C2.7.1 Required Openings in Foundation Walls and Walls of Enclosures The requirement for openings does not apply to nonresidential structures that are dry floodproofed in accordance with Section 6.2 of this standard.

Openings are required in foundation walls that enclose areas below the DFE in order to equalize hydrostatic pressures and prevent damage or collapse. Although openings in interior walls are not required by this section, designers should consider whether such openings are necessary to ensure that floodwaters can reach all portions of enclosed areas in order to minimize unbalanced hydrostatic loads on foundation walls and exterior walls. In addition, designers should consult with the authority having jurisdiction about requirements for such openings.

C2.7.1.1 Openings in Breakaway Walls The 2014 edition of this standard includes two significant changes to this section. First, the 2005 edition did not require openings in breakaway walls in Coastal High Hazard Areas, while this edition does; it requires openings in breakaway walls in all flood hazard areas. Second, the 2005 edition had two calculations for opening areas depending on flood zone and whether the walls were breakaway walls. This edition has a single calculation that is used for all openings, whether in nonbreakaway walls or breakaway walls.

Breakaway walls are intended to fail under wave loads. However, experience shows that some breakaway walls fail under water depths and wave conditions that are significantly less than base flood conditions. Experience also shows that openings in breakaway walls limit failure under these more frequent "shallow" flooding events. When breakaway walls stay intact during more frequent flooding, (1) the interiors of enclosed areas are not exposed to wind-driven rain and sand, (2) there is less debris added to floodwaters, and (3) building owners suffer less out-of-pocket costs to replace breakaway walls and repair flood damage.

C2.7.2 Design of Openings Flood openings can be engineered or non-engineered but should safely allow equalization of hydrostatic pressure outside and inside any enclosure below the DFE. FEMA Technical Bulletin 1, *Openings in Foundation Walls and Walls of Enclosures* (FEMA 2008d) has an expanded discussion of opening requirements.

C2.7.2.1 Non-Engineered Openings The prescriptive requirement for non-engineered openings specifies 1 sq in. of net opening area per square foot of enclosed area. The area of the enclosure is measured on the outside, which allows inspection and verification without requiring entry into the enclosed area or crawlspace. The sum of the net open area of all non-engineered openings provided for a specific enclosure must equal or exceed the required net open area for that enclosure. The minimum dimension of an opening in the wall must not be less than 3 in., as measured in any direction in the plane of the wall.

To determine the net open area of a non-engineered opening, the actual area through which water flows shall be measured. If a device is inserted into or affixed over an opening in the wall, the measurement of the net open area is not based on the dimensions of the opening in the wall but must account for the presence of the device. Area that is obstructed or covered in any way (other than by screening) shall not be counted as open area.

Any louvers, blades, screens, and faceplates or other covers and devices should be selected or specified so as to minimize the likelihood of blockage by small debris and sediment. Where experience has shown that a particular device or type of device has been blocked or clogged by flood debris or sediment, use of such devices should be avoided.

The requirement for flood openings may be satisfied by use of ventilation devices that commonly are used for foundation ventilation. When foundation ventilation devices are installed in accordance with Section 2.7.3, such devices are to be permanently disabled in the open position in order to satisfy the requirement that flood openings allow for the automatic entry and exit of floodwaters. Covers that must be removed and devices that must be manually opened do not satisfy the requirement for automatic entry and exit of floodwaters, and such covers and devices should not be specified by the designer.

Methods used by the ventilation industry to calculate the net open area of ventilation devices, for example, vents with fixed louvers, may be applied to determine the net open area for non-engineered flood openings. FEMA (2008d) advises that manufacturers of air vents typically indicate the number of square inches their air vents provide for air flow; that same number of square inches may be used for flood opening applications.

C2.7.2.2 Engineered Openings Engineered openings are intended to provide an alternate to the non-engineered or prescriptive requirement (1 sq in/sq ft of enclosed area), while still satisfying the required opening performance (automatic entry and exit of floodwaters with no more than 1 ft of difference between the exterior and interior water levels).

The NFIP and building codes require the design of engineered openings to be certified by a registered design professional. Certification requires more than simply applying the equation in this section; it requires consideration of a number of factors that represent expected base flood conditions. Worst case rates of rise and fall must be determined, opening shape and size (which affect flow efficiency) must be assessed, the potential for debris blockage must be evaluated, and the effects of any louvers, blades, screens, grilles, faceplates, or other covers and devices must be considered. The best means to certify performance is to test engineered opening devices under conditions that mimic a range of rising and falling floodwaters, preferably floodwaters that contain debris typical of floodwaters around buildings.

The standard indicates that a minimum rate of rise and fall of 5 ft/h should be used in the absence of reliable data or analysis. This rate of rise, only 1 in./min, is not representative of many flood hazard areas where both past experience or numerical modeling indicate much faster rates of rise and fall, suggesting designers should be cautious about relying on the 5 ft/h minimum rate. Depending on factors, such as watershed size, nature of land use, topography, and soil type, rainfall quickly runs off many watersheds, resulting in rates of rise and fall that exceed 1 in./min. Depending on coastal storm characteristics such as track, forward speed, and intensity, storm surge flooding also can result in rates of rise and fall that exceed 1 in./min. Information on rates of rise for specific areas may be available from stream gauges and tide gauges.

Information may also be available from sources familiar with past flooding characteristics at specific locations, including federal agencies such as USGS, NRCS, or NOAA; and state and local sources, such as floodplain management and building departments, emergency management agencies, public works departments, transportation agencies, and universities. Video documentation of rates of rise is becoming readily available for many flood events and may also serve as a basis for estimating rates of rise.

Unless an engineered opening is uniquely designed for a specific location, the performance of engineered openings should be tested over a range of rates of rise, including rates that are many times the minimum rate, so that designers have sufficient information on which to base decisions regarding whether to increase the total net area to account for faster rates of rise, as indicated in item 5 of this subsection.

Net open area of an engineered opening (A_o) should be measured in the same manner as for a non-engineered opening based on the actual area through which water flows, and excluding any area that is obstructed or covered (except by screening).

Discharge coefficients shown in Table 2-2 for unobstructed flow conditions were taken from or derived from standard hydraulics texts, and the values represent free-flowing, unobstructed openings. The coefficient represents the ratio of the actual flow through an opening divided by the ideal flow, where ideal flow is given by

$$Q = A_o(2\,g\,H)^{0.5}$$

where

Q = ideal flow (cfs)
A = net cross-sectional area of opening (sq ft)
H = depth of water above the bottom of the opening (ft)
g = gravitational constant (32.2 ft/s^2).

Note that the 2014 edition of this standard added a coefficient of discharge of 0.20 for openings that are partially obstructed. This standard classifies any opening with louvers, blades, screens, grilles, faceplates, or other covers or similar devices that will be in place during the design flood, as partially obstructed. A partially obstructed condition will also occur if debris blocks part of an opening even if there are no louvers, blades, screens, grilles, faceplates, or other covers or similar devices.

In the case of unobstructed circular openings, hydraulics references indicate the discharge coefficient for a circular, sharp-edged orifice in a vertical wall will be approximately 0.60 under low head conditions, which are required here (maximum head difference across opening equal to 1 ft). Coefficients for unobstructed rectangular and square openings were calculated for typical opening sizes (i.e., 12 in. × 12 in. or 8 in. × 16 in., corresponding to nominal masonry unit sizes) using the ideal flow discharge relationship as shown and the following discharge relationship for a contracted rectangular weir:

$$Q = 3.33(L - 0.2\,H)\,H^{1.5}$$

where

Q = flow through opening in cfs
L = horizontal length, ft
H = depth of water above the bottom of the opening, in ft.

Other unobstructed opening shapes were assigned a coefficient of 0.30 based on flow through a V-notch or trapezoidal weir.

If no louvers, blades, screens, grilles, faceplates or other covers, or similar devices are used, and if the designer is certain the potential for blockage by debris is low, unobstructed discharge coefficients in Table 2-2 between 0.25 and 0.60 may be used, depending on the opening shape.

This standard permits a more exact determination of a coefficient of discharge for a particular opening/device and debris condition by laboratory testing or numerical modeling of the opening/device, provided the resulting coefficient is no more than 10% greater than that shown in Table 2-2, and in no case shall a coefficient greater than 0.60 be used.

If an engineered device contains more than one open area through which water flows, the designer may assign a discharge coefficient to each open area based on the shape of each open area. This allowance is not intended to be applied such that portions of a partially obstructed device (see footnote b in Table 2-2) can be reclassified as unobstructed by making individual flow calculations for many small open areas in the device.

C2.7.3 Installation of Openings All openings, whether non-engineered or engineered, are to be installed as specified in this section. The minimum requirements for at least two openings and for openings in at least two walls are intended to minimize the likelihood that flood debris will block openings and prevent them from functioning as intended. Buildings on solid perimeter walls that are set into sloping sites may require installation of openings along the sloping grade, provided the openings are below the DFE (illustrated in FEMA 2008d).

Rising floodwater exerts unbalanced hydrostatic loads on a wall when the exterior water level rises above the interior floor level or when the interior water level is above the exterior grade. This is why the bottoms of openings are to be positioned relative to the higher of the final interior grade or floor and the finished exterior grade immediately under the openings. Designers are reminded that floodwaters of 1 ft depth may be trapped inside crawlspaces and enclosures, contributing to moisture problems during cleanup. To minimize this effect, openings may be positioned closer to grade.

Openings and opening devices may be distributed around the perimeter of an enclosed area and may be grouped. If grouped, whether side-by-side or stacked vertically, the installation requirements apply. If stacked vertically, a closely spaced group of openings or opening devices can be assumed to function as a single opening and the bottom of the lowest opening or opening device should be positioned to meet the height-above-grade requirement.