ASCE 24: Improving the Performance of Buildings and Structures in Flood Hazard Areas

John L. Ingargiola, EI, CFM, CBO[1] Christopher P. Jones, P.E.,[2] and Rebecca C. Quinn, CFM[3]

[1]Building Science Branch, Federal Emergency Management Agency, U.S. Department of Homeland Security; 500 C St. NW, Washington D.C. 20472; PH (202) 646-3452; email: john.ingargiola@fema.dhs.gov
[2]5525 Jomali Drive, Durham, NC 27705; email: chris.jones@earthlink.net
[3]RCQuinn Consulting, Inc., 104 4th Street NE, Charlottesville, VA 22902; PH (434) 296-1349; email: rcquinn@earthlink.net

ABSTRACT

Design standards for buildings and structures in flood hazard areas were published for the time in 1998 in the first edition of the American Society of Civil Engineers (ASCE) standard *Flood Resistant Design and Construction* (ASCE 24). ASCE 24-98 was revised in 2005 (ASCE 24-05) and is currently being revised again. The release of the next edition is anticipated in late 2012 or early 2013.

Since 2000 ASCE 24 has been referenced in model building codes, which include the 2000–2012 editions of the International Code Series (I-Codes) and the 2003–2012 editions of the National Fire Protection Association's NFPA 5000 *Building Construction and Safety Code*.

National Flood Insurance Program (NFIP) regulations, which are largely performance standards, are the minimum requirements that must be enforced by communities that participate in the program. The I-Codes and NFPA 5000 contain provisions that are consistent with NFIP regulations, in large part by references to ASCE 24 and ASCE 7, *Minimum Design Loads for Buildings and Other Structures*. Communities can satisfy the NFIP requirements for participation by adopting building codes and/or floodplain management regulations.

This paper presents (1) an introduction to ASCE 24; (2) a description of the relationship between the NFIP, the I-Codes and NFPA 5000, and ASCE 24; (3) milestones in the development of ASCE 24 (and ASCE 7); (4) the ASCE 24 provisions that are more specific than the NFIP minimum requirements, and those that exceed the minimum NFIP requirements; and (5) a list of the more significant changes between ASCE 24-98 and ASCE 24-05, and a list of possible revisions under consideration for in the next edition.

This is the final draft of the paper submitted to ASCE after peer review and prior to copyediting or other ASCE production activities. This material may be downloaded for personal use only. Any other use requires prior permission of the American Society of Civil Engineers. The published version, part of the proceedings of the ATC & SEI Conference on Advances in Hurricane Engineering 2012, may be found at http://ascelibrary.org/doi/abs/10.1061/9780784412626.006.

INTRODUCTION

The American Society of Civil Engineers (ASCE) standard *Flood Resistant Design and Construction* (ASCE 24) applies to new structures and to work on existing structures when the work is determined to be substantial improvement (including repair of substantial damage), provided the existing structure is not designated as a historic structure. The exclusion for historic structures parallels the National Flood Insurance Program (NFIP) provision that permits historic structures to be substantially improved provided the improved structures will retain their designation as historic structures. ASCE 24 uses the NFIP definition of "historic structure."

Standards to make buildings and structures resistant to site-specific flood loads and conditions were published for the time in 1998 in the first edition of ASCE 24. The standard was revised in 2005 (ASCE 24-05) and is currently being revised again. The release of the next edition is anticipated in late 2012 or early 2013.

Revisions of ASCE 24 are developed by a balanced committee that includes designer professionals, building professionals, manufacturers, government officials, and academic representatives. The committee is not required to mimic NFIP requirements for buildings and structures and thus has incorporated a number of provisions that are "higher standards." Many provisions are more detailed and specific than NFIP requirements, while some exceed the minimum NFIP requirements to achieve the desired building performance when exposed to flooding. The committee takes care not to reduce the requirements in NFIP regulations.

ASCE 24 is a referenced standard in the International Code Series (I-Codes) and the National Fire Protection Association (NFPA) 5000 *Building Construction and Safety Code***.** In large measure, these model building codes are consistent with NFIP regulations through their references to ASCE 24.

ASCE 24-05 covers the following topics:

- Scope, definitions, structure classification, and the basic requirements applicable to all flood hazard areas
- Basic requirements for flood hazard areas (Zone A) that are not identified as Coastal A Zones
- Requirements for high risk areas
- Requirements for coastal high hazard areas (V Zones) and Coastal A Zones
- Materials
- Dry and wet floodproofing

This is the final draft of the paper submitted to ASCE after peer review and prior to copyediting or other ASCE production activities. This material may be downloaded for personal use only. Any other use requires prior permission of the American Society of Civil Engineers. The published version, part of the proceedings of the ATC & SEI Conference on Advances in Hurricane Engineering 2012, may be found at http://ascelibrary.org/doi/abs/10.1061/9780784412626.006.

- Utilities
- Building access
- Miscellaneous construction

NATIONAL FLOOD INSURANCE PROGRAM

More than 21,600 local jurisdictions currently participate in the NFIP, and many of them have been enforcing floodplain management regulations for decades. Participating jurisdictions must incorporate at least the minimum NFIP requirements in their floodplain management regulations. They may adopt more restrictive requirements.

NFIP regulations (44 CFR Parts 59 and 60) specify the required lowest floor elevation of new and substantially improved buildings and structures in flood hazard areas but otherwise are essentially performance standards. For the most part, the regulations identify minimum requirements but do not prescribe how structures in flood hazard areas should be designed and do not indicate how design loads should be calculated. It is up to the designer, builder, and owner to develop designs and specifications that satisfy NFIP regulations.

The NFIP performance statement for flood-resistant construction, which is in 44 CFR § 60.3(a)(3), requires local jurisdictions to:

> Review all permit applications to determine whether proposed building sites will be reasonably safe from flooding. If a proposed building site is in a flood-prone area, all new construction and substantial improvements shall
>
> (i) be designed (or modified) and adequately anchored to prevent flotation, collapse, or lateral movement of the structure resulting from hydrodynamic and hydrostatic loads, including the effects of buoyancy,
>
> (ii) be constructed with materials resistant to flood damage,
>
> (iii) be constructed by methods and practices that minimize flood damages, and
>
> (iv) be constructed with electrical, heating, ventilation, plumbing, and air conditioning equipment and other service facilities that are designed and/or located so as to prevent water from entering or accumulating within the components during conditions of flooding.

This is the final draft of the paper submitted to ASCE after peer review and prior to copyediting or other ASCE production activities. This material may be downloaded for personal use only. Any other use requires prior permission of the American Society of Civil Engineers. The published version, part of the proceedings of the ATC & SEI Conference on Advances in Hurricane Engineering 2012, may be found at http://ascelibrary.org/doi/abs/10.1061/9780784412626.006.

RELATIONSHIP BETWEEN NFIP, I-CODES, AND ASCE 24

Because the I-Codes contain provisions that are consistent with NFIP regulations, in large part by references to ASCE 24 and ASCE 7 (*Minimum Design Loads for Buildings and Other Structures*), states and communities have two primary tools for regulating development in flood hazard areas: (1) building codes that govern the design and construction of buildings and structures and (2) floodplain management regulations that satisfy all other NFIP requirements for participation, including an administrative framework and specifications for regulation of all development other than buildings. Communities that enforce both building codes and floodplain management regulations should ensure that the codes and regulations are coordinated and designed to work together (Figure 1).

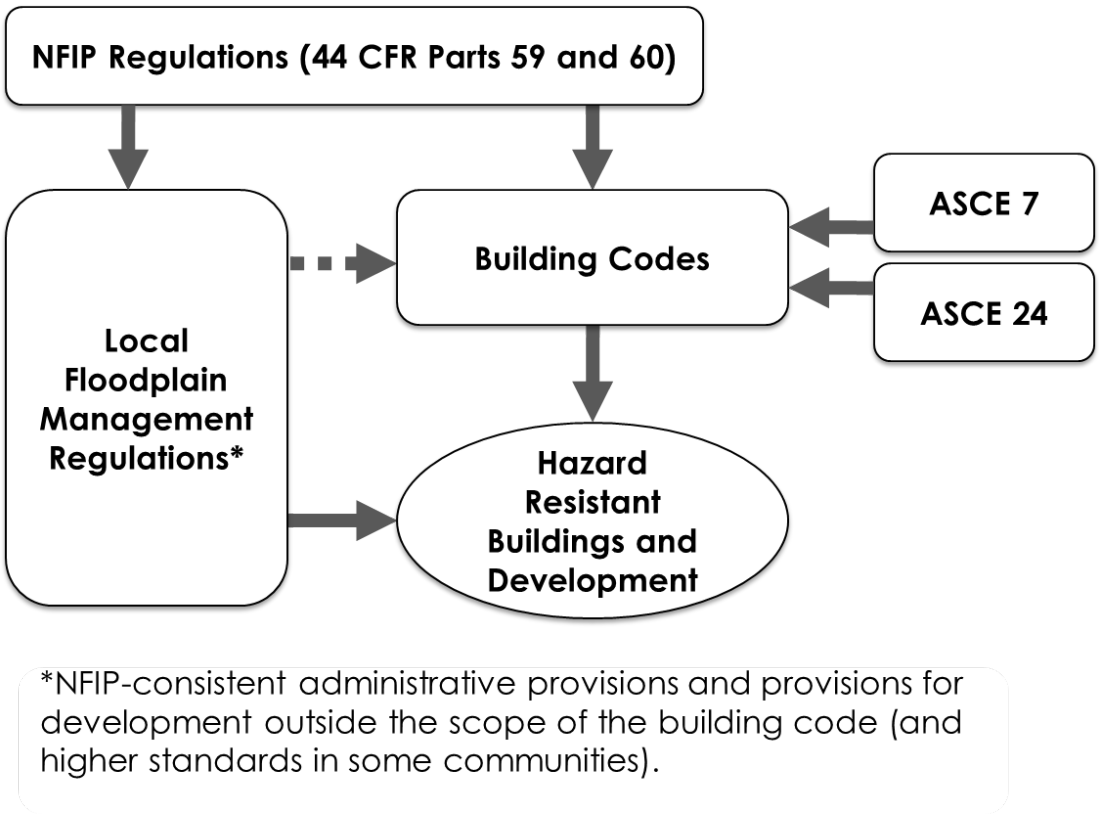

Figure 1. Coordinating local flood regulations and building codes.

The major model building codes in the United States have included flood provisions since the first edition of the I-Codes (2000) and the 2003 edition of NFPA 5000 (see Table 1). In the *International Building Code* (IBC), flood provisions are included primarily by reference to ASCE 24. The *International Residential Code* (IRC) contains prescriptive flood provisions instead of referring to ASCE 24 but requires dwellings in floodways to be designed in accordance with ASCE 24.

This is the final draft of the paper submitted to ASCE after peer review and prior to copyediting or other ASCE production activities. This material may be downloaded for personal use only. Any other use requires prior permission of the American Society of Civil Engineers. The published version, part of the proceedings of the ATC & SEI Conference on Advances in Hurricane Engineering 2012, may be found at http://ascelibrary.org/doi/abs/10.1061/9780784412626.006.

Effective in the 2009 IRC, ASCE 24 can be used as an alternative to the prescriptive provisions.

Table 1. Flood Provisions and References to ASCE 24 in the I-Codes and NFPA 5000.

Editions of I-Codes / NFPA 5000		Flood Provisions	Reference to ASCE 24		
			1998	2005	2012/13
2015	IBC and IRC	✓			✓*
	NFPA 5000	✓		✓	
2012	IBC and IRC	✓		✓	
	NFPA 5000	✓		✓	
2009	IBC and IRC	✓		✓	
	NFPA 5000	✓		✓	
2006	IBC	✓		✓	
	NFPA 5000	✓		✓	
2003	IBC	✓	✓		
	NFPA 5000	✓	✓		
2000	IBC	✓	✓		

*FEMA will propose updating the ASCE 24 reference to ASCE 24-12 in the 2015 I-Codes

MILESTONES: ASCE 24 AND ASCE 7

1993. ASCE produced a Prestandard document on flood-resistant design and construction. The effort, funded by a grant from FEMA, was undertaken by a group of engineers, educators, and public officials with the assistance of ASCE staff. The first edition of ASCE 24 (1998) is based on the Prestandard.

1995. Under an agreement with FEMA, ASCE initiated preparation of the standard that would become ASCE 24. The work was performed in accordance with ASCE's procedures that conform to the standards of the American National Standards Institute (ANSI) for accredited standards developing organizations. The Flood Resistant Design and Construction Standard Committee included approximately 40 nationally recognized individuals in floodplain management, construction techniques, and building codes and regulations.

1995. ASCE published ASCE 7-95, which included flood loads for the first time (Section 5.3) and added flood loads to load combinations in Section 2.

This is the final draft of the paper submitted to ASCE after peer review and prior to copyediting or other ASCE production activities. This material may be downloaded for personal use only. Any other use requires prior permission of the American Society of Civil Engineers. The published version, part of the proceedings of the ATC & SEI Conference on Advances in Hurricane Engineering 2012, may be found at http://ascelibrary.org/doi/abs/10.1061/9780784412626.006.

1998. ASCE published ASCE 7-98, which introduced the following concepts: (1) the design flood and design flood elevation (DFE), (2) the flood hazard area and flood hazard map, and (3) Coastal A Zone. Minimum elevation requirements for lowest floors, including freeboard requirements for certain structures, were added to Section 5.3. Load factors for flood loads and load factors for combined wind and flood loads were revised based on research supported by FEMA (Mehta et al., 1998).

1998. ASCE published the first edition of ASCE 24. It referenced ASCE 7-98 for flood loads and load combinations.

2002. ASCE published ASCE 7-02. Provisions pertaining to flood-resistant design and construction (e.g., lowest floor elevation, foundation requirements, enclosures below the design flood elevation) were deleted because these provisions appeared in ASCE 24-98. Commentary on flood-borne debris impact loads was added based on FEMA-funded research (Kriebel et al., 2000; Haehnel and Daly, 2001, 2002). Breakaway wall loading provisions were revised, and ASCE 24-98 was referenced for breakaway wall design and construction.

2005. ASCE published the second edition of ASCE 24 (ASCE 24-05). It references ASCE 7-02 for flood loads and load combinations.

2005. ASCE published ASCE 7-05. Flood loads were moved into a separate section (Section 5). Coastal A Zone was redefined as requiring a 1.5-foot breaking wave height (previous editions of ASCE 7 that mentioned the Coastal A Zone did not have the 1.5-foot wave height specification).

2010. ASCE published ASCE 7-10. No changes were made to the flood load provisions.

2011. ASCE appointed a committee to revise ASCE 24-05.

2012. The next edition of ASCE 24 is underway and anticipated at the end of 2012 or early 2013.

ASCE 24: REQUIREMENTS THAT ARE MORE SPECIFIC THAN NFIP REQUIREMENT AND REQUIREMENTS THAT EXCEED NFIP REQUIEMENTS

A basic requirement of building codes is that buildings and structures must be designed and constructed to support the factored loads in load combinations without exceeding the appropriate strength limits for the materials used in the construction. Buildings must be designed to resist anticipated loads where the anticipated loads are prescribed based on site-specific conditions. Design loads that depend on location may include wind loads, seismic loads, snow loads, and flood loads.

This is the final draft of the paper submitted to ASCE after peer review and prior to copyediting or other ASCE production activities. This material may be downloaded for personal use only. Any other use requires prior permission of the American Society of Civil Engineers. The published version, part of the proceedings of the ATC & SEI Conference on Advances in Hurricane Engineering 2012, may be found at http://ascelibrary.org/doi/abs/10.1061/9780784412626.006.

ASCE 24 details the necessary requirements that must be satisfied in order to produce buildings that will resist site-specific flood loads and conditions. In other words, its purpose is to produce buildings that will satisfy, and in some ways exceed, the broad performance statement in the NFIP.

ASCE 24 is more specific than NFIP minimum requirements in that it specifies that designs must be governed by the loading provisions in ASCE 7. ASCE 7 includes a performance statement for flood loads that is equivalent to the performance statement in NFIP regulations: "Structural systems of buildings or other structures shall be designed, constructed, connected, and anchored to resist floatation, collapse, and permanent lateral displacement due to action of flood loads associated with the design flood … and other loads in accordance with the load combinations …"

ASCE 24 requires the designer to determine flood loads in accordance with ASCE 7. To do this, the designer must assess several factors associated with the base flood. The factors include flood depth, velocity of floodwaters, presence of waves, potential for flood-borne debris and ice, and whether the site is subject to erosion or scour (see Section 1.4 of ASCE 24-98 and Section 1.6 of ASCE 24-05). Flood loads include hydrostatic loads, hydrodynamic loads, wave loads (breaking wave loads on pilings and columns, and on walls), and impact loads from debris and ice. ASCE 7 requires the inclusion of the effects of erosion and scour in load calculations by assuming that loss of soil increases depth of water, thus increasing some flood loads.

The following sections describe some of the key requirements of ASCE 24-05 that are more specific than the minimum NFIP requirements and some of the requirements that exceed the minimum NFIP requirements.

Design Flood Elevation. NFIP requirements reference the base flood elevation (BFE). The BFE is the elevation associated with the base flood—the flood having a 1 percent chance of being equaled or exceeded in any given year (commonly called the 100-year flood). The BFE is indicated on FEMA Flood Insurance Rate Maps (FIRMs).

ASCE 24 and ASCE 7 use the terms "design flood" and "design flood elevation." The DFE is the elevation of the design flood, where the design flood is the greater of the base flood or the flood corresponding to the area designated on the community's flood hazard map. If a community regulates to a more severe flood than FEMA's base flood, the flood hazard area will be greater than the Special Flood Hazard Area (SFHA) shown on the FIRM, and the DFE will be higher than the BFE. If a community regulates to NFIP minimum requirements, the DFE will be equal to the BFE. The DFE will always be equal to or greater than the BFE, never less.

ASCE 24-05 elevation requirements are expressed as "BFE + x feet or DFE, whichever is higher," where "x" is added height above BFE (commonly called

This is the final draft of the paper submitted to ASCE after peer review and prior to copyediting or other ASCE production activities. This material may be downloaded for personal use only. Any other use requires prior permission of the American Society of Civil Engineers. The published version, part of the proceedings of the ATC & SEI Conference on Advances in Hurricane Engineering 2012, may be found at http://ascelibrary.org/doi/abs/10.1061/9780784412626.006.

freeboard). Some communities may require additional freeboard and may state that the DFE corresponds to the community-mandated freeboard elevation.

Coastal A Zone. The Coastal A Zone is an area subject to damaging waves less than 3 feet in height (3 feet is the threshold used by FEMA to delineate the inland boundary of areas subject to high velocity wave action, which are designated as Zone V). ASCE 24-05 requires new construction in Coastal A Zones to be treated the same way as new construction in Zone V.

Coastal A Zone is defined in ASCE 7-05 and ASCE 24-05 as an "area within a *special flood hazard area*, landward of a *V Zone* or landward of an open coast without mapped *V Zones*. In a Coastal A Zone, the principal source of flooding must be astronomical tides, storm surges, seiches, or tsunamis, not riverine flooding. During the *base flood* conditions, the potential for breaking wave heights shall be greater than or equal to 1.5 feet."

Importantly, in ASCE 24-05, the requirements for Coastal A Zones are effective regardless of whether the inland extent of the 1.5-foot wave is delineated on a flood hazard map. Designers are required to determine loads according to ASCE 7. To determine flood loads associated with base flood conditions, the designer has to determine local flood depth and wave conditions, regardless of the base flood conditions indicated on the FIRM. The designer must determine the site-specific design wave conditions for both Zone A and Zone V. Effective for all new detailed coastal mapping studies started in fiscal year 2009, FEMA will determine the Limit of Moderate Action, which is the inland extent of the 1.5-foot wave.

The concept of Coastal A Zone was introduced in ASCE 7-98 and redefined in ASCE 7-05, following many post-disaster investigations that determined waves between 1.5 and 3 feet high caused considerable damage to conventional construction—specifically, damage to homes and other light-frame construction on shallow foundations. This conclusion is supported by laboratory study and field observations (see Jones et al., 2001).

Elevation Requirements Based on Occupancy Category. NFIP regulations require buildings in SFHAs to be elevated so that they are reasonably safe from flooding. In Zone A, the walking surface of the lowest floor must be at or above the BFE. In Zone V, the bottom of the lowest horizontal structural member of the lowest floor must be at or above the BFE. Nonresidential buildings in Zone A can be dry floodproofed to the level of the BFE, rather than elevated.

Table 1-1 in ASCE 24-98 and ASCE 24-05 describe the classification of structures by occupancy category. Every building is assigned an occupancy category, from Category I to Category IV, which is a way to recognize the importance of buildings in terms of protection of occupants as well as protection of function. The elevation tables in ASCE 24-05 correspond to the structure category classification

This is the final draft of the paper submitted to ASCE after peer review and prior to copyediting or other ASCE production activities. This material may be downloaded for personal use only. Any other use requires prior permission of the American Society of Civil Engineers. The published version, part of the proceedings of the ATC & SEI Conference on Advances in Hurricane Engineering 2012, may be found at http://ascelibrary.org/doi/abs/10.1061/9780784412626.006.

used in ASCE 7-05 (and the IBC). The increasing importance of the four occupancy categories is recognized in ASCE 24 because the level of protection (by elevation or floodproofing) is a function of occupancy category and flood zone. In general, the higher the occupancy category, the higher a building must be elevated. This concept of importance is not reflected in the NFIP minimum requirements, which treat all buildings the same regardless of importance.

Requirements in ASCE 24-05 for the elevation of lowest floors (Zone A) and the elevation of the lowest horizontal structural member of the lowest floor (Zone V and Coastal A Zone) are summarized in Table 2.

Table 2. Lowest Floor/Lowest Horizontal Structural Member Elevation Requirements in ASCE 24-05.

Elevation	Flood Zone	Occupancy Category			
		I	II	III	IV
Elevation of Lowest Floor (A Zone: see Table 2-1 in ASCE 24-05)	All A Zones not identified as Coastal A Zones: elevation of lowest floor	DFE	BFE +1 ft or DFE, whichever is higher	BFE +1 ft or DFE, whichever is higher	BFE +2 ft or DFE, whichever is higher
Elevation of Bottom of Lowest Horizontal Structural Member (V Zone: see Table 4-1 in ASCE 24-05)	All V Zones and Coastal A Zones: where the lowest horizontal structural member is parallel to direction of wave approach	DFE	DFE	BFE +1 ft or DFE, whichever is higher	BFE +1 ft or DFE, whichever is higher
	All V Zones and Coastal A Zones: where the lowest horizontal structural member is perpendicular to direction of wave approach	DFE	BFE +1 ft or DFE, whichever is higher	BFE +2 ft or DFE, whichever is higher	BFE +2 ft or DFE, whichever is higher

Source: ASCE 24-05; summarized in FEMA, n.d.

Elevation Based on Orientation of the Lowest Horizontal Structural Member (Zone V and Coastal A Zone). In coastal high hazard areas (Zone V) and Coastal A Zones, ASCE 24-05 requires the bottom of the lowest horizontal structural member supporting the lowest floor to be at or above the BFE. The minimum requirement is provided because wave loads can be quite large, and the entire floor system must be above the wave crest elevation, unlike in other flood hazard areas not subject to waves (Zone A), where only the top of the lowest floor (walking surface) must be at

This is the final draft of the paper submitted to ASCE after peer review and prior to copyediting or other ASCE production activities. This material may be downloaded for personal use only. Any other use requires prior permission of the American Society of Civil Engineers. The published version, part of the proceedings of the ATC & SEI Conference on Advances in Hurricane Engineering 2012, may be found at http://ascelibrary.org/doi/abs/10.1061/9780784412626.006.

or above the BFE. In addition, buildings in Zone V and the Coastal A Zone must be elevated on pilings or columns that allow the passage of floodwaters—buildings must be "free of obstructions" (see next section). Under the NFIP, these design limitations apply only in coastal high hazard areas [see 44 CFR § 60.3(e)(4)].

Post-disaster investigations indicated that the orientation of the lowest horizontal structural members has an effect on structural performance. If the lowest horizontal structural members supporting the elevated floor are oriented parallel to the direction of wave approach, the horizontal structural members present less area for impact than if they are perpendicular. Thus, ASCE 24-05 incorporated a higher requirement by specifying elevation as a function of orientation of the lowest horizontal structural member. If the members are perpendicular to the direction of wave approach, ASCE 24-05 requires an additional foot of elevation to further reduce the likelihood and impacts of wave crests striking horizontal structural members supporting the elevated floor (see Table 2).

Pile Foundations (Zone V and Coastal A Zone). ASCE 24-05 requires buildings in coastal high hazard areas (Zone V) and Coastal A Zones to have pile or column foundations, and requires the structural design, specifications, and plans for construction to be developed or reviewed by a registered design professional. The design and methods of construction are required to be certified as being in accordance with accepted standards of practice for meeting the provisions of the regulations. Under the NFIP, these requirements apply only in coastal high hazard areas [see 44 CFR § 60.3(e)(4)].

ASCE 24 sets forth accepted standards of practice. It has extensive and detailed specifications for pile foundations. Geotechnical considerations must account for instability and decreased structural capacity associated with erosion, scour, and shoreline movement that must be taken into consideration when designers specify foundation embedment. ASCE 24 provides requirements for different types of piles (wood, steel H, concrete-filled steel pipe, prestressed concrete, precast concrete, cast-in-place concrete) and aspects of foundation design, including lateral resistance, capacity of supporting soils, minimum penetration, pile spacing, pile caps, grade beams, pile splicing, and connections. Footings, mats, rafts, grade beams, and slabs are permitted at or below grade. Bracing specifications include limitations based on orientation relative to the primary direction of wave forces.

Dry Floodproofing (Zone A). Floodproofing is defined in NFIP regulations with a performance statement—the measures used to floodproof a building are to reduce or eliminate flood damage. ASCE 24 divides floodproofing into "wet" floodproofing and "dry" floodproofing, where the latter keeps water out of enclosed spaces below the flood level, while the former allows water in (but limits the amount of flood damage that will be tolerated to clean-up and repainting). Wet floodproofing is permitted by ASCE 24-05 only for Category I structures, functionally dependent

This is the final draft of the paper submitted to ASCE after peer review and prior to copyediting or other ASCE production activities. This material may be downloaded for personal use only. Any other use requires prior permission of the American Society of Civil Engineers. The published version, part of the proceedings of the ATC & SEI Conference on Advances in Hurricane Engineering 2012, may be found at http://ascelibrary.org/doi/abs/10.1061/9780784412626.006.

structures, certain agricultural structures, and enclosures used solely for parking, building access or storage.

NFIP regulations specify that dry floodproofing is permitted only for nonresidential buildings but does not define "nonresidential." ASCE 24-05 defines both "residential" and "nonresidential," and the terms are used only to distinguish whether a building, or a portion of a mixed-use building, may be dry floodproofed.

Unlike the NFIP, which only requires dry floodproofing to extend to the BFE, ASCE 24-05 requires dry floodproofing to extend to higher elevations. Elevation of the floodproofing measures is a function of Occupancy Category. See Table 3, taken from "Highlights of ASCE 24" (FEMA n.d.).

Table 3. Elevation Requirements in ASCE 24-05 for Dry Floodproofing of Non-Residential Structures and Non-Residential Portions of Mixed-Use Buildings.

Flood Zone	Occupancy Category			
	I	II	III	IV
All A Zones not identified as Coastal A Zones: elevation to which dry floodproofing extends	BFE +1 ft or DFE, whichever is higher	BFE +1 ft or DFE, whichever is higher	BFE +1 ft or DFE, whichever is higher	BFE +2 ft or DFE, whichever is higher
All V Zones and Coastal A Zones: dry flood-proofing not allowed	Not permitted	Not permitted	Not permitted	Not permitted

Source: Table 6-1, ASCE 24-05; summarized in FEMA, n.d.

The NFIP requires designs for floodproofing to be certified by a registered design professional that they are "in accordance with accepted standards of practice." ASCE 24 sets forth accepted standards of practice. To be successful, submerged walls and floors of dry floodproofed buildings must be designed to resist flood loads, including lateral and vertical (buoyancy) hydrostatic loads, hydrodynamic loads and other flood loads.

NFIP regulations do not explicitly recognize that some flood conditions may affect whether it is feasible, based on site-specific conditions, to protect buildings by dry floodproofing. Nor do the regulations explicitly address incorporation of measures that require human intervention, such as installing designed flood panels or closing flood doors when flood conditions threaten. ASCE 24 recognizes that the success of floodproofing and the safety of occupants involve more than just designing a building that is robust enough to resist flood loads.

ASCE 24-05 limits the use of dry floodproofing and specifically sets limits on the use of measures that require human intervention. According to ASCE 24, dry floodproofed buildings are:

This is the final draft of the paper submitted to ASCE after peer review and prior to copyediting or other ASCE production activities. This material may be downloaded for personal use only. Any other use requires prior permission of the American Society of Civil Engineers. The published version, part of the proceedings of the ATC & SEI Conference on Advances in Hurricane Engineering 2012, may be found at http://ascelibrary.org/doi/abs/10.1061/9780784412626.006.

- Permitted only outside high risk flood hazard areas, coastal high hazard areas (Zone V), and Coastal A Zones
- Not permitted where flood velocities exceed 5 feet per second
- Required to have at least one exit door above the design flood elevation (DFE)
- Allowed where warning time is a minimum of 12 hours if human intervention measures are specified, unless a community warning system provides a minimum warning time sufficient for responsible persons to get to the site, to install or activate measures, and to evacuate all occupants
- Required to have a flood emergency plan that addresses specified elements and actions and that is approved by the community and posted in at least two conspicuous locations if human intervention measures are specified

Additional More Specific Requirements. ASCE 24 also includes the following requirements for other components associated with buildings and structures that are more specific than NFIP requirements:

- Section 4.8: Decks, concrete pads, and patios (Zone V and Coastal A Zone)
- Section 5: Flood damage resistant materials
- Section 7.1: Platforms for utility equipment
- Section 7.2: Electric components required to meet life safety requirements
- Section 7.3.1: Underground plumbing system elements
- Section 7.4: Duct systems
- Section 7.4.1: Tanks
- Section 9.5: Pools

CHANGES BETWEEN ASCE 24-98 AND ASCE 24-05

The more significant changes between ASCE 24-98 and ASCE 24-05 are:

- Relocation of requirements that apply in all flood hazard areas to Chapter 1
- Relocation of requirements specific to flood hazard areas not subject to high velocity wave action (Zone A) to Chapter 2
- Relocation of requirements specific to flood hazard areas subject to high velocity wave action to Chapter 4

This is the final draft of the paper submitted to ASCE after peer review and prior to copyediting or other ASCE production activities. This material may be downloaded for personal use only. Any other use requires prior permission of the American Society of Civil Engineers. The published version, part of the proceedings of the ATC & SEI Conference on Advances in Hurricane Engineering 2012, may be found at http://ascelibrary.org/doi/abs/10.1061/9780784412626.006.

- Revision of Table 1-1, Classification of Structures, to match the classification of structures table in ASCE 7-02
- Addition of definitions of "residential" and "nonresidential" to distinguish between buildings and portions of buildings that may be dry floodproofed
- Incorporation of additional elevation (freeboard) based on structure category, with the amount of additional elevation dependent on structure category and flood hazard area
- Addition of the definition of "Coastal A Zone," consistent with the inclusion of Coastal A Zone considerations in ASCE 7-05; to determine loads, the designer must determine flood conditions, including whether Coastal A Zone conditions are present
- Addition of a requirement that buildings in Coastal A Zones to meet the requirements for coastal high hazard areas (Zone V) and have flood openings in breakaway walls

REVISIONS UNDER CONSIDERATION FOR THE NEXT EDITION OF ASCE 24

The more significant revisions under consideration by the ASCE 24 committee to produce the next edition (anticipated in late 2012 or early 2013) are:

- Incorporate the Risk Category Table from ASCE 7-10 and define Flood Design Categories I, II, III and IV specifically for application of ASCE 24.
- Change the Coastal A Zone determination requirement from the designer's responsibility to one depending on delineation of a Limit of Moderate Wave Action (LiMWA) on a Flood Insurance Rate Map, or to a designation by the Authority Having Jurisdiction.
- Separate specifications for flood openings (non-engineered and engineered) from the installation requirements and require the presence of louvers, blades, screens and faceplates, or other covers and devices to be accounted for in determining net open area for non-engineered openings or the performance of engineered openings.
- For Flood Design Category IV structures, require the minimum lowest floor elevation (or floodproofing level of protection) to be the higher of the 500-year flood elevation or a specific height above BFE.
- Require flood openings in breakaway walls.
- In coastal high hazard areas and Coastal A Zones:
  - Make explicit that designs must account for local scour and erosion

This is the final draft of the paper submitted to ASCE after peer review and prior to copyediting or other ASCE production activities. This material may be downloaded for personal use only. Any other use requires prior permission of the American Society of Civil Engineers. The published version, part of the proceedings of the ATC & SEI Conference on Advances in Hurricane Engineering 2012, may be found at http://ascelibrary.org/doi/abs/10.1061/9780784412626.006.

  - Provide for shallow foundations in Coastal A Zones under certain circumstances
  - Eliminate orientation of the lowest horizontal structural member as a factor to determine lowest floor elevation
  - Require exterior doors at the top of stairways that are located inside enclosed areas with breakaway walls
  - Consolidate requirements for all nonstructural concrete slabs
- Clarify requirements for garages, carports, and accessory storage structures.
- Consolidate requirements for tanks and more clearly distinguish between requirements based on flood hazard area.
- Update references.

CONCLUSIONS

This paper is a summary of the history and evolution of flood-resistant design and construction requirements in ASCE 24 and flood provisions in the corresponding load standard, ASCE 7. ASCE 24 is incorporated by reference in the *International Building Code* and is an alternative available in the *International Residential Code*. ASCE 7 is incorporated by reference in ASCE 24.

REFERENCES

ASCE (American Society of Civil Engineers). (2002). *Minimum Design Loads for Buildings and Other Structures*. ASCE Standard 7-02. ASCE: Reston, VA.

ASCE. (2005a). *Flood Resistant Design and Construction*. ASCE Standard 24-05. ASCE: Reston, VA.

ASCE. (2005b). *Minimum Design Loads for Buildings and Other Structures*. ASCE Standard ASCE 7-05. ASCE: Reston, VA.

ASCE. (2010). *Minimum Design Loads for Buildings and Other Structures*. ASCE Standard ASCE 7-10. ASCE: Reston, VA.

ASCE/SEI (American Society of Civil Engineers / Structural Engineering Institute). (1998). *Flood Resistant Design and Construction*. ASCE/SEI Standard 24-98. Reston, VA: ASCE.

FEMA (Federal Emergency Management Agency). (n.d.). "Highlights of ASCE 24-05: Flood Resistant Design and Construction." Available at http://www.floods.org/PDF/ASCE24_Highlights_1008.pdf. Accessed March 27, 2012.

Haehnel, R. and Daly, S. (2001). Debris Impact Tests. Prepared for ASCE by the U.S. Army Cold Regions Research and Engineering Laboratory. CRREL: Hanover, N.H.

This is the final draft of the paper submitted to ASCE after peer review and prior to copyediting or other ASCE production activities. This material may be downloaded for personal use only. Any other use requires prior permission of the American Society of Civil Engineers. The published version, part of the proceedings of the ATC & SEI Conference on Advances in Hurricane Engineering 2012, may be found at http://ascelibrary.org/doi/abs/10.1061/9780784412626.006.

Haehnel, R. and Daly, S. (2002). Maximum Impact Force of Woody Debris on Floodplain Structures. Prepared for FEMA by the U.S. Army Cold Regions Research and Engineering Laboratory. CRREL Technical Report ERDC/CRREL TR-02-2. CRREL: Hanover, N.H.

ICC (International Code Council, Inc.). International Code Series (I-Codes). Multiple editions and multiple volumes, 2000 through 2012. ICC: Country Club Hills, IL.

Jones, C.P., Coulbourne, W.L, and Tertell, P. (2001). *Consideration of a New Flood Hazard Zone: the Coastal A Zone.* Proceedings of the 25th Annual Conference of the Assoc. of State Floodplain Managers. ASFPM: Madison, WI.

Kriebel, D.L., Buss, L., and Rogers, S. (2000). *Impact Loads from Flood-Borne Debris*. Prepared for ASCE. ASCE: Reston, VA.

Mehta, K.C., Kriebel, D.L., Smith, D.A., and White, G.J. (1998). An Investigation of load factors for flood and combined wind and flood. Prepared for FEMA. FEMA: Washington, D.C.

NFPA (National Fire Protection Association). (multiple editions, 2003 through 2012). *Building Construction and Safety Code.* NFPA 5000. NFPA: Quincy, MA.

This is the final draft of the paper submitted to ASCE after peer review and prior to copyediting or other ASCE production activities. This material may be downloaded for personal use only. Any other use requires prior permission of the American Society of Civil Engineers. The published version, part of the proceedings of the ATC & SEI Conference on Advances in Hurricane Engineering 2012, may be found at http://ascelibrary.org/doi/abs/10.1061/9780784412626.006.