Resilience Contributions of the International Building Code

INTERNATIONAL CODE COUNCIL

Introduction to Resilience

So far in 2019, communities across the United States have been exposed to numerous hazards including earthquakes, hurricanes, tornadoes, flooding, hail storms and extreme heat and cold. Few places are without some risk. In fact, the frequency and impact of hazard events is increasing. In 2017, the U.S. saw a record number of events causing over $1 billion in damages with 16, causing a total of over $300 billion in damages. Fourteen such events occurred in 2018, resulting in almost $100 billion in damage. See Figures 1 and 2. Governments, businesses and citizens cannot sustain the investments necessary to return devastated communities back to "normal."

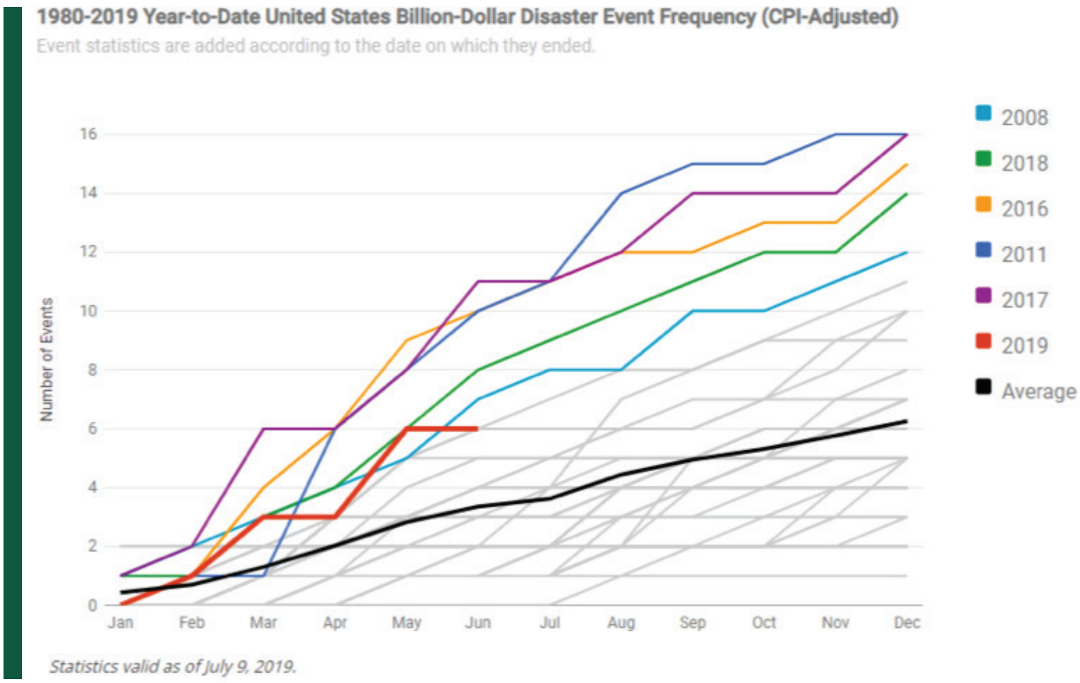

Figure 1: Number of Disasters Costing $1 Billion or More (NOAA)

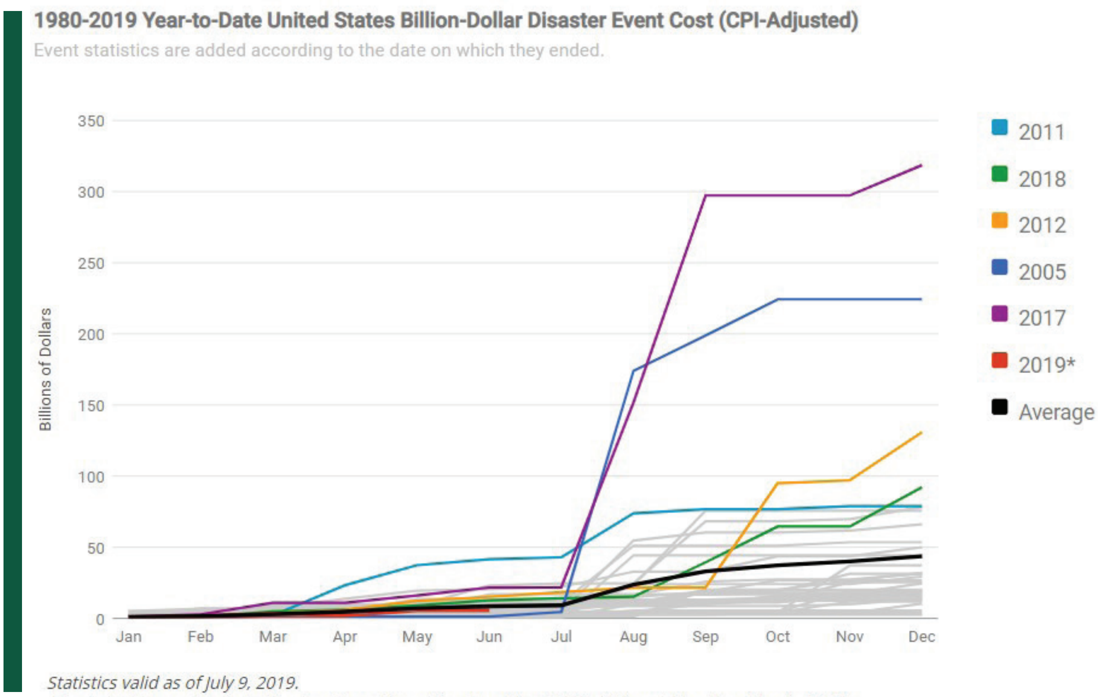

Figure 2: Cumulative Costs of Disasters of $1 Billion or More (NOAA)

A new approach is necessary—one that focuses on strategies that prepare and protect communities ahead of such potentially devastating events. This approach aims to enhance community resilience.

The National Academies (2012) have defined resilience as, "the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events." The building industry, including organizations representing planning, design, construction, ownership, operation, regulation and insurance, have embraced the definition put forward by the National Academies. Nearly 50 building industry organizations signed on to an Industry Statement on Resilience recognizing the need for coordinated action through research, advocacy, education, planning and response (AIA 2019).

To achieve resilience, communities must understand their risks and identify activities designed to reduce those risks. Communities often struggle to define what specific risks they should consider in defining their own resilience (e.g., resilient to what?). Risks vary by community based on geography and social, economic or organizational issues. Risks may be acute in the form of shocks from natural or man-made hazards or chronic in the form of stresses that develop over time. The American Institute of Architects has identified multiple shocks and stresses that impact communities (Figure 3). Some of these shocks and stresses are clearly tied to the condition of a community's building stock while others reflect other community characteristics.

Figure 3: Community Shocks and Stresses (AIA 2017)

Shocks	**Stresses**
Infrastructure failure	Affordability
Hurricanes	Aging population
Earthquakes	Environmental degradation
Wildfires	Sea level rise
Heat waves	Growing wealth gap
Blizzard	Drought
Epidemics	Species extinction
Flooding	Aging infrastructure
Tornadoes	Population growth
Acts of terrorism	Unemployment
Civil unrest	Melting polar ice
Dam failure	Global warming
Subsidence	Food scarcity
	Increasing pollution

Some stresses clearly cut across both social and infrastructural aspects of communities. Buildings can play a part in contributing to their resolution. Many communities are struggling with providing access to affordable housing. Model building codes are developed with affordability in mind. Through a national consensus-based process, efficiencies are captured that help establish consistency across the design, construction, operations and regulatory process—thus saving money for all stakeholders.

The condition of the local environment can impact a community's resilience and the ability of its residents to thrive. During their design, construction and operations, buildings can influence the environmental state of the community including through generation and management of waste products, contributions to both indoor and outdoor pollution, and their locational efficiency. Some of these influences can be addressed through building codes.

This report is the first of a multi-part series examining how the codes that make up the International Codes (I-Codes) contribute to resilience. It expands on the introductory report *Building Community Resilience through Modern Model Building Codes* (ANCR/ICC) released in December 2018.

Building Codes and Resilience

Building codes are a fundamental contributor to community resilience. A community cannot be resilient without resilient buildings and the codes that support their development. As identified in the initial report on building codes and resilience, "Resilience in the built environment starts with strong, regularly adopted, and properly administered building codes." (ANCR/ICC 2018)

Numerous studies have been conducted to date to determine the effectiveness of codes and support updates based on lessons learned following disasters. A FEMA analysis estimated approximately $500 million in annualized loss avoided in eight southeastern states due to the adoption of modern building codes (FEMA 2014).

The National Institute of Buildings Sciences (NIBS) in its *Natural Hazard Mitigation Saves: 2018 Interim Report* found that adoption of the 2018 International Building Code (IBC) and the 2018 International Residential Code (IRC) provide an $11 benefit for every $1 invested when compared to codes in place around 1990 (NIBS). Higher benefits can accrue when benefits and costs are studied at a more localized level. See Figures 4 and 5 for benefit cost ratios (BCRs) by hazard and location.

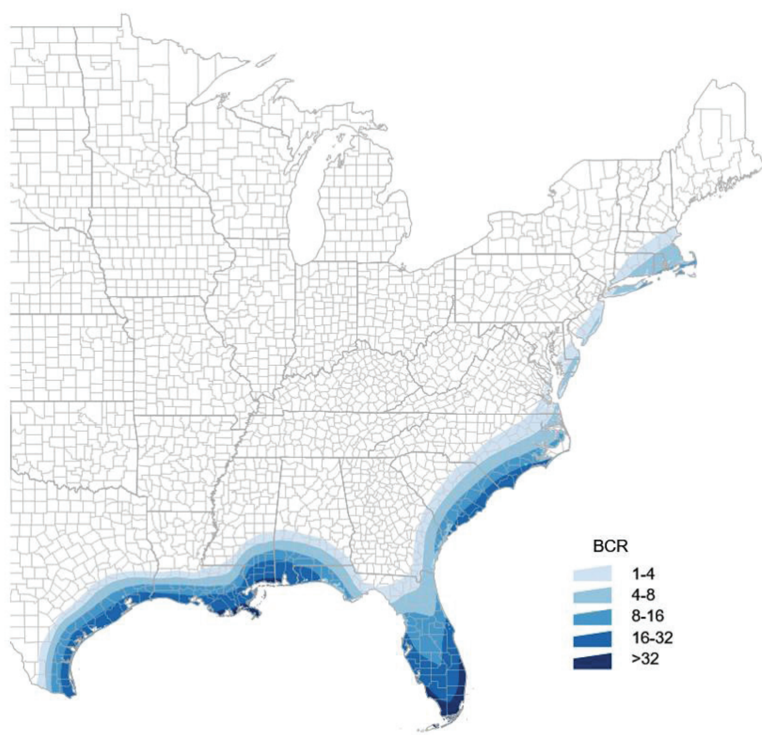

Figure 4: BCR of hurricane wind mitigation by increasing roof strength in new buildings to meet the 2018 IBC and IRC (by wind band) (NIBS)

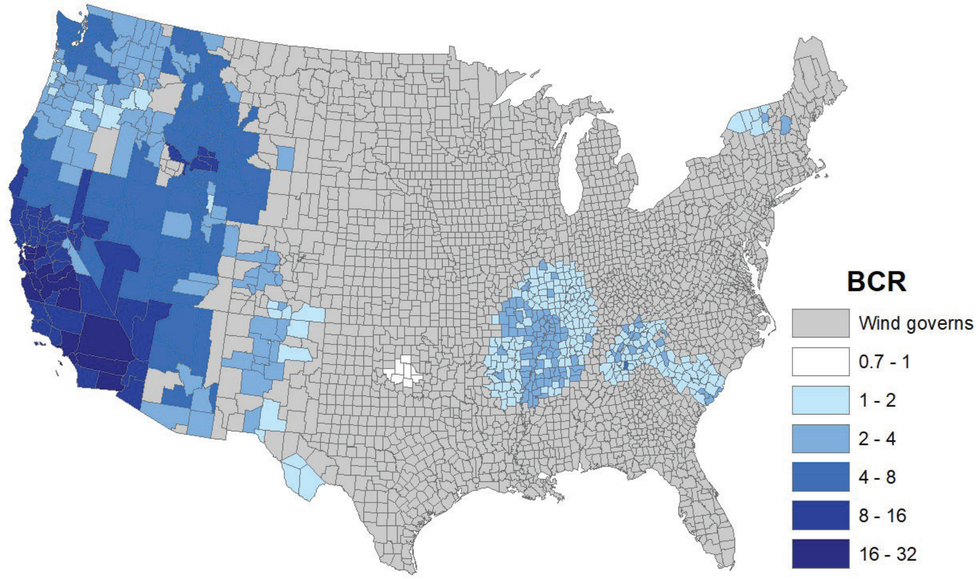

Figure 5: BCR of earthquake mitigation by increasing strength and stiffness in new buildings (by county) to meet the 2018 IBC and IRC (NIBS)

Following major disasters, Federal Emergency Management Agency (FEMA) and National Institute of Standards and Technology (NIST) conduct field evaluations and studies to determine the common modes of failure. These studies help identify where additional guidance or code and standard updates would lead to improved outcomes. These feedback loops into the code development process assure that codes capture the latest knowledge. Through regular updates of codes at the state and local level, communities can capture the benefits associated with research findings and new technologies and practices.

Congress has also recognized that the adoption and enforcement of up-to-date building codes is a cost-effective strategy to address the growing costs of recovery placed on taxpayers. Through the Bipartisan Budget Act (BBA) passed in February 2018 and the Disaster Recovery Reform Act (DRRA) passed in October 2018 Congress directed FEMA to incentivize states and localities to adopt and enforce the latest codes. The specifics of such efforts are still being finalized, but key provisions are outlined below.

The BBA authorized an increase in the federal cost share amount following a disaster based on the resilience measures undertaken including mitigation planning, adoption and enforcement of codes, participation in the Community Rating System (CRS) under the National Flood Insurance Program (NFIP) and the establishment of incentive programs.

DRRA provides communities with additional resources for the implementation of building codes post-disaster, increases funding for competitive pre-disaster mitigation (PDM) grants, allows PDM grants to be used for code adoption and enforcement, increases jurisdictions' chances of receiving PDM awards based on their adoption of the latest codes, and codifies FEMA's requirement that federally assisted repair and rebuilding efforts be built to the latest code requirements.

About the International Building Code

The IBC is a model code published by the International Code Council. It is developed through a consensus-based process conducted on a three-year cycle that allows for the incorporation of the latest technologies, practices and research findings. As a model code, it is available for adoption by state and local governments and other entities that regulate or specify buildings.

In fact, the IBC is in use in every state, but how it is used and the editions adopted vary significantly. To learn more about the code adoption process visit www.iccsafe.org/CodesSave. Figure 6 includes information on the status of adoption of the 2018 IBC and IRC (as of May 2019).

Figure 6: 2018 Code Adoption Projections

The federal government also relies on the IBC and other I-Codes. The Community Rating System (CRS), which provides federal flood insurance discounts for communities undertaking disaster mitigation measures, recognizes the flood mitigation value provided by the IBC and other I-Codes.[1] CRS also uses Building Code Effectiveness Grading Schedule (BCEGS) scores, which evaluates adoption and enforcement codes including the IBC. Finally, FEMA requires adherence to the latest edition of the IBC, IRC, and International Existing Building Code (IEBC) as minimum codes and standards for rebuilding using post-disaster public assistance funding (FEMA's "Minimum Standards Requirement").[2] The U.S. General Services Administration and the Department of Defense mandate use of the IBC for their building projects.

As identified in the scope and administration chapter of the IBC (Section 101.2), "The provisions of this code shall apply to the construction, alteration, relocation, enlargement, replacement, repair, equipment, use and occupancy, location, maintenance, removal and demolition of every building or structure or any appurtenances connected or attached to such buildings or structures."[3]

The intent of the IBC is (Section 101.3), "to establish the minimum requirements to provide a reasonable level of safety, public health and general welfare through structural strength, means of egress facilities, stability, sanitation, adequate light and ventilation, energy conservation, and safety to life and property from fire, explosion and other hazards, and to provide a reasonable level of safety to fire fighters and emergency responders during emergency operations."

The IBC either incorporates or correlates with codes that address important building systems or characteristics—it provides a holistic approach. In the interest of keeping this report concise, the topics covered in the other codes will be addressed in greater depth in future reports in this series. The specific codes incorporated or correlated are listed in Table 1. In addition, the IBC captures the technical knowledge contained in multiple standards—particularly ASCE 7: Minimum Design Loads and Associated Criteria for Buildings and Other Structures.

Table 1: Incorporated/Correlated Codes within the IBC

Incorporated/Correlated Code	IBC Chapter
International Fire Code (IFC)	Chapters 7-10, 27
International Energy Conservation Code (IECC)	Chapter 13
International Mechanical Code (IMC)	Chapter 28
International Fuel Gas Code (IFGC)	Chapter 28
International Plumbing Code (IPC)	Chapter 29
International Residential Code (IRC)	Parts of Chapter 3

The International Building Code and Resilience

The scope of the IBC is clearly focused on assuring that a community's building stock supports the resilience of the community. Reducing the impacts on people and property in the face of multiple shocks and stresses allows communities to survive and ultimately thrive.

Through its organization and the topics covered, the IBC takes several approaches to addressing risks posed by multiple hazards. Many of the requirements contained in the code are organized around the building's use and occupancy as defined in Chapter 3. As identified in the introductory pages to the IBC, "Defining the use of the buildings is very important as it sets the tone for the remaining chapters of the code. Occupancy works with the height, area and construction type requirements in Chapters 5 and 6, as well as the special provisions in Chapter 4, to determine "equivalent risk," or providing a reasonable level of protection or life safety for building occupants. The determination of equivalent risk involves three interdependent considerations: (1) the level of fire hazard associated with the specific occupancy of the facility; (2) the reduction of fire hazard by limiting the floor area and the height of the building based on the fuel load (combustible contents and burnable building components); and (3) the level of overall fire resistance provided by the type of construction used for the building. The greater the potential fire hazards indicated as a function of the group, the lesser the height and area allowances for a particular construction type."

In addition to the risks associated with a building's occupancy, the safety of a structure is determined by the characteristics of building materials and systems. The IBC includes chapters focused on materials typically used in building construction and how they should perform to meet the intent of the code. The materials are captured in chapters 19 through 26 (concrete; aluminum; masonry; steel; wood; glass and glazing; gypsum board, gypsum panel products and plaster; and plastic, respectively) whereas systems are covered in chapters 27 through 29 (electrical, mechanical systems, and plumbing systems, respectively). Where applicable, industry standards and related I-Codes are referenced.

Hazard maps incorporated into the IBC help communities determine their risk exposure and identify the measures within the Code that will help them adequately respond to such risks. The maps cover risks associated with snow loads, wind loads (including both hurricanes and tornadoes), rain loads, seismic loads, and termite infestations.

Like all the I-Codes, the IBC is focused on life-safety, protecting occupants from adverse impacts from buildings. However, it also recognizes where buildings intersect with other important community functions that support overall safety including utility connections, the performance of community shelters, building codes and code departments as part of the emergency planning process, and the importance of critical facilities.

Specific sections of the IBC and their contributions to resilience are outlined in Table 2. However, the discussion that follows examines what the IBC covers regarding the shocks and stresses identified above.

Hurricanes: The IBC includes multiple strategies for protecting structures and occupants against hurricane events. These include provisions associated with structural strength including wind and rain loads, protection of openings from flying debris and preventing the creation of flying debris, elevating structures to mitigate flooding and storm surge, preventing water intrusion and providing for storm shelters. Provisions for building enclosures (exterior walls and roofs) help maintain their integrity including through nailing patterns for roof decks and wall sheathing along with wind resistance of exterior materials including shingles, metal or tile and siding, stucco and masonry.

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Tornadoes: Like hurricanes, provisions for storm shelters, prevention of flying debris, and structural strength contribute to tornado resistance.

Earthquakes: Protection from earthquakes relies heavily on designing for structural loads. Soil conditions also contribute to seismic risk and are addressed within the IBC. Securing appliances such as water heaters help prevent them from separating or falling, causing fires due to gas leaks or severed electrical connections.

Tsunami: In addition to requirements focused on structural integrity, the IBC includes an appendix covering specific conditions associated with tsunami-related flooding.

Fire: Whether a primary hazard in and of itself or secondary to another hazard event, fire can have a significant impact. The IBC looks to provisions from the International Wildland-Urban Interface Code (IWUIC) and IFC to reduce fire risk. Egress provisions help assure that occupants (including those with disabilities) can safely evacuate in the case of fire.

Heat Waves: Protecting occupants from extreme heat and uncomfortable temperatures requires focus on a few strategies including ventilation and maintaining comfortable temperatures. Provisions in the IBC and the IECC protect occupant comfort through ventilation, insulation and reduction of solar heat gain and urban heat island. The IECC is incorporated into the IBC as Chapter 13 and its contribution to resilience will be examined in a future report in this series.

Blizzards: Like heat waves, temperature control is an important aspect of resilience in the face of blizzards and other extreme cold events. In addition to measures in the IECC, the IBC includes provisions to assure buildings can support anticipated snow loads and associated water management due to snow melt.

Flooding: The IBC includes provisions covering flood loads and elevation of structures to reduce impacts of flood events. The Code prescribes overall structural strength to withstand hydrostatic forces of water and wave action. The IBC's requirements for flood mitigation closely follow or exceed those of the National Flood Insurance Program (NFIP)/Community Rating System (CRS) to support a community's compliance with both. Grading of the building site is also included to reduce the impact of floods. Specific provisions covering flood-resistant design are included in an appendix.

Subsidence: Addressing soil characteristics, water drainage, site grading and foundation design is necessary to help avoid subsidence. All these matters are included within the IBC.

Affordability: Embedded within the development process for the I-Codes is the concept of affordability. All potential updates from edition to edition are examined for their cost effectiveness. This assures that building safety is achieved without overburdening contractors and building owners.

Aging Populations: In addition to means of egress and accessibility requirements that address a wide variety of occupant needs—including those of aging populations—the IBC includes provisions specifically applicable to healthcare facilities. Such facilities include assisted living and nursing home type environments. Code provisions applicable to these building types specifically address the needs of their occupants and the risks they may face.

Environmental Degradation and Pollution: A wide variety of practices within a community can contribute to environmental degradation. For buildings, community-level environmental degradation is addressed in multiple ways through building codes. Through a focus on reducing the impacts of disaster, the IBC limits the clean-up required post-disaster. It also addresses indoor environmental quality. The IECC and the International Green Construction Code (IgCC) address energy use and the associated greenhouse gas emissions. The IgCC also addresses construction waste and the impact of material choices on the environment.

All potential updates from edition to edition are examined for their cost effectiveness.

Sea Level Rise: Some degree of protection from sea level rise is captured in the elevation requirements within the IBC. As codes evolve to respond to changing risks, additional measures on addressing sea level rise will be developed.

Drought: Provisions specifically focused on water conservation appear within the IPC, IECC and IgCC, but the IBC does include provisions focused on soils which could be impacted by changing moisture content or water table levels. The IPC and IRC provide requirements governing the construction, installation, alteration, and repair of on-site nonpotable water reuse systems, nonpotable rainwater collection and distribution systems, and reclaimed water systems. CSA B805/ICC 805 Rainwater Harvesting Standard and ASABE/ICC 802 Landscape Irrigation Sprinkler and Emitter Standard provide additional criteria to support the safe use of nonpotable water.

Table 2: Select IBC Provisions Contributing to Resilience

Selected Code Topic	Relevant Sections (2018 IBC)	Supported Resilience Strategy	Relevant Hazards
Critical facilities identification	307	• Emergency planning • Community operations • Response and recovery	• Flooding • Hurricanes • Tornadoes • Blizzards • Terrorist • Wildfire
Hazardous or combustible materials	413, 414	• Isolating risks	• Terrorist • Fire • Flooding • Hurricanes • Tornadoes
Storm Shelters/Areas of Refuge	423, 1009, 1026	• Shelter in place/Refuge • Robustness • Community protection	• Tornado • Terrorist • Fire
Flammability of materials	Chapter 6, 7, 8	• Fire resistance • Egress • Indoor environmental quality • Smoke exposure	• Fire • Secondary to other hazards
Protection of openings	Chapter 7, 1609.2	• Structural integrity • Debris impacts	• Hurricanes • Tornadoes
Fire suppression/ protection. Smoke control	Chapter 9	• Fire resistance • Egress • Property protection	• Fire • Secondary to other hazards
Communication	907, 908, 917	• Public safety • Evacuation	• Fire • Terrorist • Earthquake • Tsunami • Tornadoes
Means of egress	Chapter 10	• Evacuation • Fire protection • Accessibility	• Flooding • Hurricanes • Tornadoes • Blizzards • Terrorist • Wildfire
Accessibility	Chapter 11	• Inclusive communities • Community cohesion • Evacuation	• Public welfare • Secondary to other hazards
Occupant health	Chapter 12	• Indoor environmental quality • Indoor air quality • Access to sanitation	• Public health • Fire • Extreme heat/cold
Exterior envelope performance	Chapter 14	• Property protection • Debris impacts • Hazard spreading	• Fire • Flooding • Hurricanes • Tornadoes
Roof assemblies	Chapter 15	• Fire resistance • Debris impacts • Sealing	• Fire • Hurricanes • Tornadoes • Extreme heat/cold

Table 2 *continued*: Select IBC Provisions Contributing to Resilience

Selected Code Topic	Relevant Sections (2018 IBC)	Supported Resilience Strategy	Relevant Hazards
Moisture protection	1209, 1402, 1503	• Durability • Mold, mildew, rot • Property protection	• Blizzards • Hurricanes • Flooding • Thunderstorms
Hazard Maps	1608, 1609, 1611, 1613, 2603	• Identifying risk	• Tornado • Hurricane • Seismic • Pests • Snow • Rain
Continuous load paths	Chapter 16	• Structural integrity • Anchorage and bracing	• Earthquake • Tornadoes • Hurricanes
Identification of risk	1604.5	• Public safety • Emergency planning	• Earthquake • Tornadoes • Hurricanes • Blizzards
Elevation of structures	1612	• Flood mitigation • Property protection	• Flooding • Hurricanes • Sea level rise
Tsunami	1615, Appendix M	• Identifying risk • Elevation above inundation • Minimum design loads • Evacuation/refuge	• Tsunami
Special inspections	Chapter 17	• Verification of performance • Structural integrity • Fire resistance	• Earthquake • Fire • Hurricanes • Flooding • Tornadoes • Blizzards
Soils and foundations	Chapter 18	• Load support • Subsidence	• Earthquake • Sea level rise • Drought • Flooding
Material performance	Chapters 19-26	• Fire resistance • Structural integrity • Product safety	• Flooding • Hurricanes • Tornadoes • Blizzards • Terrorist • Wildfire
Safety during construction	Chapter 33	• Public safety • Fire safety • Means of egress	• Fire • Civil unrest
Fire Districts	Appendix D	• Fire safety	• Fire
Flood Resistance	Appendix G	• Flood mitigation • Property protection	• Flooding • Hurricanes • Sea level rise

Achieving Community Resilience

The Alliance for National & Community Resilience (ANCR) identified 19 functions that communities provide. The resilience of these functions contributes to the overall resilience of the community. These functions cut across social, organizational and infrastructural aspects of communities. See Figure 7. To be resilient, communities must address the resilience of each of these functions. ANCR is in the process of developing benchmarks for each of these functional areas to allow communities to assess and improve their resilience.

Figure 7: Community Functions

The first ANCR benchmark focused on buildings—an essential element of almost all community functions identified by ANCR. Utilities rely on structures to support their operational activities and represent a large portion of their customer base; schools, hospitals, governments and businesses rely on buildings to provide their services; and public safety officials rely on fire and police stations and emergency operations centers. As discussed above, buildings and the codes that govern their delivery of health, safety and welfare are an essential component of achieving a resilient community.

As recognized within ANCR's Community Resilience Benchmarks (CRBs), adopting model building codes is an essential first step to achieve a baseline level of safety and recoverability from disasters. Individual communities are at various stages in achieving resilience. With respect to their buildings, many regularly adopt and enforce up-to-date building codes, capturing the benefits identified in this white paper. These communities are encouraged to identify and implement strategies that further enhance their resilience through evaluation and rating of their existing building stock, high-performance design criteria for new buildings, and retrofit of older structures. The Enhanced and Exceptional requirements of the ANCR Building Benchmark can provide such strategies.

Conclusion

Building codes will continue to evolve to meet the changing needs of communities. Several communities are looking to extend the role of codes beyond immediate life-safety to assure that buildings continue to support the social and economic needs of a community following a disaster event. These efforts at immediate occupancy or functional recovery will require the development of performance goals and accompanying strategies to achieve those goals. Codes will need to interact with other community-level policies to assure coordination in achieving resilience against all shocks and stresses faced by the community.

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Future editions of the IBC will include additional content aimed at improving community resilience. ICC-500: Standard for the Design and Construction of Storm Shelters will be updated in 2020 for inclusion in the 2021 edition of the IBC. ASCE 7: Minimum Design Loads and Associated Criteria for Buildings and Other Structures will include a new chapter on tornado loads in its 2022 edition and is planned for reference in the 2024 I-Codes. Additionally, a new ASCE/SEI/AMS standard on wind speed estimation for tornadoes is in development, significantly improving the current EF-scale.

As communities recognize the growing risks they face and the importance of implementing policies and practices that enhance their resilience, the adoption and enforcement of up-to-date building codes is a fundamental part of the solution. A community cannot be resilient without building codes. The International Building Code provides communities with essential requirements for addressing their risks.

Endnotes

[1] National Flood Insurance Program Community Rating System Coordinator's Manual, FIA-15/2017 (2017).

[2] Public Assistance Program and Policy Guide, FP 104-009-2 (2018).

[3] Some residential structures may comply with either the IBC or the IRC.

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