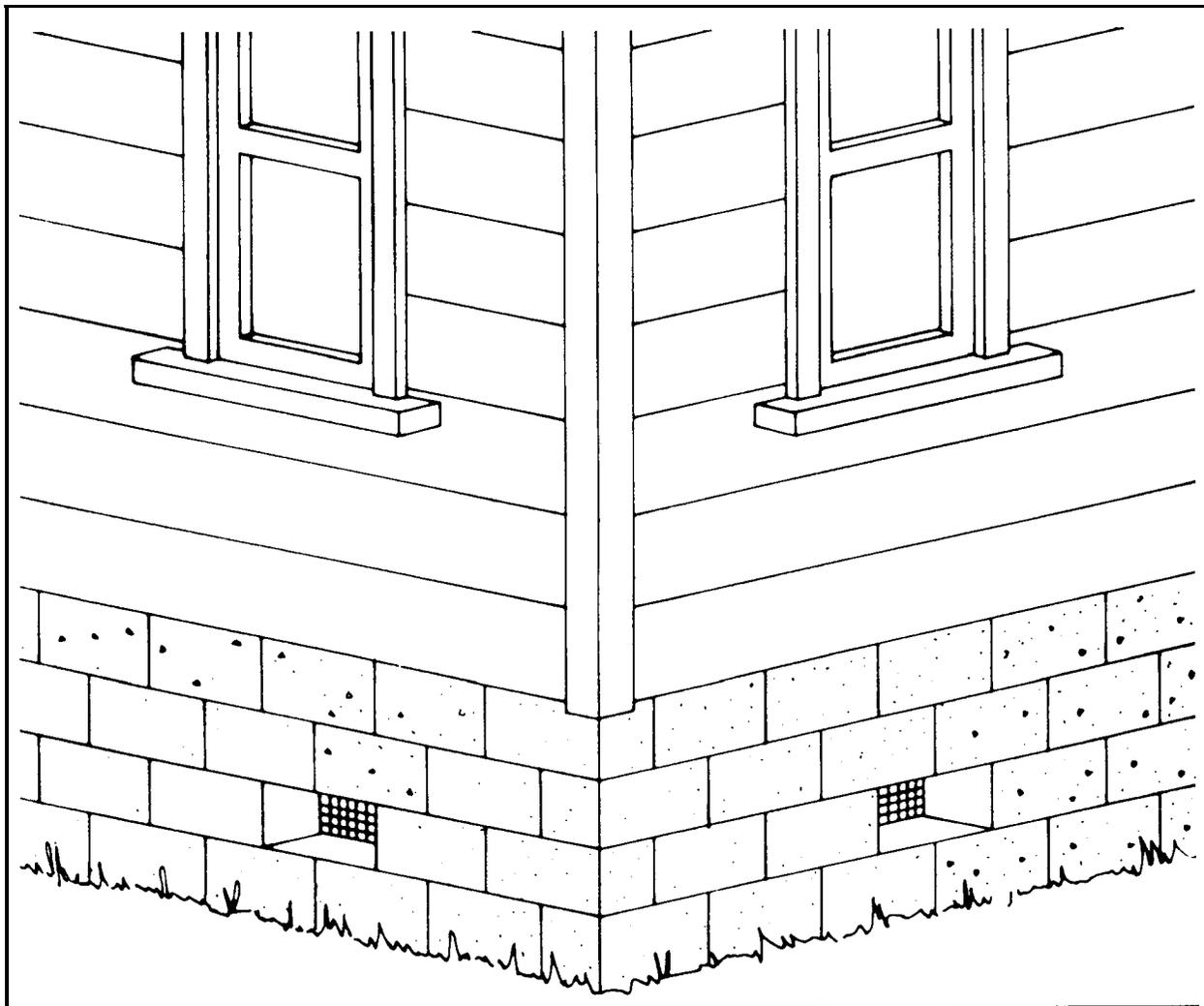




Technical
Bulletin
1-93

Openings in Foundation Walls for Buildings Located in Special Flood Hazard Areas

in accordance with the
National Flood Insurance Program



FEDERAL EMERGENCY MANAGEMENT AGENCY
FEDERAL INSURANCE ADMINISTRATION

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Key Word/Subject Index:

This index allows the user to quickly 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

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Any comments on the Technical Bulletins should be directed to:

FEMA/FIA
Office of Loss Reduction
Technical Standards Division
500 C St., SW, Room 417
Washington, D.C. 20472

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

TECHNICAL BULLETIN 1-93

Openings in Foundation Walls Required for Buildings Located in Special Flood Hazard Areas in accordance with the National Flood Insurance Program

Introduction

An important objective of the National Flood Insurance Program (NFIP) is to protect buildings constructed in floodplains from structural damage caused by flood forces. In support of this objective, the NFIP regulations include building design criteria that apply to new construction and substantial improvements of existing buildings in Special Flood Hazard Areas (SFHAs). According to these criteria, residential buildings constructed in A zones (Zones A, AE, A1-A30, AR, AO, and AH) must have their lowest floors at or above the base flood elevation (BFE). Non-residential buildings constructed in A zones must either have their lowest floors at or above the BFE or be dry floodproofed (made watertight) to or above the BFE. Residential and non-residential buildings whose lowest floors have been constructed at or above the BFE usually are elevated on piers, columns, piles, extended foundation walls, or fill. While the main portion of such a building is protected from the 100-year and lesser-magnitude floods, the foundation and any enclosures below the BFE used for parking, building access, or limited storage will be exposed to flood forces.

For buildings constructed on extended foundation walls or that have other enclosures below the BFE, these flood forces include the hydrostatic pressure of floodwaters against the foundation or enclosure walls. If the walls are not designed to withstand hydrostatic pressure, they can be weakened or can fail and the building damaged. Therefore, the NFIP regulations require that foundation and enclosure walls that are subject to the 100-year flood contain openings that will permit the automatic entry and exit of floodwaters. These openings allow floodwaters to reach equal levels on both sides of the walls and thereby lessen the potential for damage from hydrostatic pressure. The requirement for openings applies to all new and substantially improved buildings in A zones. This Technical Bulletin explains the requirement for openings and provides guidance for designing and constructing foundation and enclosure walls that include the required openings.

Extended foundation and enclosure walls below the BFE may also be threatened by hydrodynamic forces resulting from velocity flows and debris impact. The requirement for openings is intended to reduce flood damage associated with hydrostatic not hydrodynamic forces. These forces are described within this bulletin, and additional design guidance is given for buildings in areas subject to velocity flood flows, which may include debris.

For buildings in V zones (Zones V, VE, and V1-V30), more stringent design and construction requirements have been established for the portions of the buildings below the BFE. For information on V-zone design and construction requirements, refer to the NFIP regulations, the Technical Bulletin series, and FEMA's "Coastal Construction Manual."

NFIP Regulations

The NFIP regulations require that all enclosures below the BFE in A zones be designed to allow for the automatic equalization of hydrostatic forces during a flood event. Section 60.3(c)(5) of the NFIP regulations states that a community shall:

“Require, for all new construction and substantial improvements, that fully enclosed areas below the lowest floor that are usable solely for parking of vehicles, building access, or storage in an area other than a basement and which are subject to flooding shall be designed to automatically equalize hydrostatic flood forces on exterior walls by allowing for the entry and exit of floodwaters. Designs for meeting this requirement must either be certified by a registered professional engineer or architect or meet or exceed the following minimum criteria: A minimum of two openings having a total net area of not less than one square inch for every square foot of enclosed area subject to flooding shall be provided. The bottom of all openings shall be no higher than one foot above grade. Openings may be equipped with screens, louvers, valves, or other coverings or devices provided that they permit the automatic entry and exit of floodwaters. ”

As stated in the regulations, buildings in A zones that are substantially damaged and/or substantially improved must meet all the NFIP requirements for new construction, including the openings requirement. All design plans for substantial improvements to buildings in A zones must be thoroughly reviewed by the community to ensure compliance with the openings requirement. Further information on substantial damage and substantial improvement may be found in the FEMA publication “Answers to Questions About Substantially Damaged Buildings.”

<p>It should be noted that Technical Bulletins provide guidance on the minimum requirements of the NFIP regulations. Community or State requirements that exceed those of the NFIP take precedence. Design professionals should contact the community to determine whether more restrictive local or State 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.</p>
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Guidance for Non-Engineered Foundation Openings

Each of the following four design criteria must be met for new and substantially improved A-zone buildings that have enclosed areas below the BFE with openings not designed and certified by a design professional:

1. There must be a minimum of two openings on different sides of each enclosed area. If a building has more than one enclosed area, each area must have openings on exterior walls to allow floodwater to directly enter.
2. The total area of all openings must be at least 1 square inch for each 1 square foot of enclosed area.

3. The bottom of each opening can be no more than 1 foot above the adjacent grade.
4. Any louvers, screens, or other opening covers must not block or impede the automatic flow of floodwaters into and out of the enclosed area.

Types of Buildings Affected

In all cases, any enclosed area below the BFE is subject to flood forces and must be equipped with exterior wall openings in accordance with the NFIP regulations, either at the time of initial construction or, if the building is being substantially improved, at the time of improvement. The only exception to this requirement is floodproofed non-residential buildings that are engineered and meet stringent watertight construction requirements. For further information on this topic, refer to Technical Bulletin 3, “Non-Residential Floodproofing — Requirements and Certification.”

Buildings Elevated on Solid Foundation Walls

When a building is elevated on solid foundation walls, an enclosed area is often created below the lowest floor. All foundation enclosures below the BFE must have openings that meet NFIP criteria. Figure 1 shows an example of a properly placed foundation opening. As discussed previously, screens, louvers, or other covers that allow floodwaters to flow freely into the enclosed area may be placed over the openings to keep out vermin and weather.

Care must be taken when placing fill dirt around the outside of the foundation. The resulting enclosed area may be considered a basement under the NFIP. A basement is defined as any area of a building having a floor (finished or unfinished) that is subgrade (below grade) on all sides. The NFIP regulations do not permit a residential building in an SFHA to have a

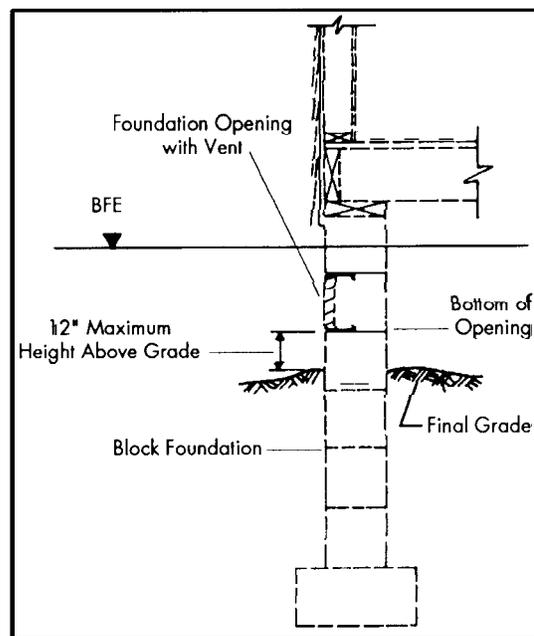


Figure 1. Opening for Solid Foundation Wall

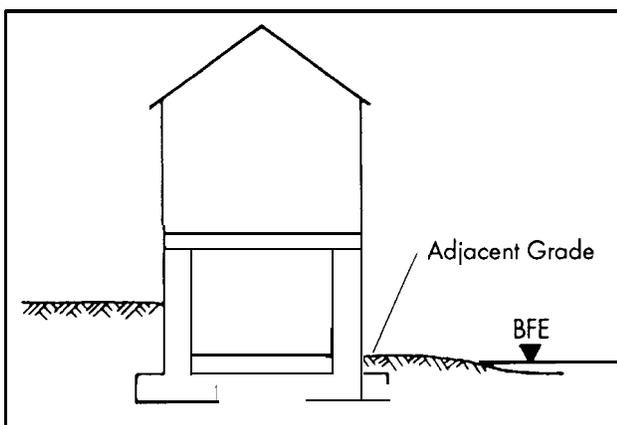


Figure 2. Compliant Grading for a Walkout Basement

basement whose lowest floor (including basement) is below the BFE.

To meet the NFIP requirements, fill placed around foundation walls must be graded so that the grade inside the enclosed area is equal to or higher than the adjacent grade outside the building on at least one side of the building (as illustrated in Figure 2). If the grade inside the foundation walls is above the BFE, openings are not required.

Buildings in Hazardous Velocity Areas

In coastal A zones, or in riverine A zones where flood velocities exceed 5 feet per second, fast-flowing floodwaters can exert considerable pressure on solid foundation walls. This hydrodynamic pressure, as described in the following section, may destroy a building’s foundation. In such areas, foundations that allow floodwaters to flow freely beneath the building should be considered. Foundations such as piles, piers, or columns will provide the appropriate level of safety to a building located in a hazardous velocity area, if properly embedded and anchored. See the discussion of hydrodynamic pressure for design guidance.

Buildings in A-zone floodplains with velocity floodwaters may have breakaway walls constructed in areas below the BFE. Compliant foundation openings are required in breakaway walls in A zones.

Buildings with Attached Garages

Any new or substantially improved residential building constructed in an A zone must have its lowest floor at or above the BFE. Many of these buildings have structurally attached garages with floor slabs below the BFE. Because such a below-BFE attached garage is an enclosed area below the BFE, openings are required either in the exterior walls of the garage or in the garage doors themselves in order to meet the NFIP openings criteria (see Figure 3). Openings are required because they prevent flood damage to the garage and subsequently to the structurally attached residence. Garage doors without openings specifically designed to allow for the free flow of floodwaters do not meet the openings requirement. The human intervention necessary to open garage doors when flooding threatens is not an acceptable means of meeting the openings requirement. Gaps that may be present between the door segments and between the garage door and the garage door jamb do not guarantee the automatic entry and exit of floodwaters. Therefore, openings are required either in the exterior walls of the enclosed area or in the garage doors themselves. Openings in garage doors must either meet the non-engineered openings requirements or be certified by a design professional.

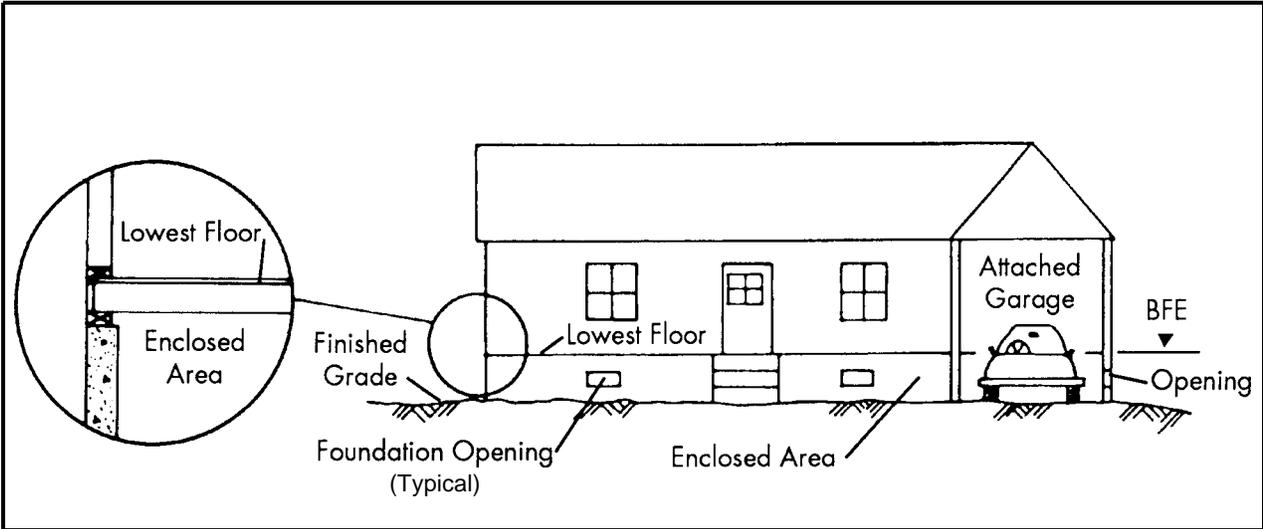


Figure 3. Compliant Residential Building Built on Solid Foundation Walls With Attached Garage

Flood Insurance Implication

If a below-BFE attached garage does not have proper openings, the Elevation Certificate prepared for the building must identify the elevation of the garage floor slab as the lowest floor (reference level) of the building. This may result in flood insurance premiums significantly higher than those that would have applied if the garage had proper openings.

Guidance for Engineered Openings

In situations where it is not feasible or desirable to meet the openings criteria stated previously, a design professional (registered engineer or architect) may design and certify openings. This section provides guidance for such engineered designs. For openings not meeting all four requirements for non-engineered openings listed on pages 2 and 3, certification by a registered professional engineer or architect is required. Such certification must be submitted to, and kept on file by, the community. These certifications must assure community officials that the openings are designed in accordance with accepted standards of practice. A certification may be affixed to the design drawings or submitted separately. It must include appropriate certification language, and the name, title, address, signature, type of license, license number, and professional seal of the certifier. Figure 4 is an example of an acceptable certification.

Project Name	
I, _____ do hereby certify that the opening(s) designed for installation in the aforementioned building will allow for the automatic equalizing of hydrostatic flood forces on exterior walls by allowing for the automatic entry and exit of floodwater during floods up to and including the base (100-year) flood.	
_____	_____
Signature	Date

Title	
_____	_____
Type of Licence	Licence Number

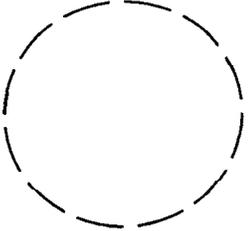
Address	
	
PROFESSIONAL SEAL	

Figure 4. Example of Openings Certificate

Calculation of Flood Forces

Floodwaters can impose both hydrostatic and hydrodynamic forces on floodprone buildings. Hydrostatic pressure is the force that water at rest exerts on any submerged object, including a floodprone building. Hydrostatic pressure is capable of collapsing, moving, and severely damaging most types of buildings. In many floods, hydrostatic pressure is the most prevalent cause of damage. Hydrodynamic pressure is the force exerted on a vertical obstruction (foundation wall) by flowing water and debris.

Hydrostatic pressure on an enclosed area above grade can be calculated by multiplying the specific weight of water (62.4 pounds per cubic foot) by the height of the water on the surface being analyzed. The application of the force generated by hydrostatic pressure is always perpendicular (normal) to the surface in question. In the case of a submerged object, this means that hydrostatic forces act in two ways. First, the force will act laterally (see Figure 5), which can result in collapse of walls or movement of the entire building off its foundation. Second, the force will act vertically (the vertical force is also known as buoyancy, see Figure 6), which can result in the building being lifted from its foundation or floor system.

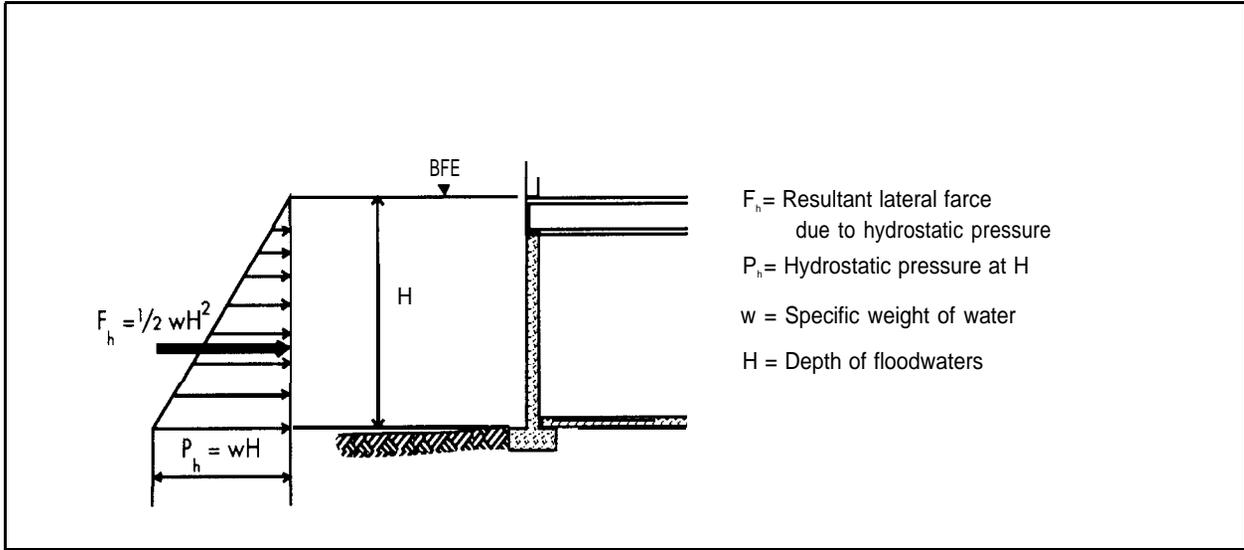


Figure 5. Lateral Hydrostatic Force and Pressure

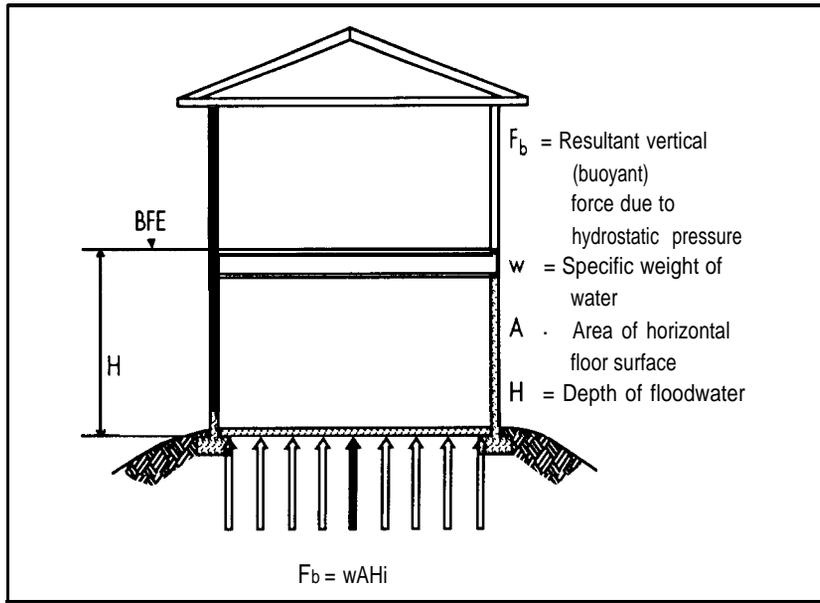


Figure 6. Buoyancy Force

To describe hydrostatic pressure in more technical terms:

The hydrostatic pressure, P_h , at a specific location on a structure is:

$$P_h = wH$$

where: P_h is the pressure in pounds per square foot
 w is the specific weight of water, 62.4 pounds per cubic foot
 H is the depth from the surface of the water to the location in question (generally from BFE to bottom of foundation wall)

The lateral force resulting from hydrostatic pressure is:

The resultant lateral (horizontal) force against the surface is:

$$F_h = \frac{1}{2}P_h H = \frac{1}{2}wH^2$$

where: F_h is the lateral force in pounds per linear foot of surface

Describing the hydrostatic vertical force (buoyancy) in more technical terms:

The buoyant (vertical) hydrostatic force acting against a horizontal surface such as a floor slab is:

$$F_b = wAH$$

where: F_b is the total buoyant force in pounds
 w is the specific weight of water, 62.4 pounds per cubic foot
 A is the area of the horizontal surface in square feet
 H is the depth of the building below the flood level

As shown in the following table, hydrostatic pressure, whether it affects a building laterally or vertically, increases rapidly as floodwater depths increase:

Height, H (in feet)	1	2	3	4	5	6	7	8
Pressure, P_h (in pounds per square foot)	62	125	187	250	312	374	437	499

Hydrodynamic pressure is exerted on all vertical surfaces of obstructions, such as building foundations, by the impact of velocity water and debris. Depending upon site-specific flood characteristics and the strength of the foundation, hydrodynamic pressure can overload and destroy a building’s foundation. The openings criteria are intended to equalize hydrostatic pressure and are not intended to minimize hydrodynamic pressure on the foundation. Hydrodynamic pressure must be considered in the design of any foundation system where velocity waters or the potential for debris flow exists. If flood velocities are excessive (greater than 5 feet per second), foundation systems other than solid foundation walls should be considered, so that obstructions to damaging flood flows are minimized. Safe foundations in such locations include pile, post, column, and pier foundations. These types of foundation systems are appropriate for A zones in coastal environs subject to waves and velocity floodwaters, as well as in riverine floodplains subject to velocity floodwaters (velocities greater than 5 feet per second) and areas subject to debris flows and ice floes. In areas with high-velocity floodwaters, it is advisable to construct any enclosures below the BFE using the breakaway wall specifications described in FEMA’s “Coastal Construction Manual.” As stated previously, breakaway walls in A zones must have openings compliant with NFIP regulatory requirements so that hydrostatic pressures are equalized during low-level flood events.

Design Criteria for Engineered Openings

Engineered openings that allow floodwaters into an enclosure for the purpose of equalizing hydrostatic pressures shall be designed using the following criteria:

- The difference between the exterior and interior floodwater levels should not exceed 1 foot at any time during the flood event. Greater differences can result in excessive hydrostatic pressures and structural damage to the enclosure walls.
- The arrangement of the openings must be capable of equalizing the hydrostatic pressures associated with the “worst-case” rate of rise of floodwaters. Historical flooding information should be used to determine rate of rise. A rate of rise of 5 feet per hour was assumed in the development of the NFIP non-engineered openings design criteria.
- Because of the large amount of debris associated with flooding and because openings will often be equipped with some form of vermin screen to meet applicable building codes, there is a high probability that openings may be obstructed during a flood. For this reason, a substantial safety factor is needed. Standard engineering practice is to use a safety factor of 5 in similar life/safety situations involving potential structural failure; therefore, a safety factor

of 5 was incorporated into the calculations that follow. Openings on the sides of the building facing the primary direction of velocity flow will add an additional safety factor however, such openings will tend to be blocked with debris sooner than other openings.

- At least two openings must be included to provide for a safety factor against debris blockage. This safety factor is enhanced when openings are located on at least two different sides of the enclosed area. This will allow for more even filling and emptying of the enclosed area and will also reduce the risk of debris being forced against an opening and blocking it.

The first step in determining the total net area required for openings is to calculate the flow rate per square foot of enclosed area, which is based on the rate of rise of the floodwaters. The assumed worst-case rate of rise is 5 feet per hour per square foot of area, or about 0.1 foot per minute. To convert this to gallons per minute per square foot of enclosed area, multiply by a conversion factor of 7.5 gallons per cubic foot. The needed flow rate into the enclosure per square foot of area is then (0.1 foot per minute) times (7.5 gallons per cubic foot), or 0.8 gallon per minute per square foot of enclosed area. The second step is outlined below.

To determine the total net area of the openings, A, needed to permit the above flow rate, the formula is:

$$Q = 38.0cA(p)^5$$

Solving for area A and multiplying by a factor of safety:

$$A = \frac{Q}{38.0 cp^5} (FS)$$

where:

A	is the net area of openings required, in square inches
Q	is the flow rate per square foot, which is 0.8 gallon per minute
c	is the coefficient of discharge, which is assumed to be 0.2
p	is the pressure, which for one square foot of differential is 62.4 pounds per square foot, or 0.4 pound per square inch
FS	is the factor of safety, which is 5

Therefore:

$$A = \frac{0.8}{38.0 \times 0.2 \times 0.6} (5)$$

= about 1.0 square inch of opening per square foot of enclosed area.

The NFIP

The NFIP was created by Congress in 1968 to provide federally backed flood insurance coverage, because it 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 inadequately protected from flood damage. The NFIP is based on a mutual agreement between the federal government and communities that have been identified as floodprone. FEMA, through the Federal Insurance Administration (FIA), makes flood insurance available to community residents provided that the participating 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 SFHAs. Through their floodplain management ordinances, communities adopt the NFIP design performance standards for new and substantially improved buildings located in floodprone areas identified on FIA's Flood Insurance Rate Maps.

Technical Bulletins

This is one of a series of Technical Bulletins 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 complying with the minimum requirements of existing NFIP regulations. Users of the Technical Bulletins who need additional guidance concerning NFIP regulatory requirements should contact the Natural Hazards Branch of the appropriate FEMA regional office. The "User's Guide to Technical Bulletins" lists the bulletins issued to date and provides a key word/subject index for the entire series.

Ordering Information

Copies of the Technical Bulletins can be obtained from the appropriate FEMA regional office. Technical Bulletins can also be ordered from the FEMA publications warehouse. Use of FEMA Form 60-8 will result in a more timely delivery from the warehouse — the form can be obtained from FEMA regional offices and your state's Office of Emergency Management. Send publication requests to FEMA Publications, P.O. Box 70274, Washington, D.C. 20024.

Further Information

The following publications provide further information concerning openings in foundation walls:

1. "Answers to Questions About Substantially Damaged Buildings," FEMA, May 1991, FEMA-213.
2. "Coastal Construction Manual," FEMA, February 1986, FEMA-55.
3. "Colorado Floodproofing Manual," Colorado Department of Natural Resources, Water Conservation Board, October 1983.
4. "Design Manual for Retrofitting Flood-Prone Residential Structures," FEMA, September 1986, FEMA-1 14.

5. "Elevated Residential Structures," FEMA, May 1986, FEMA-54.
6. "Elevating Flood-Prone Buildings: A Contractor's Guide," Illinois Department of Transportation, Division of Water Resources, 1985.
7. "Flood Proofing Regulations," U.S. Army Corps of Engineers, March 1992, EP 1165-2-314.
8. "Flood Proofing Systems and Techniques," U.S. Army Corps of Engineers, December 1984.
9. "Foundation Analysis and Design," Second Edition, Joseph E. Bowles, McGraw-Hill Book Co., New York.

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).

Base Flood Elevation (BFE) — The height of the base flood, usually in feet, in relation to the National Geodetic Vertical Datum of 1929 or other datum as specified.

Basement — Any area of a building having its floor subgrade (below ground level) on all sides.

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.

Federal Emergency Management Agency (FEMA) — The independent federal agency that, in addition to carrying out other activities, oversees the administration of the National Flood Insurance Program.

Federal Insurance Administration (FIA) — The component of FEMA directly responsible for administering the National Flood Insurance Program.

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

Floodprone area — Any land area susceptible to being inundated by floodwater from any source.

Lowest floor — The lowest floor of the lowest enclosed area of a building, including a basement. Any NFIP-compliant unfinished or flood-resistant enclosure useable solely for parking of vehicles, building access, or storage (in an area other than a basement) is not considered a building's lowest floor.

Special Flood Hazard Area (SFHA) — Area delineated on a Flood Insurance Rate Map as being subject to inundation by the base flood and designated as Zone A, AE, A1-A30, AR, AO, AH, V, VE, or V1-V30.

Substantial damage — 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 — 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.