carolina State University and Oregon State University evaluated the failure mechanisms (see *Further Information* on page 14 of this bulletin). The research included full-scale, laboratory wave-tank tests of breakaway wall panels. This bulletin describes prescriptive design details that comply with the requirements of the NFIP regulations and that may be used by design professionals as an alternative to the performance requirements listed in the regulations.

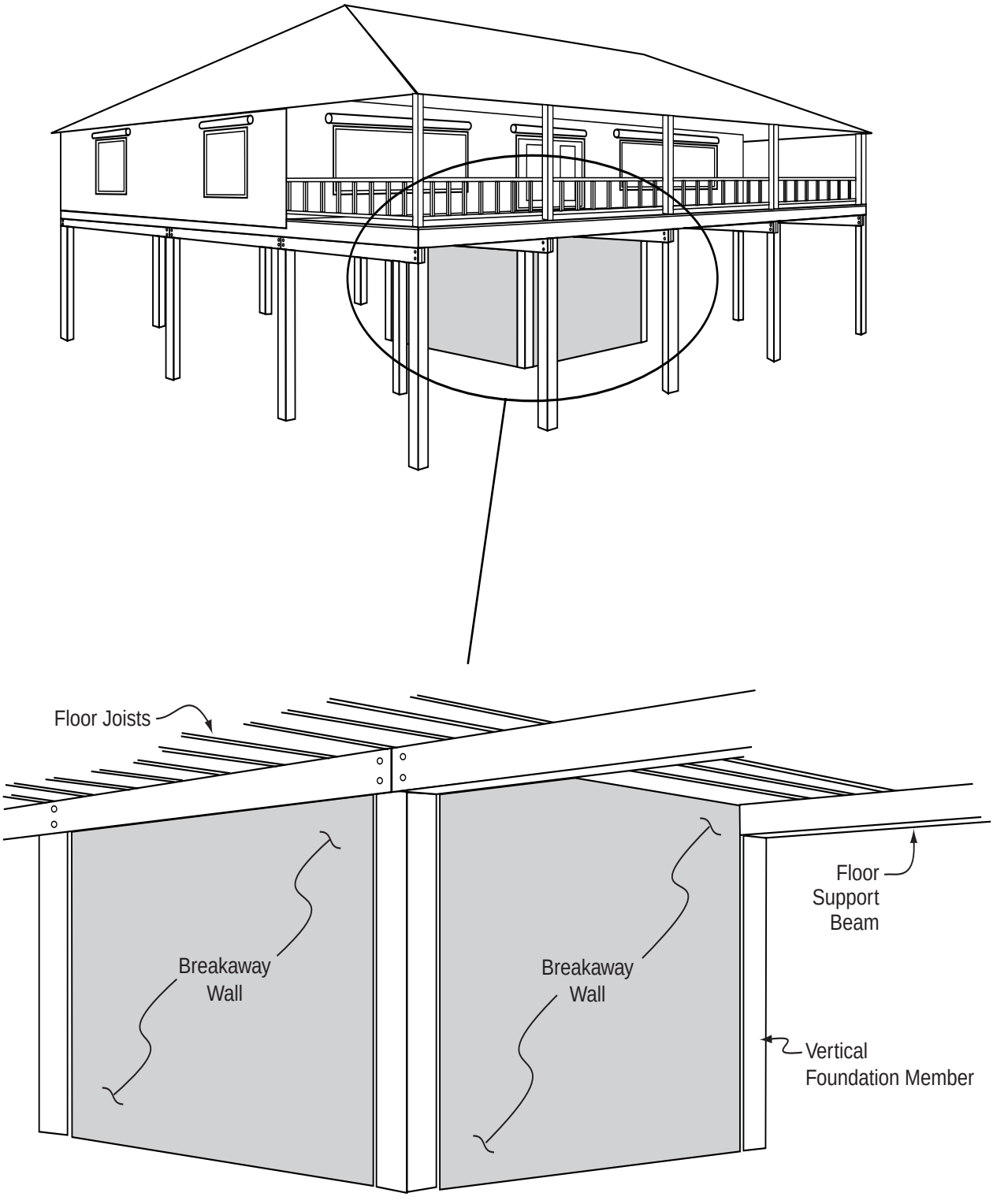

Figure 1 Area enclosed by breakaway walls below an elevated building.

NFIP Regulations

Section 60.3(e)(4) of the NFIP regulations states that the community shall:

> ***"Provide that new construction and substantial improvements in Zones V1-V30, VE, and also Zone V if base flood elevation data is available on the community's FIRM, are elevated on pilings and columns so that (i) the bottom of the lowest horizontal structural member of the lowest floor (excluding the pilings or columns) is elevated to or above the base flood level; and (ii) the pile or column foundation and structure attached thereto is anchored to resist flotation, collapse and lateral movement due to the effects of wind and water loads acting simultaneously on all building components. Water loading values shall be those associated with the base flood. Wind loading values used shall be those required by applicable State or local building standards. A registered professional engineer or architect shall develop or review the structural design specifications and plans for the construction, and shall certify that the design and methods of construction to be used are in accordance with accepted standards of practice for meeting the provisions of paragraphs (e)(4)(i) and (ii) of this section."***

Section 60.3(e)(5) further states that a community shall require:

> ***"...that all new construction and substantial improvements within Zones V1-V-30, VE, and V on the community's FIRM have the space below the lowest floor either free of obstruction or constructed with non-supporting breakaway walls, open wood lattice-work, or insect screening intended to collapse under wind and water loads without causing collapse, displacement, or other structural damage to the elevated portion of the building or supporting foundation system. For the purpose of this section, a breakaway wall shall have a design safe loading resistance of not less than 10 and no more than 20 pounds per square foot. Use of breakaway walls which exceed a design safe loading resistance of 20 pounds per square foot (either by design or when so required by local or State codes) may be permitted only if a registered professional engineer or architect certifies that the designs proposed meet the following conditions: (i) Breakaway wall collapse shall result from a water load less than that which would occur during the base flood; and (ii) The elevated portion of the building and supporting foundation system shall not be subject to collapse, displacement, or other structural damage due to the effects of wind and water loads acting simultaneously on all building components (structural and non-structural). Water loading values used shall be those associated with the base flood. Wind loading values used shall be those required by applicable State or local building standards. Such enclosed space shall be useable solely for parking of vehicles, building access, or storage."***

Technical Bulletins provide guidance on the **minimum** requirements of the NFIP regulations. State or local requirements that exceed those of the NFIP take precedence. Design professionals should contact community officials to determine whether more restrictive State or local regulations apply to the building or site in question. All applicable standards of the State or local building code must also be met for any building in a flood hazard area.

Below-Building Enclosure Options Compliant With the Regulations

According to Section 60.3(e)(5) of the NFIP regulations, areas below elevated buildings in Coastal High Hazard Areas (Zones V1-V-30, VE, and V) may be enclosed in one of two ways: (1) with insect screening or open latticework or (2) with breakaway walls.

Insect Screening and Open Latticework

Insect screening and open latticework below elevated buildings are not considered obstructions as long as they meet the performance requirements of Section 60.3(e)(5) of the NFIP regulations. To increase the likelihood that the screen or latticework will collapse as intended, without transferring loads to the building or its foundation, this bulletin recommends that the vertical framing members on which the screen or latticework is mounted (such as 2 x 4's) be spaced at least 2 feet apart. Either metal or synthetic insect screening is acceptable. Lattice is available in 4' x 8' sheets in wood or plastic. The material used to fabricate the lattice should be no thicker than ½ inch, and the finished sheet should have an opening ratio of at least 40 percent. (Although Section 60.3(e)(5) specifies wood lattice, plastic lattice is acceptable as long as it meets the requirements listed above.)

Breakaway Walls

Section 60.3(e)(5) of the NFIP regulations requires that breakaway walls either (1) be constructed to meet prescriptive criteria for resistance to wind and water loads or (2) be certified by a registered professional engineer or architect.

Walls Meeting the Prescriptive Criteria

According to NFIP performance criteria for breakaway walls, any wall with a designed safe working resistance of not less than 10 and not more than 20 pounds per square foot (psf) is considered a breakaway wall and does not require certification by an engineer or architect. Previous NFIP design guidance, in the 1986 edition of FEMA's *Coastal Construction Manual*, specified standard stud wall panels placed between pilings or other vertical foundation members, but connected to the building only at the top and bottom of the panel with a specific number of fasteners intended to restrict the capacity of the wall to the 10- to 20-psf range. Higher loads will cause a failure at the top or bottom connections. Breakaway walls built according to this previously developed guidance continue to be compliant with the NFIP performance criteria.

Walls Requiring Certification

In many coastal areas, local building codes include wind design requirements that exceed the 20-psf maximum described above. NFIP performance criteria allow for construction of breakaway walls that meet these wind requirements. Breakaway walls with capacities higher than 20 psf are permitted if an engineer or architect certifies that (1) the wall will collapse before base flood conditions are reached and (2) the elevated building will not be damaged by combined wind and flood loads on all building components. The remainder of this bulletin presents a prescriptive description of breakaway walls that meet the two certification conditions based on more recent research.

Wave Forces and Rising Storm Surge

The results of previous breakaway wall analyses, which served as the basis of recommendations in the 1985 edition of FEMA's *Coastal Construction Manual*, assumed design flood conditions and oscillating (non-breaking) wave conditions. The more recent research conducted by North Carolina State University and Oregon State University assumed two significant differences to better model coastal storms: breaking waves and rising water levels with time. In addition, full-scale wall panels were tested in a wave tank at Oregon State University to confirm the theoretical results.

The severity of the flood hazard in V zones and coastal A zones is greater than that in non-coastal A zones, primarily because of the presence of breaking waves, which generally do not occur in non-coastal A zones. As a breaking wave passes a piling foundation or other open foundation, the structure experiences an oscillating, high-velocity flow that peaks at the wave crest, just as the wave breaks. While there are drag forces on the foundation, most of the flow under the building is undisturbed, making open foundations a manageable design. When a breaking wave hits a vertical surface, the effect is quite different. When the crest of a breaking wave impacts a vertical surface, a pocket of air is trapped and compressed by the wave (see Figure 2). As the air pocket collapses, an exceedingly high-pressure burst is placed on the wall, centered around the stillwater level. For example, peak pressures from a 5-foot breaking wave can be 100 times higher than the 10- to 20-psf range specified in the NFIP regulations.

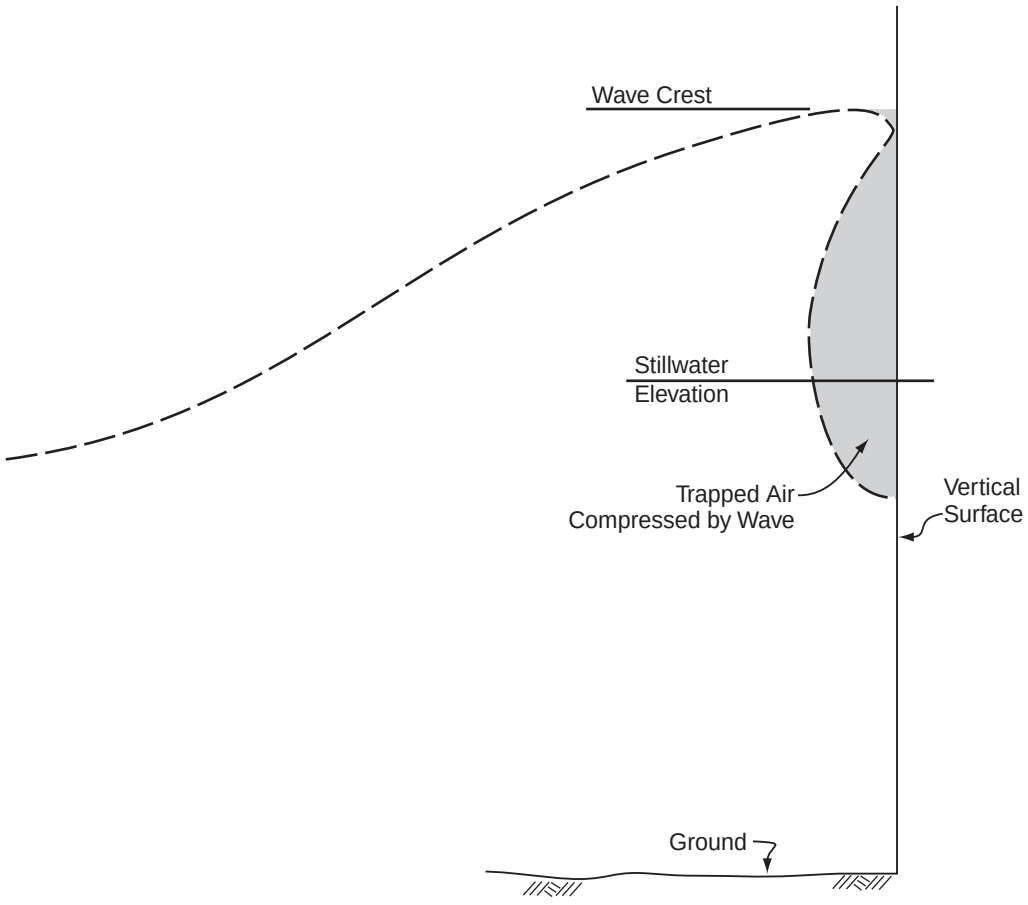

Figure 2 Impact of breaking wave on vertical surface.

The research found that standard wood stud wall construction with structural wood sheathing failed after being hit by several breaking waves averaging 2 feet in height. Those conditions will occur early in the storm when the stillwater depth is approximately 2 feet. Although the forces acting on the wall are high, they can be expected to act close to the ground, where much of the force is transferred into the ground or to the foundation near the ground. Therefore, prior to failure, the forces transferred to the elevated building by the breakaway wall can be minimized.

The full-scale tests conducted as part of the research showed that wood-frame breakaway walls designed to meet high-wind conditions will fail reliably at the connection between the bottom plate of the wall and the floor (see Figure 3a). The tests showed that the failure begins with the bowing and gradual displacement of the bottom plate (see Figure 3b) or a similar secondary failure beginning with the central studs of the breakaway wall. Wood-frame breakaway walls built according to the criteria presented in the following section of this bulletin are expected to fail in this manner. In addition, the tests demonstrated a secondary failure mode that occurs if the bottom plate of the wall fails to break away. In that situation, failure will occur at the connection between the bottom plate of the wall and the bottom of each wall stud, with little increase in capacity (see Figure 4). The conclusion of the research is that wood-frame breakaway walls will fail well before they transfer excessive loads caused by higher wave forces to the elevated building or foundation.

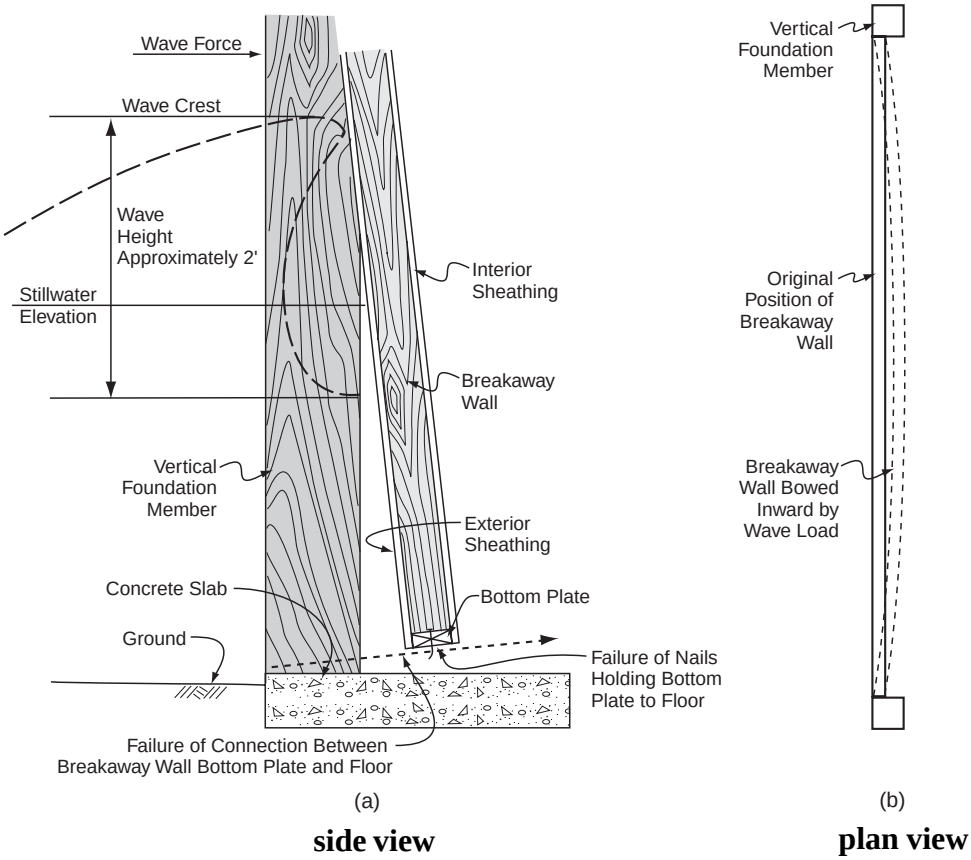

Figure 3 Expected failure mode of wood-frame breakaway wall based on full-scale testing – side view (a) and plan view (b).

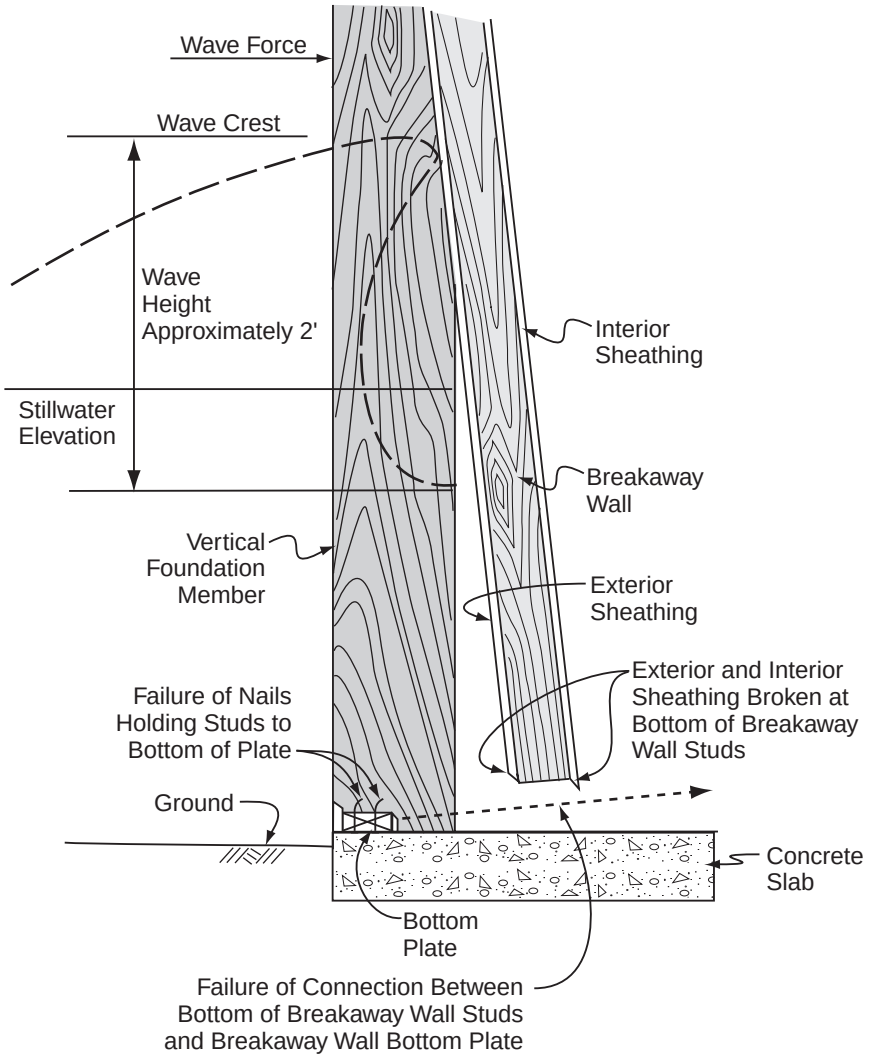

Figure 4 Secondary failure mode of wood-frame breakaway wall as determined from full-scale testing.

Breakaway walls consisting of unreinforced masonry are expected to fail at the mortar joints between the masonry units, beginning near the stillwater level (see Figure 5), where the pressure on the wall is greatest.

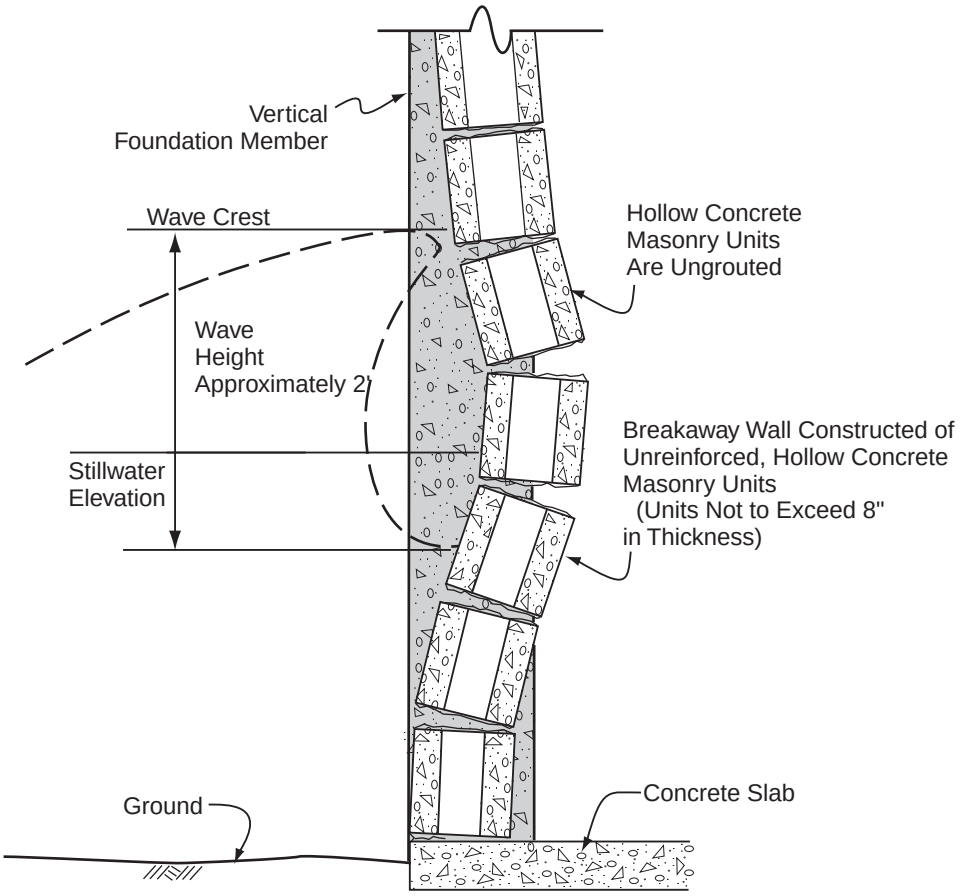

Figure 5 Expected failure mode of unreinforced masonry breakaway wall.

Prescriptive Breakaway Wall Criteria

Design and Construction

A professional designer may specify a breakaway wall with a capacity outside the 10- to 20-psf range using the following specifications.

1. The building must be elevated on a piling or other open foundation designed to withstand wind and water loads acting simultaneously and any other loads prescribed by applicable State or local building codes or other applicable laws, ordinances, or regulations.
2. Breakaway walls shall be designed to meet or exceed all applicable building code requirements for wind, earthquake, and other criteria.

3. The floors of areas enclosed with breakaway walls are assumed to be soil or unreinforced concrete slabs less than 4 inches thick. An unreinforced concrete slab has no wire mesh or steel rods. Floor slabs shall not be structurally attached to the pilings or other vertical foundation members.
4. Breakaway wall panels may be attached to the pilings or other vertical foundation members, elevated floor support beams, or slab floor with nails or other comparable-capacity fasteners (see Figure 6). All four sides of the wall panel may be attached to the foundation and elevated building. High-capacity connectors such as bolts, lag screws, metal straps, or hurricane fasteners (e.g., clips or straps) shall not be used.
5. The exterior sheathing on breakaway wall panels placed between pilings or other vertical foundation members may overlap and be attached to the vertical foundation members.
6. Breakaway walls may be constructed as continuous, non-bearing walls, attached to the floor and elevated floor joists, with or without attachment to the pilings or other vertical foundation members.
7. Breakaway wall sheathing and siding may overlap and attach to elevated floor beams and joists provided a separation joint is present to prevent damage to the sheathing or siding of the elevated building if the breakaway wall collapses (see Figure 7). As shown in Figure 7, separation joints shall be fitted with a watertight seal that prevents wind-driven rain water and sea spray from entering the building envelope.
8. Utilities, including electrical wiring, breaker boxes, power meters, plumbing, conduits, and ventilation ducts, shall not be placed in or on a breakaway wall panel. Building supply lines and other utility line components, such as light switches or electrical outlets, may be attached to pilings or other vertical foundation members as allowed by applicable building codes and floodplain management ordinances and laws (which generally require that utilities be elevated above the BFE). If utility lines must be routed into or out of an area enclosed by breakaway walls, one or more of the walls shall be constructed with a utility blockout (see Figure 6). Utility lines that pass through the blockout will be independent of the walls and therefore will not be damaged if the wall panel breaks away under flood or wind loads.
9. Breakaway wall panels shall be positioned such that on failure, they do not collapse against cross-bracing or threaten other foundation components.
10. Standard residential garage doors may be considered breakaway panels. Although these doors were not tested, published loading capacities for garage doors are comparable to the ultimate capacity for the tested breakaway walls (55 psf).
11. Because enclosures below buildings in V zones must be constructed with breakaway walls that meet the performance requirements of the NFIP regulations, flood vents or openings are not required for such enclosures. Note: Numerous State and local governments require openings in breakaway walls. See your local building official or floodplain administrator for further information.

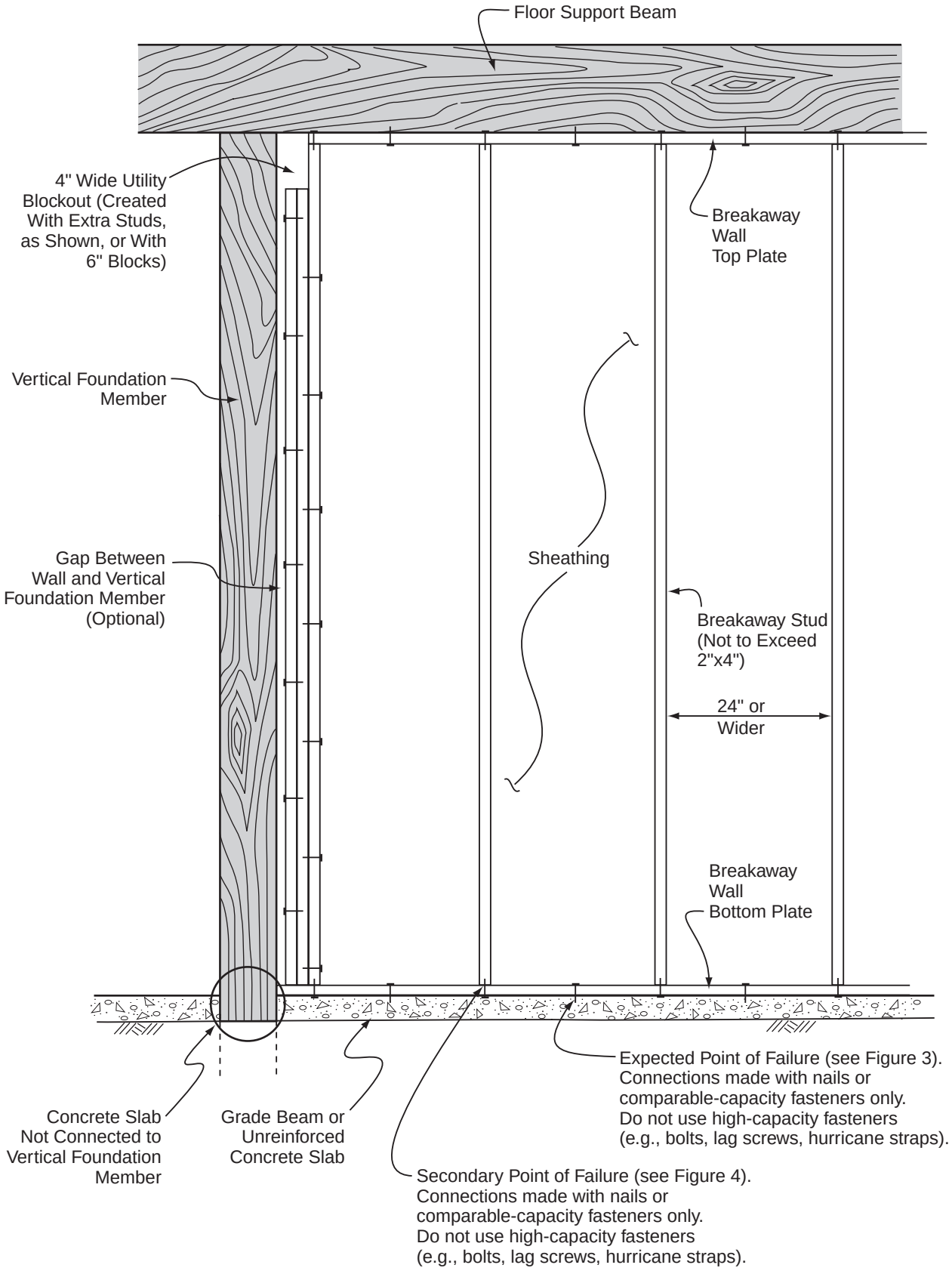

Figure 6 Typical wood-frame breakaway wall construction.

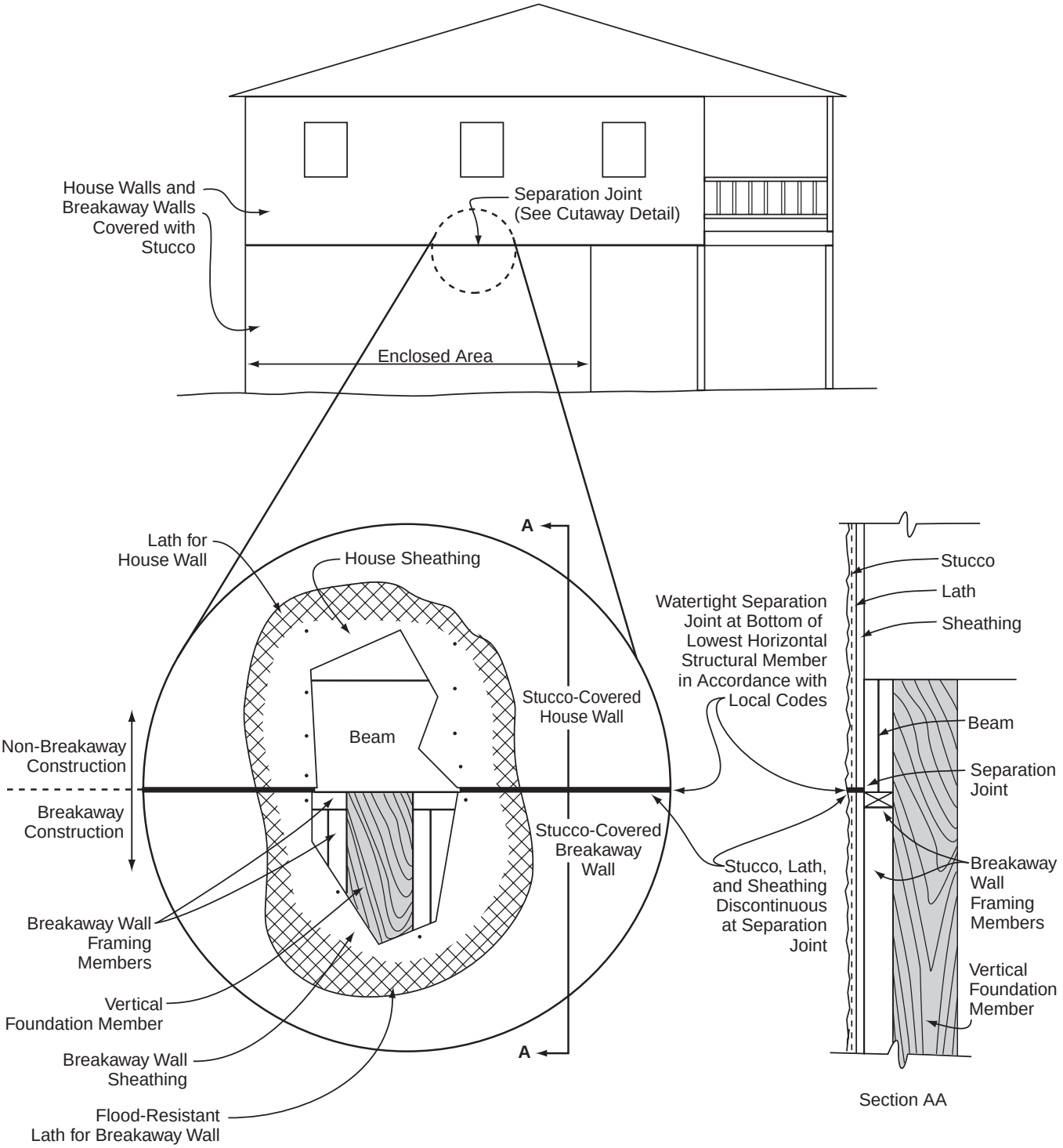

Figure 7 **Separation joint between sheathing and wall covering (e.g., stucco, siding) on house walls and breakaway walls.**

Construction Materials

As explained in FEMA Technical Bulletin 2-93, *Flood-Resistant Materials Requirements for Buildings Located in Special Flood Hazard Areas*, construction materials used below the BFE must be resistant to flood damage. "Flood-resistant" construction materials are those capable of withstanding direct and prolonged contact (i.e., at least 72 hours) with floodwaters without suffering significant damage (i.e., damage requiring more than cleanup or low-cost cosmetic repair, such as painting). The requirement for flood-resistant construction materials applies to breakaway walls.

In addition, except where heavier materials are required by the local building code, construction materials used for breakaway walls should meet the following specifications:

Wood-Frame Materials

- Exterior siding on breakaway wall panels shall be no thicker than ½-inch plywood, APA 32/16 rated sheathing or other equivalent sheathing material.
- Breakaway wall studs shall be no larger than 2 inches x 4 inches (nominal dimensions).
- Breakaway wall stud spacing shall be 24 inches on center or greater.
- Breakaway wall panels attached to concrete slabs shall be constructed with single top and bottom plates. Walls that enclose areas with earth floors may use a double bottom plate.
- Interior wall sheathing on breakaway wall panels shall be a maximum of ¼-inch plywood or equivalent material.

Other Materials

- Light-gauge steel framing, such as steel studs, is expected to perform in a manner similar to wood studs and may be used with the conditions for wood framing listed above.
- Stucco, Exterior Insulation Finishing System walls, and other lightweight exterior sheathing material may be applied over breakaway walls, provided a separation joint is installed in any sheathing (see Figure 7), insulation, or reinforcing where attached at or near the bottom of the elevated floor beam or joists.
- Unreinforced, ungrouted hollow-cell masonry units with a width of 8 inches or less may be attached to floor beams and to concrete or masonry vertical foundation members with standard mortars. Minimum perimeter connections are acceptable as long as the wall is unreinforced.

Warning: Unreinforced masonry walls shall not be used in earthquake hazard areas. Consult local building officials for seismic safety requirements.

Other Regulatory Requirements

In addition to the NFIP regulatory requirements cited in this bulletin, State and local requirements, and the recommendations listed above, other regulatory requirements may apply, such as those listed in the following FEMA Technical Bulletins:

- *Flood-Resistant Material Requirements*, FIA-TB-2
- *Elevator Installation*, FIA-TB-4
- *Free-Of-Obstructions Requirements*, FIA-TB-5
- *Corrosion Protection for Metal Connectors in Coastal Areas*, FIA-TB-6

Flood Insurance Considerations

The presence of breakaway walls or other obstructions below an elevated building in the Coastal High Hazard Area (Zones V1-V30, VE, or V) significantly increases the cost of flood insurance. Generally, flood insurance rates increase as the size of the enclosure increases. Flood insurance policies place significant limits on the coverage of any enclosure and/or stored contents below the elevated building. Contact an insurance agent before installing breakaway walls or other obstructions.

The NFIP

The NFIP was created by Congress in 1968 to provide federally backed flood insurance coverage, because flood coverage was generally unavailable from private insurance companies. The NFIP is also intended to reduce future flood losses by identifying floodprone areas and ensuring that new development in these areas is adequately protected from flood damage. The NFIP is based on an agreement between the Federal government and participating communities that have been identified as floodprone. FEMA, through the Federal Insurance Administration (FIA), makes flood insurance available to the residents of a participating community, provided the community adopts and enforces adequate floodplain management regulations that meet the minimum NFIP requirements. The NFIP encourages communities to adopt floodplain management ordinances that exceed the minimum NFIP criteria. Included in the NFIP requirements, found under Title 44 of the U.S. Code of Federal Regulations, are minimum building design and construction standards for buildings located in Special Flood Hazard Areas. Through their floodplain management ordinances or laws, communities adopt the NFIP performance standards for new, substantially improved, and substantially damaged buildings in floodprone areas identified on FEMA's Flood Insurance Rate Maps.

Technical Bulletins

This publication is one of a series of Technical Bulletins that FEMA has produced to provide guidance concerning the building performance standards of the NFIP. These standards are contained in Title 44 of the U.S. Code of Federal Regulations at Section 60.3. The bulletins are intended for use primarily by State and local officials responsible for interpreting and enforcing NFIP regulations and by members of the development community, such as design professionals and builders. New bulletins, as well as updates of existing bulletins, are issued periodically, as

necessary. The bulletins do not create regulations; rather they provide specific guidance for conforming with the minimum requirements of existing NFIP regulations. Users of the Technical Bulletins who need additional guidance concerning NFIP regulatory requirements should contact the Mitigation Division of the appropriate FEMA regional office or the local floodplain administrator. The *User's Guide to Technical Bulletins* (FIA-TB-0) lists the bulletins issued to date, provides a key word/subject index for the entire series, and lists addresses and telephone numbers for FEMA's 10 regional offices.

Ordering Information

Copies of FEMA Technical Bulletins can be obtained from the FEMA regional office that serves your area. In addition, Technical Bulletins and other FEMA publications can be ordered from the FEMA Publications Service Center at 1-800-480-2520. The Technical Bulletins are also available at the FEMA web site at www.fema.gov.

Further Information

The following publications contain further information concerning breakaway walls:

Federal Emergency Management Agency. 2000. *Coastal Construction Manual – Principles and Practices of Planning, Siting, Designing, Constructing, and Maintaining Residential Buildings in Coastal Areas*. (Available spring 2000.)

Rogers, Spencer M. 1991. "Foundations and Breakaway Walls of Small Coastal Buildings in Hurricane Hugo." *Proceedings of Coastal Zone '91*. American Society of Civil Engineers. New York, NY.

Tung, C.C.; Bohumil Kasal; Spencer M. Rogers, Jr.; S.C. Yeh. 1999. *Behavior of Breakaway Wall Subjected to Wave Forces: Analytical and Experimental Studies*. North Carolina Sea Grant, North Carolina State University. Raleigh, NC.

Glossary

Base flood – The flood that has a 1-percent probability of being equaled or exceeded in any given year (also referred to as the 100-year flood).

Coastal High Hazard Area – An area of special flood hazard extending from offshore to the inland limit of a primary frontal dune along an open coast, and any other area subject to high-velocity wave action from storms or seismic sources. These areas are identified as V zones.

Federal Emergency Management Agency (FEMA) – The independent Federal agency that, in addition to carrying out other activities, administers the NFIP.

Federal Insurance Administration (FIA) – The component of FEMA directly responsible for administering the flood insurance aspects of the NFIP.

Flood Insurance Rate Map (FIRM) – The insurance and floodplain management map issued by FEMA that identifies, on the basis of detailed or approximate analysis, areas of 100-year flood hazard in a community.

Floodprone area – Any land area susceptible to being inundated by flood water from any source.

Mitigation Directorate – The component of FEMA directly responsible for administering the flood hazard identification and floodplain management aspects of the NFIP.

New construction/structure – For floodplain management purposes, new construction means structures for which the start of construction commences on or after the effective date of a floodplain management regulation adopted by a community and includes subsequent improvements to the structure. These structures are often referred to as "post-FIRM" structures.

Special Flood Hazard Area (SFHA) – Area subject to inundation by the base flood, designated Zone A, A1-30, AE, AH, AO, V, V1-V30, or VE.

Substantial damage – At minimum, 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. More stringent local requirements may apply.

Substantial improvement – At a minimum, 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. More stringent local requirements