AIRCURRENTS

THE EVOLUTION OF BUILDING CODES IN THE UNITED STATES WITH RESPECT TO HURRICANE WINDS

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EDITOR'S NOTE: Building codes exist to make sure that a building is structurally sound and will serve its intended purpose over its lifetime—and also withstand possible unusual stresses that may occasionally be placed on it. Codes vary with the intended purpose of a structure: a warehouse is subject to different codes than a public building or a private home. And since different geographical regions are subjected to different hazards, building codes vary by region. In this article, AIR Principal Engineer Dr. Vineet Kumar Jain and AIR Senior Engineer Guillermo Leiva describe how building codes have become a comprehensive, if patchwork, system of regulations across the U.S. The implications for estimating building vulnerability is that the year of construction matters: building codes and their enforcement change over time, as do the materials and construction methods used to implement the codes. Added to these complexities are the mitigating effects of upgrades and retrofits and the exacerbating effects of structural aging.

By Dr. Vineet Kumar Jain and Guillermo Leiva

A LONG HISTORY

Civilizations are known not least by their surviving edifices. Many of these, even the most ancient, were built according to codes. The Code of Hammurabi of circa 2000 BCE—usually considered to be the earliest known set of written legal proscriptions—includes penalties for faulty construction practices. Its Law 229 states: "If a builder build a house for someone and does not construct it properly, and the house which he built fall in and kill its owner, then that builder shall be put to death."

Today, building a safe structure in the United States requires following two closely connected sets of guidelines: building standards and building codes. Research on how structures respond to specific weather and geological hazards determines the building *standards* that specify the loads different structures must be able to bear. These minimum design loads are periodically updated by the American society of Civil Engineering (ASCE), the American Society of Testing Materials (ASTM), and similar professional organizations.

Building *codes* are written by regional and/or local authorities—which use the standards determined by the professional organizations as guidelines. Legally, and in construction practice, it is the locally adopted building codes that a builder must implement, not the load *standards*.

Many countries employ a single national building code that is applied to all regions of a country. The United States, however, has never had one national building code. Indeed, as many as 5,000 separate codes have been in use in the country at a time. However, over the past roughly 75 years, three sets of "model" building codes came to be widely accepted as the basis for most of the local codes now in use: the Uniform Building Code (UBC), the Standard Building Code (SBC), and the National Building Code (NBC). State and local authorities increasingly came to adopt one or another of these model codes, sometimes in their entirety, usually with locally-determined modifications. Finally, in 1994, the International Code Council (ICC) was formed to develop a single, comprehensive—and national— set of building codes. For a variety of reasons discussed in this article, the mission of the ICC remains a work in progress.

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Building Codes in the United States

The earliest of the organizations that developed model codes was the Building Officials and Code Administration (BOCA). It formed in 1915 in the Northeast. However, the model codes BOCA developed, the National Building Code (NBC), weren't actually published as a single compilation until 1950. The first set of model codes to be published—in 1927—was the Uniform Building Code (UBC). It was developed by the International Council of Building Officials (ICBO), an organization active largely in the West. The Southern Building Code Congress International (SBCCI) was founded in 1940, and in 1945 it published the first edition of its Standard Building Code (SBC), which was used mainly in the South. Figure 1 below shows the regions where these model codes were primarily adopted as local building codes. (Note Wisconsin and New York developed their own codes.)

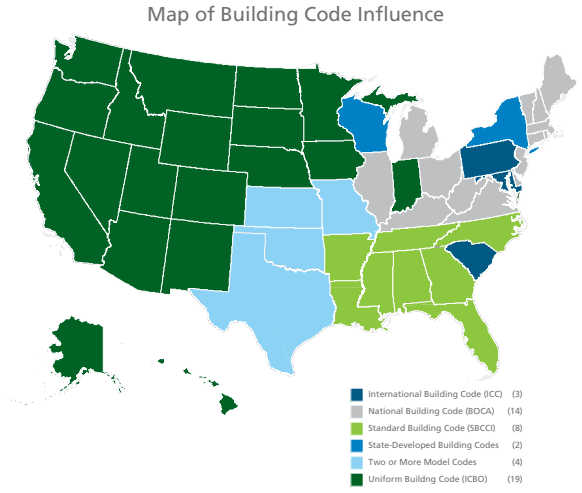

Figure 1: Model Building Codes by Region. (Source: BNI® Building News, 2002)

In 1972 these three groups (BOCA, ICBO, SBCCI) created an umbrella organization—the Council of American Building Officials, or CABO—in order to develop a single model code for conventional single-family construction that could be used nationwide. Two decades later, in 1994, the three groups formally consolidated into a single organization, the International Code Council (ICC). After several years of research and development, the first set of codes was introduced in 2000. Since then, four editions of an ICC suite of model codes have been published, most recently in 2009.

Wind Provisions Introduced

Building standards and codes began to include provisions for materials and construction methods that could withstand the effects of severe winds in the 1950s. It was at this time that the Federal Housing Administration began to introduce such provisions into their standards for the design of one- and two-family houses. The provisions were periodically modified to incorporate changes in wind load standards.

More substantive changes, however, usually came in response to catastrophic events, which revealed inadequacies in the codes. Before Hurricanes Hugo (1989) and Andrew (1992), for example, building codes focused chiefly on the "MWFRS" (the "Main Wind Force Resistant System") being able to withstand possible wind damage. (In layman's language: the codes detailed how a building's frame—the MWFRS—should be built and of what it should be made in order to hold up against winds of different strengths.) Hugo and Andrew brought the importance of the building envelope—and, in particular, the roof covering—into sharper focus.

Roof shingle testing and roof sheathing connection testing began to be introduced into existing codes in the mid-1990s. At that time, changes also were made to glazing standards. However, until the appearance of the ICC model codes in 2000, these standards were not widely implemented outside of the South Florida building code.

THE EVER-PRESENT ISSUE OF ENFORCEMENT

The fact is that wind load *standards* have changed relatively little over the years. Design wind load estimates made for several selected coastal and inland cities from four decades ago do vary compared to estimates made more recently, but the changes show no clear pattern of increase or decrease, even though the methods used to arrive at them have become more sophisticated and complex. This consistency suggests that the standards themselves have been basically sound. It also suggests that, in the effort to improve safety, the most urgent goal is to ensure that the existing standards are actually implemented into the codes—and effectively enforced.

Enforcement is not everywhere the same. In some localities, enforcement is "mandatory" and no changes to instituted codes are allowed. Other localities may allow changes only if the modified codes are more restrictive than the ones they replace. In some states, a state authority can declare certain codes (or sets of codes) to be mandatory state-wide. Nonetheless, since local control prevails, a locality still gets to choose whether or not it will adopt the mandatory code. Thus, a code will be mandatory *in actual practice* only in those localities that choose to adopt it.

These local variations are important. As analysis of the damage caused by Hurricane Andrew and other more recent storms has clearly indicated, the failure to *enforce* codes, not simply an *inadequacy* of the codes to begin with, has contributed significantly to large losses. Even for areas where enforcement is mandatory, however, rigorous enforcement depends on the availability of adequate resources.

Some regions may be more proactive with respect to enforcement precisely because of their greater experience with hurricane wind damage. Florida, for example, before it certifies construction plans, requires engineering load calculations to be performed to make sure that the plans meet the state's wind load requirements. In most other coastal regions in the United States, simple inspection without prior engineering calculations is sufficient. And there are many localities where even inspection is not required.

THE IMPLICATIONS OF REGIONAL ADOPTION ON VULNERABILITY

The American practice of each community setting its own building regulations and enforcement measures has created a patchwork of different codes and enforcement efforts across the country. One community might have excellent standards and a sound record of implementation while a neighboring community may have no building regulations at all or a poor enforcement record.

For example, the loss data from recent hurricanes show that the stringent building codes put in place in Florida after Hurricane Andrew—together with their vigorous enforcement—have contributed to lower wind vulnerability of structures built in the state after 1995. Indeed, compared to other coastal states, Florida's building stock enjoys a lower vulnerability generally.

In contrast, Mississippi has never had a state-wide mandated building code. The higher overall vulnerability of buildings there relative to other coastal states is revealed in both claims data and damage surveys. Similarly, building code requirements with respect to wind hazard are, in general, less stringent in the Northeast than requirements in the high-frequency hurricane region of the Southeast.

Of course, building code requirements in the coastal regions of a state compared to requirements further inland in that state can also be different, thereby contributing to different vulnerabilities even within a single state. For insurance purposes, this geographic variability makes determining the vulnerability of specific properties especially challenging.

Before 1995, building codes were mandatory in only a few states. At present, most states do have statewide mandated codes, and regional and local building code authorities generally base their codes on model codes. The process by which this happens, however, usually involves reconciling all the various and sometimes conflicting interests of locally affected parties—which can significantly change the original model guidelines. For example, the 2006 edition of the ICC (see sidebar) codes states that all structures within a mile of the coastline must have built-in protection (such as shutters) of open building features (such as windows). However, the one-mile requirement was reduced to just 1500 feet in North Carolina.

THE IMPLICATIONS OF YEAR OF ADOPTION ON VULNERABILITY

It is a commonly—and mistakenly—held belief that changes in building codes have a discrete and immediate effect on vulnerability. (See this month's *AIR Current* "Anatomy of a Damage Function: Dispelling the Myths " for further discussion of this and other similar misconceptions.) While the ICC updates its model codes every few years, and these changes are adopted at the local and regional level even less frequently, this periodicity does not translate into discrete, step changes in building stock vulnerability. As observed in actual loss data, changes in vulnerability over time are virtually continual.

Vulnerability does change with building code changes, of course, but vulnerability is also subject to other factors at different moments in time, including changes in code enforcement, changes—especially advances—in building materials and construction practices, the degree of engineering attention that goes into designing new structures, the variable effects of structural aging and the mitigating effects of upgrade and retrofit efforts. These factors, particularly when viewed cumulatively, result in virtually continual, albeit gradual, changes in the vulnerability of the existing building inventory. From the perspective of catastrophe modeling, therefore, the year of construction is a critically important variable—and one that should not be bulk coded.

CONCLUSION

Today, most states have either already adopted or are in the process of adopting building codes based on the International Code Council model codes. However, because of the complex and diffuse historical evolution of building codes in the United States, the vulnerability of the existing building stock varies by region, by state and even by locality within states. And while actual catastrophes have been effective catalysts for triggering building code changes and inspiring their adoption and effective enforcement, it takes time for the benefits of newer and more stringent codes to be realized.

In order to produce reliable estimates of loss potential, catastrophe models need to capture these complexities. To that end, the upcoming release of the AIR Hurricane Model for the United States incorporates exhaustive research by AIR wind engineers into the regional and temporal variations in building codes in the U.S. and, as well, the record of their enforcement success.

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