9 Non-Engineered Flood Openings and Engineered Flood Openings

The NFIP regulations, described in previous sections, identify options for providing sufficient size and number of flood openings to allow for the automatic (free) entry and exit of floodwater. This section describes how the automatic entry and exit of floodwater can be accomplished by the use of:

- Non-engineered openings that meet the prescriptive requirement to provide 1 square inch of net open area for each square foot of enclosed area, where the enclosed area is measured on the exterior of the enclosure walls. Section 9.2 describes a variety of options that can serve as non-engineered openings.
- Engineered openings for which Evaluation Reports are issued by the ICC Evaluation Service (ICC-ES), a subsidiary of the ICC, or equivalent reports issued by other product certification organizations.
- Engineered openings designed and certified by a registered design professional for a specific building and site-specific conditions.

All of the following requirements for installation apply regardless of whether engineered openings or non-engineered openings are used to satisfy the NFIP requirements (also see Section 8):

- Each enclosed area must have a minimum of two openings. When multiple enclosed areas are present, each area must have openings in its exterior walls. Section 8.3.5 describes connecting multiple areas by installing openings in interior walls or partitions to ensure that floodwater can reach all enclosed areas.
- The bottom of each opening must be no more than 1 foot above the higher of the final interior grade or floor or the finished exterior grade immediately under the opening.
- Insect screens, grates, grilles, fixed louvers, blades, faceplates, or other devices, if any, must not block the automatic flow of floodwater into and out of the enclosed area.

Section 9.1 provides a list of measures that are not acceptable as flood openings.

I-CODE REQUIREMENTS FOR FLOOD OPENINGS

The IRC includes requirements for non-engineered and engineered flood openings, and the IBC includes the same requirements by reference to ASCE 24.

FLOOD DAMAGE-RESISTANT MATERIALS

Flood openings must be made of flood damage-resistant materials in order to satisfy the requirement that materials used below the BFE be resistant to flood damage. Metals should be corrosion resistant, and plastics should be weather resistant. For guidance, see NFIP Technical Bulletin 2, *Flood Damage-Resistant Materials Requirements*.

9.1 Measures Not Acceptable as Flood Openings

FEMA has determined that the following measures do not satisfy the requirements for flood openings:

- Standard foundation air-ventilation devices that can be closed manually unless they are permanently disabled in the open position because otherwise, they do not allow for the automatic entry and exit of floodwater (see Figure 17).
- Standard foundation air-ventilation devices that have detachable solid covers intended to be manually installed over the vent because they do not allow for the automatic entry and exit of floodwater when the cover is in place.
- Standard foundation air-ventilation devices that are designed to open and close based on temperature unless they are also designed to allow for the automatic entry and exit of floodwater.
- Devices with covers or panels that are intended to displace when floodwaters rise on only one side of a wall because they do not satisfy the requirement for automatic entry and exit of floodwater in both directions.
- Windows below the BFE because the automatic entry and exit of floodwater cannot be satisfied by the expectation that windows will break under rising floodwater.
- Garage doors without openings because human intervention is required to open garage doors when flooding is expected. Gaps between the garage door and the door jamb or walls do not count toward the net open area requirement.

Figure 17: Standard air vent that is unacceptable as a flood opening because it is not disabled in the open position

9.2 Non-Engineered Flood Openings

Flood openings without moving parts are non-engineered openings, while those with moving parts should be certified as engineered openings (see Section 9.3). Non-engineered openings are used to provide 1 square inch of net open area for each square foot of enclosed area. The size of an enclosed

area in square feet should be measured on the exterior of the enclosure walls. A variety of non-engineered opening options are available.

"Net open area" refers to the permanently open area of a non-engineered opening. The NFIP regulations indicate that flood openings may be equipped with "coverings or devices" if they permit the automatic (free) entry and exit of floodwater in both directions.

The measurement of the net open area must take into consideration any solid obstructions such as grilles, fixed blades and louvers, or faceplates. Methods used by the ventilation industry to account for such obstructions when determining net open area for air flow may be used. Figure 18 shows a typical standard air-vent faceplate and measurements of the net open area. Figure 19 shows a typical ventilation louver with fixed blades and indicates how the net open area is determined.

Some manufacturers of standard air vents stamp the number of square inches the device provides for air flow into the frame of the device or may note the number in the packaging. The measurement accounts for

MEASUREMENT MUST ACCOUNT FOR OBSTRUCTIONS

Section C2.7.2.1 of the ASCE 24 commentary emphasizes that the measurement of net open area is not based on the dimensions of the opening (void) in the wall. The measurement must account for any portion of the void that is obstructed or covered in any way (other than by screening).

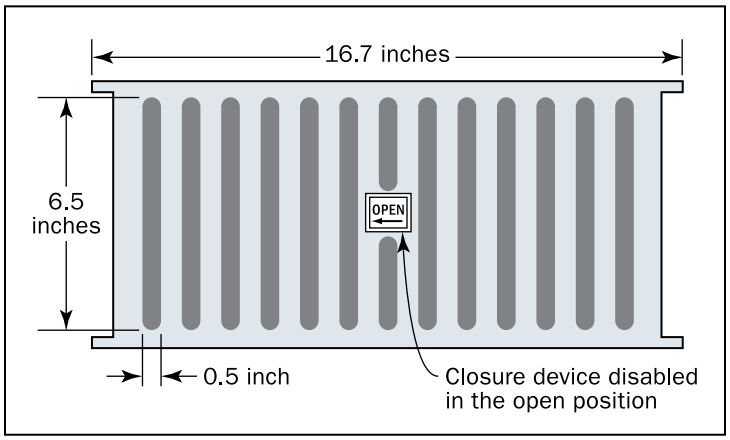


Figure 18: Example of non-engineered opening: Typical standard air vent faceplate providing 42 square inches of net open area if disabled in the open position; measurement of net open area uses a slot width of 0.5 inch times a slot height of 6.5 inch times the total number of slots

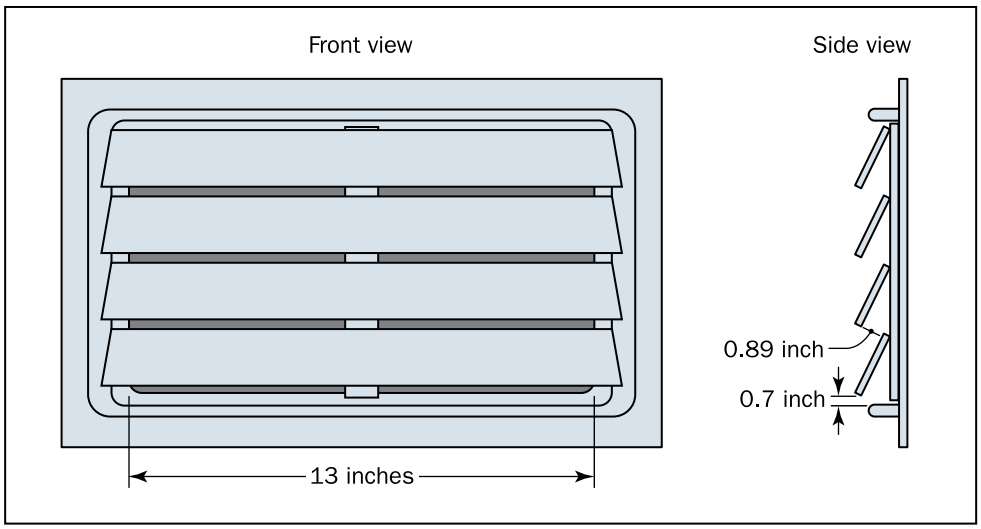


Figure 19: Example of non-engineered opening: Typical standard air vent with fixed, angled blades providing approximately 44 square inches of net open area; measurement of net open area uses slot width of 13 inches times the sum of the spaces between the blades

the presence of fixed blades, insect screens, and other obstructions. The same number of square inches should be used for the net open area calculation when these devices are installed as non-engineered openings. If not indicated by the manufacturer, the net open area must be measured. Guidance on measuring the net opening area may be available from manufacturers or other sources.

To qualify as non-engineered flood openings that permit the automatic entry and exit of floodwater:

- Standard air vents must not have solid covers (detachable or integrated with the vent) that are intended to be manually installed.
- Typical air-vent devices that are designed to be opened and closed manually must be disabled permanently in the open position.
- Air-vent devices that are designed to open and close based on temperature must also be designed to allow the automatic entry and exit of floodwater.

Insect screens that do not block the entry and exit of floodwater are allowed and do not affect the determination of the net open area. Communities that administer the IBC or IRC should note the requirement to cover ventilation openings for crawlspaces and under-floor spaces. The codes provide a list of acceptable covering materials.

The IBC and IRC commentaries note that some covering materials for ventilation openings may reduce the gross open area of the vent by as much as 50 percent. Although the net open area is not reduced by screens, in areas where floodwater is expected to carry debris such as grass clippings and leaves, insect screens tend to clog (see Figure 20). Engineers, architects, and local officials may determine that a different type of opening is appropriate or that more than the minimum number of flood openings is required to increase the likelihood that openings will perform as expected during flooding, even if some of them become clogged with debris.

AREAS LIKELY TO HAVE DEBRIS AND SEDIMENT

Section C2.7.2.1 of the ASCE 24 commentary suggests using caution in selecting or specifying openings with louvers, blades, screens, or faceplates that may be blocked by debris and sediment. In areas where experience indicates that floodborne debris and sediment are likely, ASCE 24 recommends avoiding the use of openings with components that have been shown to become blocked or clogged.

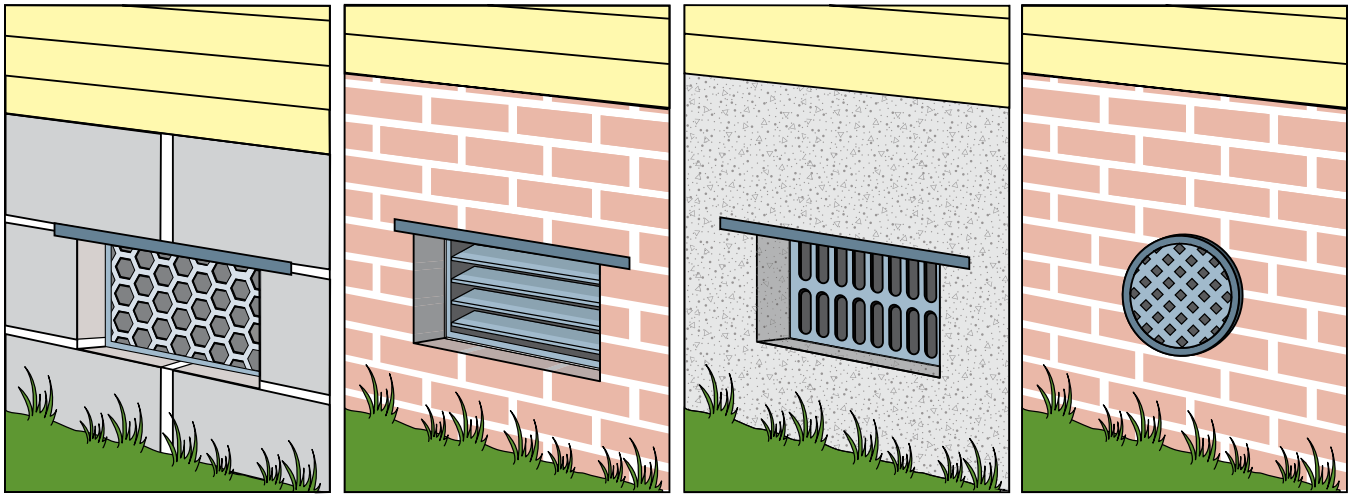
Figure 20: Typical air vents with insect screens blocked by flood debris

Examples of non-engineered openings are described below and shown in Figures 21 through 24.

- Figure 21 shows typical standard air-ventilation devices that are intended for crawlspace foundation walls. If installed as flood openings, they must be disabled permanently in the open position to satisfy the requirement for automatic entry and exit of floodwater.
- Figure 22 shows decorative masonry units and decorative brickwork with closely spaced, open holes. Only the net open area of each hole is counted.
- Figure 23 shows standard concrete blocks that are turned sideways and have insect screening. The voids in the blocks are measured to determine the net open area.
- Figure 24 shows a foundation in which a hole was created when the concrete was poured. The horizontal dimension should be greater than the vertical dimension to facilitate flow-through. A wood frame covered with insect screening is inserted into the hole. The framed void is measured to determine the net open area. A similar situation results when a block is omitted from perimeter foundation walls constructed of concrete masonry units, resulting in a void the size of the omitted block.

MINIMUM DIMENSION SPECIFIED BY I-CODES

The IRC and IBC (by reference to ASCE 24) require that openings be not less than 3 inches in any direction in the plane of the wall. This requirement applies to the opening in the wall, excluding any device that may be inserted.



Grate **Fixed blades** **Faceplate or grille** **Decorative faceplate**

Figure 21: Examples of typical air vents in crawlspace foundation walls used as flood openings with varying net open areas

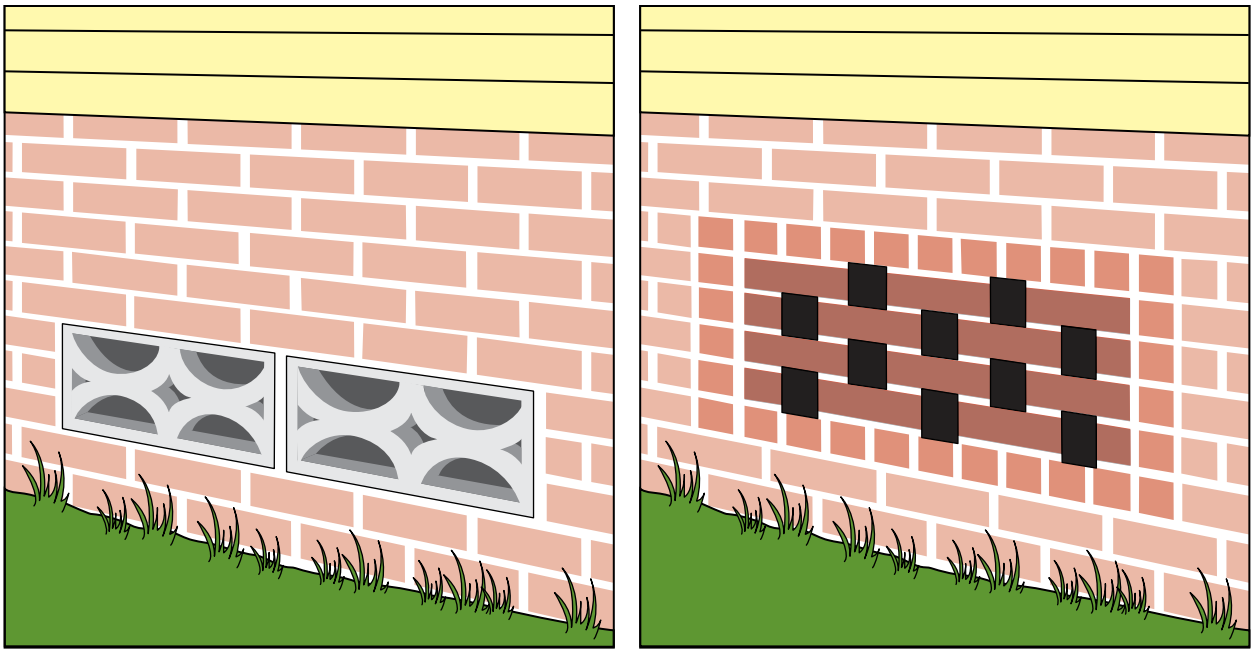


Figure 22: Decorative masonry units and closely spaced holes in brickwork; the area of each hole counts toward the total net open area

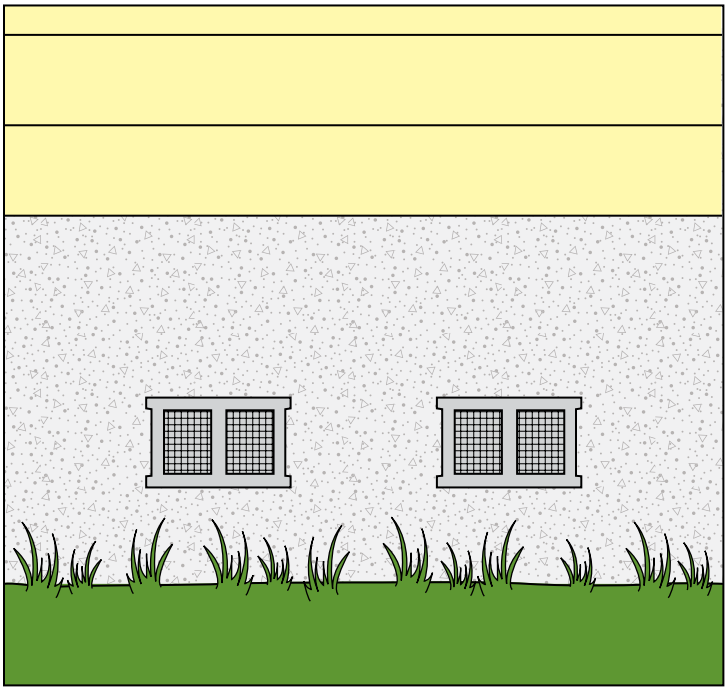


Figure 23: Concrete blocks turned sideways with insect screening; a typical 8- by 16-inch block provides approximately 60 square inches of net open area

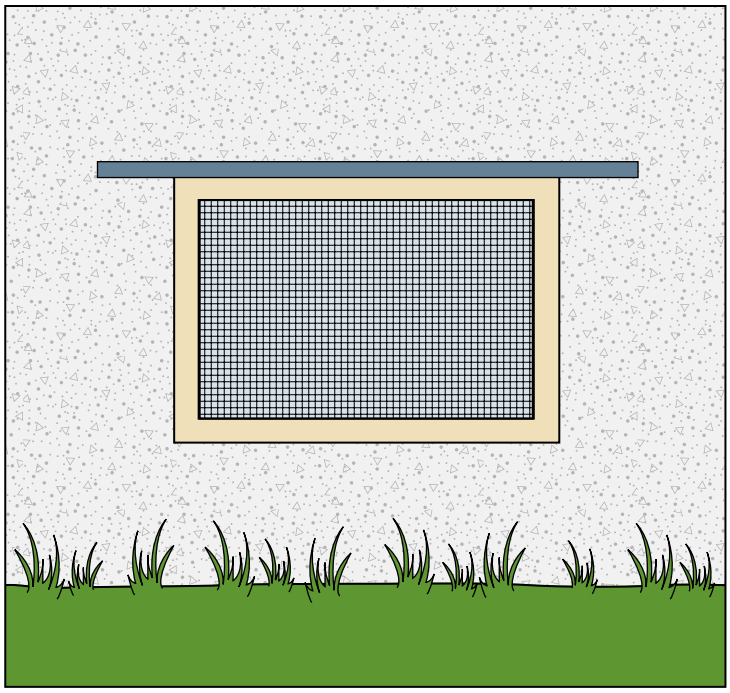


Figure 24: Wood frame with insect screen inserted in void in poured concrete foundation wall; inside dimensions of frame determine net open area

9.3 Engineered Flood Openings

Engineered flood openings, which have moving parts, must be designed and certified by registered design professionals as engineered flood openings (see Section 9.2 for openings without moving parts). The certification must specifically address the performance required by the NFIP regulations. Devices with moving parts should be certified as engineered openings. In general, engineered openings remain closed until flood conditions trigger the movable parts to allow floodwater and debris to freely and automatically enter or exit. This section describes the design and performance requirements and the certification and documentation requirements for engineered openings.

9.3.1 Design and Performance Requirements

The design and performance criteria for engineered openings are in ASCE 24, Section 2.7.2.2. Section C2.7.2.2 of the ASCE 24 commentary provides additional information on engineered openings and the best means to test expected performance.

The equation from ASCE 24, shown in Figure 25, is used to determine the total net area of engineered openings required for a given total enclosed area, based on some of the characteristics of the openings. The calculated minimum net area of engineered openings may be called the "coverage" or "rated" area.

$$A_0 = 0.033\,[1/c]\,R\,A_e$$

Where:
- A_0 = total net area of openings required (in^2)
- 0.033 = coefficient corresponding to a factor of safety of 5.0 ($in^2 \cdot hr/ft^3$)
- c = opening coefficient (non-dimensional; see ASCE 24, Table 2-2)
- R = worst case rate of rise and fall (ft/hr)
- A_e = total enclosed area (ft^2)

Figure 25: Equation used to determined total net area of engineered openings (ASCE 24-14; used with permission)

The equation includes a coefficient (0.033) that corresponds to a factor of safety of 5, which is consistent with design practices related to the protection of life and property. The ASCE 24 commentary provides additional background on the derivation of the equation.

Design and performance criteria for engineered openings specified in ASCE 24 include all of the following:

- Performance must allow for the automatic entry and exit of floodwater. The ASCE 24 commentary notes that the certification requires consideration of a number of factors that represent expected base flood conditions and not simply application of the equation. (Flood conditions in different areas can vary widely; in some areas, the onset of flooding may be rapid while in other areas, flood conditions may develop over much longer periods.)
- Performance must account for the presence of obstructions such as louvers, blades, screens, grilles, faceplates, and devices that are part of the engineered opening assembly itself. In accordance with ASCE 24, Table 2-2 (see Table 3 of this Technical Bulletin), the opening coefficient of discharge *(c)* is 0.20 for openings of all shapes if partially obstructed during design flood conditions by "louvers, blades, screens, grilles, faceplates, or other covers or devices [that] are present during the design flood," as opposed to blocked by debris.

ASCE 24 EMPHASIS ON PERFORMANCE AND CERTIFICATION

Engineered opening requirements changed between the 2005 and 2014 editions of ASCE 24. The 2014 edition places more emphasis on evidence of performance and consideration of factors that represent expected flood conditions. Section C2.7.2.2 of the ASCE 24-14 commentary notes that the best means to certify performance is to test engineered openings under conditions that mimic a range of rates of rise and fall, including rates many times the minimum rate of 5 feet per hour.

Documentation of performance under faster rates of rise and fall provides building designers and local officials with sufficient information on which to base decisions regarding whether to increase the number or size of openings to account for faster rates. The ASCE 24 commentary also notes that testing should be done with water containing debris typical of flooding around buildings (e.g., leaves, grass clippings, small branches, trash).

(The coefficient of discharge, also called an orifice coefficient, is selected to characterize the shape of the portion of an engineered opening through which water flows.)

Table 3: Flood Opening Coefficient of Discharge[1]

Opening Shape and Condition	*c*
All shapes, partially obstructed during design flood[2]	0.20
Circular, unobstructed during design flood	0.60
Rectangular, long axis horizontal, short axis vertical, unobstructed during design flood	0.40[3]
Square, unobstructed during design flood	0.35
Rectangular, short axis horizontal, long axis vertical, unobstructed during design flood	0.25[4]
Other shapes, unobstructed during design flood	0.30

Source: ASCE 24-14, Table 2-2 (used with permission)

(1) Different coefficients of discharge shall be permitted: (1) where a designer has performed detailed, opening-specific calculations, a coefficient of discharge up to 10% different than given in Table 2-2 shall be permitted; or (2) where laboratory testing or numerical modeling of flow through the opening has been conducted, the resulting coefficient of discharge shall be permitted. In no case shall a coefficient of discharge >0.60 be permitted.

(2) Openings shall be classified as partially obstructed if louvers, blades, screens, grilles, faceplates, or other covers or devices are present during the design flood.

(3) When the horizontal dimension is twice or more the vertical dimension, use 0.4; as the dimensions approach a square, interpolate from 0.4 to 0.35.

(4) When the horizontal dimension is half or less the vertical dimension, use 0.25; as the dimensions approach a square, interpolate from 0.25 to 0.35.

- Performance must account for the potential for debris blockage even if there are no louvers, blades, screens, grilles, faceplates, or other devices, preferably by allowing typical floodborne debris to pass through.
- Performance must ensure that the difference between the exterior and interior water levels will not exceed 1 foot. (Because the minimum requirement allows the bottom of openings to be no more than 1 foot above the higher of the finished interior grade [or floor] or exterior grade, a difference of no more than 1 foot is maintained when water begins to pass through as it crests the bottom of the opening frame.)
- The minimum dimension of an opening in a wall must not be less than 3 inches in any direction in the plane of the wall.

FLOODWATER RATE OF RISE AND FALL

Section C2.7.2.2 of the ASCE 24 commentary notes that a rate of rise of 5 feet per hour, only 1 inch per minute, is not representative of many flood hazard areas and advises building designers to be cautious about relying entirely on that rate. Faster rates of rise and fall are likely in watersheds where rainfall runoff accumulates rapidly and in many areas that are subject to storm surge flooding. ASCE 24 advises that information on rates of rise may be available from stream and tide gauges; federal, state, and local sources; and video documentation of past flood events.

- Reliable data on the rates of rise and fall at specific locations are usually not readily available. Therefore, engineered openings must be designed and must function based on the assumption that the minimum rate of rise and fall will be 5 feet per hour. Reinforcing the importance of testing for

faster rates of rise and fall, building designers must increase the specified total net area of engineered openings when site-specific data or analyses of anticipated flood conditions indicate that more rapid rates of rise and fall are likely.

9.3.2 Documentation of Engineered Openings for Compliance

Engineered openings should be accepted by local officials when the designs are certified and the certifications are submitted as part of permit applications. Acceptable documentation of certification are the certification reports (i.e., ICC-ES Evaluation Reports or equivalent reports from other product certification organizations) and individual certifications for specific buildings (see Section 9.3.4).

Copies of the certifications must be kept in the community's permanent permit files. Community retention of these documents is important not only to demonstrate compliance but also in the event that future building owners do not receive copies of the certifications when they buy buildings. Owners must submit certifications with applications for NFIP flood insurance policies.

I-CODES REQUIRE DESIGN STATEMENTS

The IBC and IRC require that construction documents submitted for building permits include design statements by registered design professionals when applicants propose using engineered openings. ICC-ES Evaluation Reports and equivalent certification reports satisfy this requirement.

Individual certifications prepared for specific buildings also satisfy the requirement for design statements.

9.3.3 Engineered Openings with Certification Reports

The ICC-ES and other product certification organizations develop criteria for acceptance of a variety of building products, construction methods, and materials. Each organization issues certification reports after technical evaluation of documentation that is submitted by manufacturers. Documentation typically includes technical design reports, certifications, and testing results to demonstrate performance and compliance with codes and standards. Certification reports provide evidence that products comply with specific building codes and standards. Designers, builders, and local officials who rely on these reports must determine whether the reports identify the editions of the building codes and ASCE 24 that are applicable to individual projects. If applicable editions of the codes and standard are not identified, the certification report should not be used.

Documentation submitted by manufacturers to obtain an ICC-ES Evaluation Report or equivalent certification report for engineered openings must be supported by certifications describing the performance of the openings and the name, title, address, type of license, license number, the state in which the license was issued, and the signature and seal of the certifying registered

SITE-SPECIFIC APPLICABILITY OF ENGINEERED OPENINGS

When an engineered opening product with a certification report issued by ICC-ES or an equivalent product certification organization is specified in construction documents, the engineer, architect, or builder should determine whether the product, given its limitations and conditions of use, is appropriate for the conditions of flooding at the site, especially the rate of rise and fall of floodwater. Designers should consult with local officials regarding observations of past rates of rise and fall during conditions of flooding.

design professional. The certification reports must include a description of installation requirements or limitations that, if not followed, would void the certification. FEMA considers the following documentation important:

- Statement certifying that the openings, when properly installed, are designed to automatically equalize hydrostatic flood loads on exterior walls by allowing the automatic entry and exit of floodwater in accordance with the design and performance requirements in ASCE 24.
- Statement certifying that the performance accounts for the presence of louvers, blades, screens, grilles, faceplates, or devices with consideration of the potential for debris blockage when these features are present.
- Description of the measurement of the actual net area of the engineered opening that is being certified and identification of the opening coefficient of discharge, which is the variable c in the formula in ASCE 24 (see Figure 25 and Table 3 of this Technical Bulletin). The coefficient of discharge is selected by the designer based on the shape and dimensions of the opening and whether the engineered opening has features such as louvers, blades, screens, grilles, faceplates, or devices that partially obstruct flow during conditions of flooding.
- The range of flood characteristics tested for which the certification is valid, specifically the rates of rise and fall of floodwater, which is the variable R in the formula in ASCE 24 (see Figure 25), and whether there are any limitations based on rates of rise and fall that are faster than 5 feet per hour. Given the ASCE 24 performance expectations, engineered openings must function during conditions of the minimum 5 feet per hour rate of rise and fall.

9.3.4 Engineered Openings Individually Certified for Specific Buildings

Engineered openings that do not have ICC-ES Evaluation Reports or equivalent certification reports must be individually certified as meeting the design requirements described in Section 9.3.1 of this Technical Bulletin and for acceptability in specific buildings based on site-specific conditions. The formula in Section 9.3.1 includes the variable R, which is the worst-case rate of rise and fall at a specific location. ASCE 24 allows the assumption of a minimum rate of rise and fall of 5 feet per hour only in the absence of reliable data on site-specific rates of rise and fall. Building designers who specify engineered openings that are individually certified should consult local officials regarding observations of past rates of rise and fall during conditions of flooding.

Generic certifications for manufactured products place the burden on users (who may not be design professionals) to determine whether a specific location is subject to rates of rise and fall greater than 5 feet per hour. For this reason, generic "fill-in-the-blank" certifications are not acceptable when a manufactured product is used for a specific building unless the builder or design professional for that building, or the local official, determines that the rates of rise and fall at the specific location are no faster than 5 feet per hour. Alternatively, the builder or design professional may submit documentation that there are no reliable data for site-specific rates of

INDIVIDUAL CERTIFICATION FOR SPECIFIC BUILDINGS MUST ADDRESS SEVERAL FACTORS

Section C2.7.2.2 of the ASCE 24 commentary indicates that "certification requires more than simply applying the equation … it requires consideration of a number of factors that represent expected base flood conditions." The commentary also notes that engineered openings should be tested unless uniquely designed for a specific location.

rise and fall, in which case the local official may concur that the rates may be assumed to be no faster than 5 feet per hour.

When engineered openings that have been individually certified for specific buildings are used, the permit application must include a certification that is signed and sealed by the registered design professional, who must be licensed to practice in the state in which the building is located. In addition, the submitted plans must identify the location for the openings and specify installation instructions.

The original certification for engineered openings prepared for specific buildings must include the design professional's name, title, address, signature, type of license, license number, the state in which the license was issued, and the signature and applied seal of the certifying registered design professional. The original certification must identify the physical location of the building in which the engineered openings will be installed.

This Technical Bulletin relies on the ASCE 24 requirements for engineered openings as the accepted standard of practice. The certification must include a description of installation requirements or limitations that, if not followed, will void the certification. In addition to the design and certification criteria listed in Section 9.3.1, the certification must include the following:

- Statement certifying that the openings, when properly installed, are designed to automatically equalize hydrostatic flood loads on exterior walls by allowing the automatic entry and exit of floodwater in accordance with the design and performance requirements in ASCE 24.
- Statement certifying that the performance accounts for the presence of louvers, blades, screens, grilles, faceplates, or devices with consideration of the potential for debris blockage when these features are present.
- Description of the measurement of the actual net area of the engineered opening and identification of the opening coefficient of discharge, which is the variable c in the formula in ASCE 24 (see Figure 25 and Table 3 of this Technical Bulletin). The coefficient of discharge is selected by the designer based on the shape and dimensions of the opening and whether the engineered opening has features such as louvers, blades, covers, screens, grilles, faceplates, or other elements that partially obstruct flow during conditions of flooding.
- Determination of the rate of rise and fall of floodwater at the site and a statement certifying that the openings are designed for that rate of rise and fall or a statement that the opening is designed for a minimum rate of rise and fall of 5 feet per hour because reliable data on site-specific rates of rise and fall are not available.

9.3.5 NFIP Elevation Certificate and Documentation of Engineered Openings for Flood Insurance

When engineered openings are used, the NFIP Elevation Certificate must be completed carefully. The question "Engineered flood openings?" must be answered with "Yes" (see A8.d and A9.d in Figure 26). The engineered opening documentation must be attached to the NFIP Elevation Certificate. Insurers and insurance agents must ask property owners to provide the documentation as part of applications for NFIP flood insurance policies. The following are acceptable forms of documentation:

- For engineered openings with ICC-ES Evaluation Reports or equivalent reports from other product certification organizations, a copy of the report that identifies the manufacturer's model number and specifies the number of such openings that are required for a specified square footage of enclosed area
- For engineered openings individually certified for installation in a specific building, a certification that is signed and sealed by a registered design professional who is licensed in the state where the building is located, and that addresses the statements described in Section 9.3.4

NFIP ELEVATION CERTIFICATES AND NON-ENGINEERED OPENINGS

When non-engineered openings are used, the total net open area of the openings that are within 1.0 foot above the higher of the exterior or interior grade or floor should be determined by measurement (see examples in Section 9.2) or by using the manufacturer's specifications.

To complete the NFIP Elevation Certificate with information required for proper rating of NFIP flood insurance policies for buildings with engineered openings, Item A8.c, "Total net area of flood openings in A8.b," must be filled in with the total coverage or rated area of engineered openings. The total coverage or rated area is the number of engineered openings identified in Item A8.b multiplied by the "coverage" area, "rated" area, or "enclosed area coverage" identified in the ICC-ES Evaluation Report, equivalent report, or individual certifications. When engineered openings are used in attached garages, Item A9.c must be completed in the same manner. The coverage or rated area usually is given in square feet of enclosed area for which an engineered opening can provide automatic inflow and outflow of floodwater, which is, in effect, equivalent to the performance that would be provided by that number of square inches of non-engineered openings.

Also, in Section D, "Check here if attachments" must be selected, and a copy of the certification report must be attached to the NFIP Elevation Certificate (see Figure 26). Notes must be added in the Section D comment section to identify the manufacturer and the manufacturer's model number of the engineered opening.

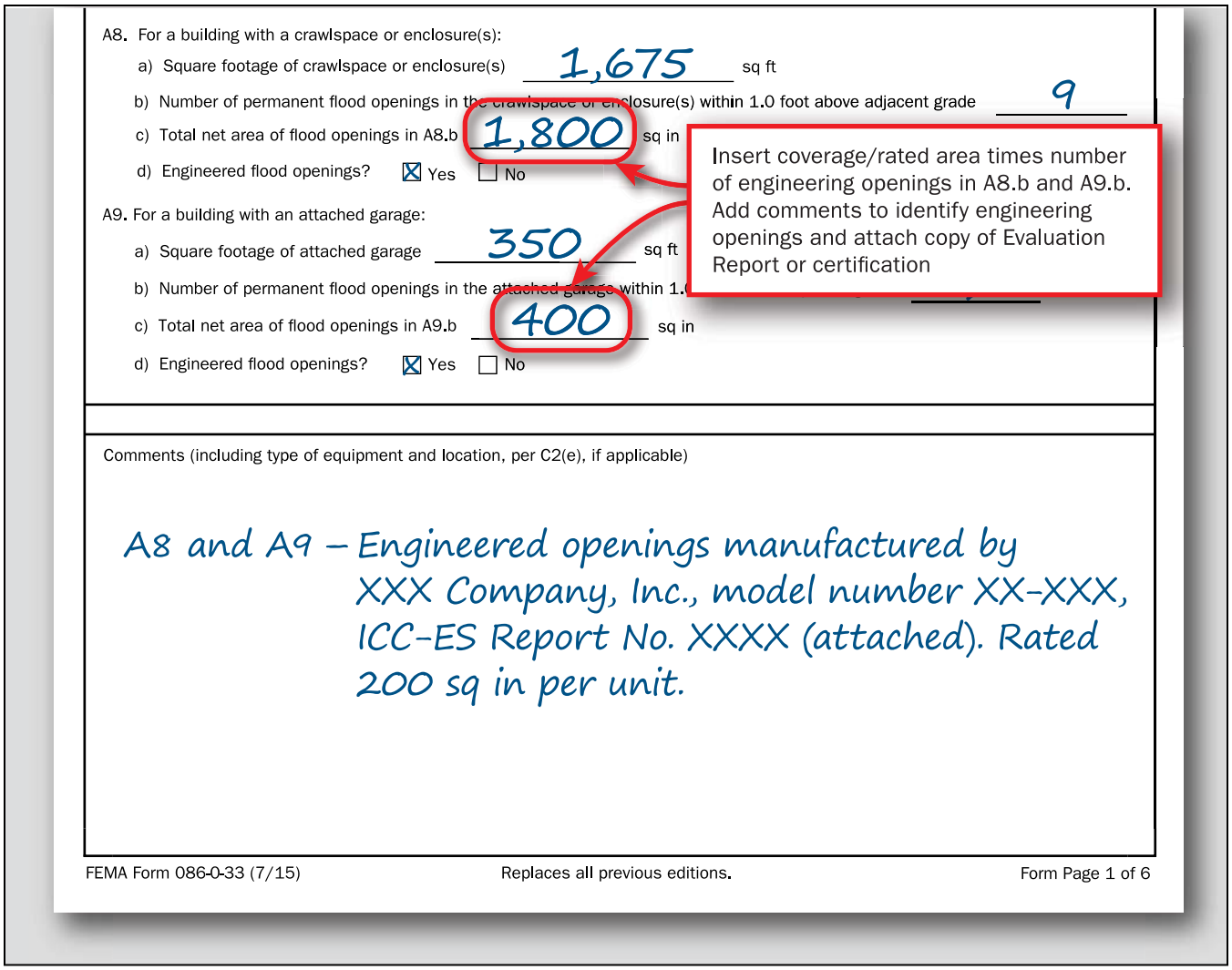


Figure 26: Completing the NFIP Elevation Certificate when engineered openings are used