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Building codes evolve through experience, research

- Building code requirements for fire resistance originated in response to large fires and continue to evolve based on experience and testing.
- Building codes were and remain largely prescriptive, requiring either standard details or testing to demonstrate equivalent fire resistance.
- Building codes are beginning to incorporate performance-based options in keeping with the current trend toward performance-based specifications.

In the United States, building design and construction are greatly influenced by building codes. Building codes represent the minimum requirements deemed necessary to provide for the safety and general welfare of the occupants, to protect property, and to ensure the safety of emergency responders. Building codes, however, are not static, but continually evolve to reflect changes in materials and methods of design and construction. Some of these changes are predicated on experience, while others are based on testing and research. This paper will look at some of the changes in building codes in the United States based on experience and research and review some of the effects on the precast concrete industry now and possibly for the future.

History

Many of the early building code provisions in the United States were intended to minimize the spread of fire. Examples include specific requirements for the construction of chimneys in the New York City Building Code in 1648 and the code of Salem, N.C., in 1788.[1,2] These requirements gave details on the materials to be used for the construction of the chimney box, hearth, and flue and specified their distance from combustible materials in the building. Occurrences of large fires also motivated cities to develop more comprehensive building code requirements. The Great Chicago Fire in 1871 and a similar conflagration in Salisbury, Md., in 1886 motivated these cities to implement stricter regulations for buildings shortly afterward.[3] These examples show

A basalt-fiber-reinforced-polymer reinforced precast concrete panel is lowered into position for testing for fire resistance in accordance with ASTM E119. New materials and construction methods that differ from the standard prescriptive assemblies must be tested to demonstrate compliance with the *International Building Code*. Courtesy of Paul Grigonis.

that experience from events such as fire has historically influenced building code requirements. The same is true today.

As more cities developed building code requirements, the need for consistency among them became evident. One of the first efforts to develop a single building code was initiated through the insurance industry. Insurance companies formed the National Board of Fire Underwriters to manage the development of comprehensive fire safety criteria to use in establishing the risk associated with buildings constructed in communities where these companies underwrote insurance for properties. These criteria evolved into the first model building code in the United States, *The Recommended Building Code*, published in 1905 and later renamed the *National Building Code* (NBC).[4] The criteria were based on the collective experience of the insurance carriers for the properties they underwrote. The National Board of Fire Underwriters published the last edition of the NBC in 1976.

As more cities developed building codes, interest grew in uniformity of code requirements within regions of the country. In 1922, building officials representing the cities on the West Coast formed the International Conference of Building Officials (ICBO) as a means to share common ideas and problems with code enforcement.[5] ICBO developed a model building code that could be adopted by member jurisdictions, eliminating the need for each jurisdiction to develop and maintain its own building code. This code, titled the *Uniform Building Code* (UBC), also better reflected building practices in the west than those commonly found in the eastern United States and reflected by the NBC.

A similar scenario played out in the southeastern United States with the formation of the Southern Building Code Congress (SBCC) in 1941.[6] There, code officials also felt the need to develop a building code that represented the design and construction practices in the Southeast. The culmination of their efforts was the *Southern Standard Building Code* (SSBC) in 1945.

The test panel is lowered into place. Courtesy of Paul Grigonis.

The code was renamed the *Standard Building Code* (SBC) in the early 1970s and the SBC became the Southern Building Code Congress International (SBCCI).

The Building Officials and Code Administrators (BOCA) formed in the northeastern United States in 1915, before either ICBO or SBCCI. They published their first model building code in 1950, the *BOCA Basic Building Code*.[7] After publication of the NBC ceased, BOCA purchased the rights to the NBC in 1982 and with the 1987 edition renamed its model building code the *BOCA National Building Code* (BNBC).

The latest significant chapter in the development of building codes in the United States occurred in the 1990s. Discussions were undertaken by BOCA, ICBO, and SBCCI to contemplate development of a single set of model building codes. Supported by the design and construction community for uniformity in building code requirements across the nation, the three groups formed the International Code Council in December 1994. Through the code development process used by all three groups, they collectively merged the three separate building codes—BNBC, SBC, and UBC—into a single comprehensive *International Building Code* (IBC).[8] Today, the previous model codes are referred to as legacy codes, while the IBC is the model building code most commonly adopted by federal, state, and local jurisdictions in the United States.

It is important to note that that the first and subsequent editions of the IBC reflect many of the same prescriptive requirements that were in the legacy codes. As noted, these prescriptive requirements were partly based on the collective experience in the building community throughout the United States.

Experience, research lead to change

In early building codes, fireplaces and masonry chimneys are examples of construction that evolved into prescriptive code requirements based on experience. These prescriptive requirements in the legacy codes eventually included fireplaces and chimneys constructed of other materials, such as metal. These revised provisions were commonly based on testing and research by manufacturers of prefabricated assemblies and introduced into the codes through the code change process. The code changes commonly included references to the research and testing done to justify their equivalence to the prescriptive provisions in the older codes based on previous experience. A quick look at the provisions in chapter 21, "Masonry," of the IBC shows that the code contains the requirements for building or installing fireplaces and chimneys constructed of masonry, which by definition includes stone, and in chapter 28, "Mechanical Systems," refers the user to the *International Mechanical Code* for fireplace-related components constructed of other materials, such as metal.[8]

For the precast/prestressed concrete industry, an excellent example of code requirements evolving through testing and research is the reference to PCI's MNL-124, *Design for*

Fire Resistance Rating for Precast/Prestressed Floors and Roof Construction

Construction		Fire resistance rating
Precast, Prestressed Concrete Units	**Top slab** – 2 in. (50 mm) minimum and 6 in. (200 mm) maximum thickness perlite concrete; on precast, prestressed double- or single-stemmed units **Ceiling** – No ceiling required; UL report R4123-13	Two hours
	Top slab: 2 in. (50 mm) minimum and 6 in. (200 mm) maximum thickness vermiculite concrete; on precast, prestressed double or single-stemmed units **Ceiling** – No ceiling required; UL report R4123-13	Two hours
Source: 1985 Standard Building Code		

Fire Resistance of Precast/Prestressed Concrete, in the IBC.[8] For many years, to meet the fire-resistance requirements in the legacy codes, the designer had to specify structural assemblies and components based on specific assemblies in the code. For example, in the 1940s designers who wanted to construct buildings in the southeastern region of the country would likely be following the requirements in the SSBC. Assuming they wanted to use concrete and assuming the floor system was required to have a minimum two-hour fire-resistance rating, they could go to Table 1007 in Chapter X of the SSBC to find several concrete structural floor systems that would meet the two-hour fire resistance.[9] One floor assembly example in Table 1007 is described as follows: "Reinforced concrete slabs on concrete joists not less than 4-inches wide and not over 30-inches on center. Reinforcement to be provided with minimum 3/4-inch concrete cover. Minimum slab thickness 2-1/4 inches with a 3/4-inch sanded gypsum plaster ceiling finish on metal or wire lath."

To use a floor assembly not specified in Table 1007 of the SSBC, the designer was required to provide documentation that the assembly had "successfully performed under tests made by a recognized laboratory in accordance with the requirements of the *Standard Specifications for Fire Test of Building Construction and Materials* (E-119-47) of the American Society of Testing Materials."[9] This statement required the designer to find tested floor assemblies to demonstrate compliance with the fire-resistance requirements in the SSBC. Such prescriptive provisions with testing as an alternative were also in the other legacy codes and remain in the IBC.[8]

The progress of the fire test is closely monitored. Courtesy of Paul Grigonis.

When precast/prestressed concrete began to emerge in the building marketplace in the 1950s, complying with fire resistance became a challenge.[10] Precast/prestressed concrete assemblies did not readily fit into the prescriptive assembly descriptions of the legacy codes, so testing these assemblies became the common method for approval. As expected, testing became a significant expense for producers to gain acceptance of their products. The burden of individual testing by producers became the impetus for formation of the PCI Fire Committee and fueled interest in funding for significant research and testing for precast/prestressed concrete assemblies to establish common parameters for predicting fire resistance. One goal would be incorporation of these common parameters into building codes as prescriptive requirements to eliminate the need for submittal of tested assemblies each time precast/prestressed concrete structural systems were to be considered for building construction where fire-resistance requirements also had to be met.

This research and testing began to pay off in terms of approving the fire resistance for precast/prestressed concrete assemblies in the building codes. Prescriptive assemblies previously covered in Chapter X of the SSBC were moved to appendix B of the renamed SBC. In addition, a new entry appeared that specifically covered precast/prestressed concrete. The additional assemblies and fire-resistance ratings in the table are from appendix B of the 1985 SBC.[11] The code assemblies refer to UL report R4123, which was one of the earliest tests (conducted in the 1950s) referred to in the previous discussion of the initial testing by the precast/prestressed concrete industry. Now, at least one of the legacy codes contained a prescriptive entry for designers to use to achieve two-hour fire resistance with precast/prestressed concrete floor assemblies.

An additional benefit was that the research and testing also formed the basis for the development of PCI's *Design for Fire Resistance of Precast Prestressed Concrete*, by Armand H. Gustaferro and Leslie D. Martin in 1977 for the PCI Fire Committee.[12] This document, which became the first edition of MLN 124, gained recognition in BOCA and ICBO through acceptance by the evaluation reports of those model code groups.[13]

Finally, the research and testing also served as the basis for development of fire-resistance calculation procedures for concrete assemblies and components that could be placed in building codes. These procedures were introduced into the SBC and UBC in the early 1980s. The provisions were placed directly into the SBC as appendix P, "Calculated Fire Resistance," and into the UBC as part of the referenced UBC standard 43-9, "Methods for Calculating Fire Resistance of Steel and Concrete."[11,14] PCI's first edition of MNL 124 was also included in SBC appendix P "for precast prestressed concrete not covered elsewhere."[11]

A different approach was used to place these calculation procedures in the BNBC based on the format used by BOCA. The BNBC referenced PCI MNL 124 directly for the calculation method for fire resistance and the code user followed the procedures in MNL 124 to document compliance. The BNBC also included a direct reference to Concrete Reinforcing Steel Institute's (CRSI's) *Reinforced Concrete Fire Resistance*.[15] CRSI's book served as the technical basis for portions of the provisions in appendix P and UBC standard 43-9.

A water tank is lowered onto the slab as the preload. Courtesy of Paul Grigonis.

One further outgrowth of the testing and research that produced the analytical procedures was the development of similar methods in standards promulgated by the American Concrete Institute (ACI) and the American Society of Civil Engineers (ASCE). ACI first published ACI 216.1, *Standard Method for Determining Fire Resistance of Concrete and Masonry Construction Assemblies*, in 1997. ASCE published ASCE 29, *Standard Calculation Method for Structural Fire Protection*, in 1999. ACI 216.1 only covers concrete and masonry, while ASCE 29 includes concrete, masonry, steel, and wood.

Today the options in the IBC for determining the fire-resistance rating of building assemblies and components include testing assemblies using ASTM E119; [16] following prescriptive tables for specifically listed assemblies and components; using the calculation procedures in the IBC; or following the procedures in PCI MNL 124, ACI 216.1, or ASCE 29 as appropriate.[8] The newest edition of PCI MNL 124 is proposed for adoption into the 2015 edition of the IBC this year.

Future code changes

It is hard to predict what the next major changes to fire-resistance design in the building codes might be. As demonstrated in the evolution of the compliance paths for determining the fire resistance of concrete assemblies, testing and research played a significant role in influencing changes to the building codes.

One area where future code changes are emerging is performance-based code provisions. Interest in performance-based methodology for the design of buildings is growing not only in the design community but also in the code community. The ICC developed a performance code to "promote innovative, flexible and responsive solutions that optimize the expenditure and consumption of resources while preserving social and economic value."[17] The National Fire Protection Association includes a performance-based option for code compliance in its model building code.[18] It is not uncommon for performance-based methodology to be used to evaluate conformance of building design features to fire-safety requirements for portions of the building codes when unusual building designs are contemplated. Performance-based design approaches for precast/prestressed concrete are also possible.

Concepts for the performance-based fire-resistance design of precast/prestressed concrete are being contemplated.[19] These concepts depend on testing and research to formulate them into solid technical design methodologies. It is reasonable to expect that future codes changes might be required in order to advance concepts such as these and the use of precast/prestressed concrete materials and assemblies. However, just as was done previously to gain acceptance of precast/prestressed concrete, testing and research will be needed to form a sufficient technical basis to justify any modifications contemplated.

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Abstract

Building code requirements for fire resistance originated in response to large fires. They continued to evolve from lessons learned through fire events as well as testing of building assemblies.

Fire codes were originally incorporated into municipal building codes, then regional and later national building codes. However, they were and remain largely prescriptive, requiring either the use of standard detailing or testing to demonstrate equivalent fire resistance. The 2012 edition of the National Fire Protection Association code includes a performance-based option, in keeping with the current trend toward performance-based specifications.

Keywords

Code, fire, performance, testing.

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