“Prescriptive or Performance: You Make the Call”

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> *“If a builder builds a house for someone, and does not construct it properly, and the house which he built falls in and kills its owner, then the builder shall be put to death”. -- Codex Hammurabi, circa 1790 BC*

Now, that’s a prescriptive building code!

For years, American architects and engineers have operated within a “prescriptive” environment when designing structures. Design and construction freedom is limited by building and fire codes that “prescribe” exactly what the architect and engineer must do to meet the code.

Among other things, building heights, areas, fire protection systems, egress plans, and sub-systems (electrical, mechanical and plumbing) fall within the rules of state or local legislation that occasionally stifles creativity in both design and construction. Building owners, architects, designers and engineers must comply with these regulations to get their project completed, and meet the public goal of life safety and fire protection.

Prescriptive design enjoys a long history in the United States. In many ways, it establishes a “culture of design” where buildings and structures assume standardized – and often bland -- design elements from one community to another. Due to both marketing decisions and building code limitations, covered shopping malls assume a surprisingly similar look and feel. High-rise office buildings begin to look alike. National chains of fast food restaurants, motor vehicle service stations and business service centers share common themes and features.

One complaint about prescriptive design is that due to code-mandated redundancies (i.e. fire resistive separations and automatic fire suppression equipment), increased construction and operational costs occur without a concurrent increase in occupant or building safety. Local amendments to building and fire codes also may restrict designs to meet local conditions and further increases development costs.

But what about those circumstances and projects where it is impossible to meet current prescriptive codes? How does an architect express himself or herself aesthetically while fulfilling a client’s special need? How can old or historically significant buildings be salvaged for re-use while improving their life safety and fire protection features? How do we encourage creativity in design and materials to compete in an increasingly competitive global marketplace?

One answer is to enable flexible “performance” techniques in building design and operations.

Performance-based Design

In "performance-based" design, many of the old ideas and prescriptive rules are set aside in favor of establishing mutually agreed upon design, construction and safety goals and objectives. This method allows the widest possible design and construction latitude while assuring a reasonable level of safety for the occupants and structure.

By definition, performance-based design is an engineering approach to design elements of a building or facility based on performance goals and objectives, engineering analysis, scientific measurements, and quantitative assessment of alternatives against the design goals and objectives, using accepted engineering tools, methodologies, and performance criteria.

Performance-based design provides a new set of challenges for the Authority Having Jurisdiction (AHJ) or code official. Rather than requiring the building to meet a list of prescriptive requirements, the AHJ must evaluate how the structure and its occupants will perform under fire conditions. This means the AHJ must be familiar with principles of fire behavior, structural performance, human response and integrated life safety and fire protection systems.

While this article emphasizes the fire protection elements of performance-based design, it is important to remember that other challenges exist: wind, earthquake, flooding, ventilation, sanitation, occupant comfort and convenience, communications, security, and visitor access are among the issues the architect or engineer must address in a performance-based design. We can expect to see more of these enterprises as the design community responds to yet another environmental threat, that of terrorist infiltration or attack. So-called "target hardening" is a predominant concern in the design community as building owners and occupants want to protect their assets from these risks. Many of these counter-terrorist strategies – such as stand-off distances, explosion- and bullet-resistant glazing, and security locking systems – will create an entirely new set of challenges for the fire service.

Some characteristics of performance-based designs are:

- Their ability to deal with unique design and engineering challenges,
- Their reliance on "stakeholder[1]" participation and goals,
- Their aim to reduce construction costs while maintaining safety,
- Their use of "bounding conditions[2]" to restrict a buildings' use and, perhaps, invalidate its' performance design, and,
- Their dependence on critical design assumptions developed early in the design process.

The performance-based design approach allows the comparison of safety levels provided by various alternative designs. Performance-based design also provides a mechanism for determining what level of safety, and, at what cost, is acceptable to the stakeholders. Performance-based codes require the use of a variety of tools for proper analysis. Such tools

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[1] "Stakeholders" are those individuals or groups that have an interest in successful project results. See discussion below.

[2] "Bounding conditions" from the ICC *Performance Code for Buildings and Facilities* are limits placed on the designs for practical applicability.

might include deterministic analysis techniques, probabilistic analysis techniques, application of the theory of fire dynamics, application of deterministic and probabilistic fire effects modeling, use of actual fire tests or test data, and application of human behavior and toxic effects modeling.

Probabilistic analysis and models deal with the statistical likelihood or chances of the occurrence of a fire and its outcome, based upon the random nature of fire and the likelihood of its occurrence. Deterministic analysis and models are based upon physical laws, or correlations developed as a result of fire test data, to predict a variety of potential fire outcomes.

Stakeholders

The performance-based design concept involves a wide range of "stakeholders." Stakeholders include all individuals or their representatives who have an interest in the successful completion of the specific project. Clearly, stakeholders include not only the members of the design team, the building owner and developer, but the code enforcement officials as well. In the broadest sense, stakeholders are not and should not be limited to only those who have a financial interest in the project. The design team is a sub-group of "stakeholders" which includes individuals such as representatives of the architect, building owner, developer, and any other pertinent engineers and designers. AHJ early participation in a performance-based design is important. Performance-based design can be used on any project, but because of its cost, it is usually used for unusual projects--especially when prescriptive codes do not exist. Performance designs also are the only designs that include fire service capacity and capability.

Experience in other countries buildings in performance-based design suggests that performance-based designs can result in equal or better fire safety, more functional buildings, and more cost-effective construction. However, most buildings are based on prescriptive codes because of the high cost of performance-based designs.

Prescriptive Codes

The traditional approach used to achieve life and property protection in the United States has been that of prescriptive building and fire codes. Prescriptive codes are *quantitative*: they rely on fixed values prescribed in the codes to achieve life safety and fire protection. Prescriptive codes establish code requirements based upon broad or generic classifications of buildings or occupancies. We may be familiar with Groups A, E, B, M, R and S occupancies, but are all hospitality occupancies alike? Do all storage occupancies contain the same type and array of materials, thereby creating common fire hazards?

Most of our fire protection equipment installation standards also are prescriptive: giving the design and installation team very specific guidance in the selection and placement of equipment and materials.

Existing prescriptive codes and standards use a “one occupancy category fits all” approach to problem solving. For example, when a fire sprinkler contractor designs a protection system for an office building, the design is “in compliance” if the system meets the “light hazard” requirements in accordance with NFPA 13 *Installation of Sprinkler Systems.* What if the office has only non-combustible steel chairs and desks on a concrete floor? Or, what if the office is full of highly combustible upholstered furniture, medical gases and patient records storage? Under a prescriptive code, either scenario would be considered “light hazard”, although intuitively we would recognize the second one as a greater fire challenge.

Requirements in prescriptive codes and standards typically are stated in terms of fixed values such as travel distance, fire resistance ratings, allowable area and height, number of plumbing fixtures, minimum ventilation rates, number and capacity of exits, fire alarm and detection system requirements, and fire suppression system demands.

Prescriptive codes cover buildings and systems, and they tend to provide only one method for addressing various design and construction issues. As an example, the prescriptive codes establish limits on travel distance; e.g. a maximum travel distance of 150 feet to an exit in a non-sprinklered building, or 200 feet in most sprinklered ones. From where did this limit come? Upon what is it based? Why is it 150 feet, not 140 feet or 220 feet?

Another example occurs where the building codes limit the floor area and height based on the construction and occupancy types. One of the current prescriptive building codes limits the area of a wood-frame office building to 9,000 sq. ft. Why is this building considered acceptable and its occupants considered reasonably safe at 9,000 sq. ft., but unacceptable or “unsafe” at 9,100 sq. ft.? These threshold limits need to be re-examined in light of current scientific knowledge.

The foundation of our prescriptive codes is based on our fire loss experiences from the 19th Century when major conflagrations were a major concern. Historically, our first attempt was to confine the size of fires “to the block of origin”. Subsequent code revisions have shrunk that size successively to the “building of origin”, to the “floor of origin”, and, finally, to the “room of origin.”

While fire research techniques in the 19th Century were nowhere so sophisticated as they are today, many early researchers worked hard to identify materials and construction techniques that would prevent fires from spreading. Their research led to the development of masonry fire walls of various thickness to achieve horizontal fire resistance, hollow clay tile floor/ceiling assemblies to prevent vertical fire spread, fire resistive roof designs to minimize flying brands, and analysis of steel and cast iron columns to identify issues of structural integrity in fire conditions.

In the early 1920’s, for example, the federal National Bureau of Standards[3] (NBS) conducted some of the first significant studies on fire behavior in buildings. NBS built some full-scale test apparatus for fire growth or what they called “burnout” studies.

[3] Renamed the National Institute of Standards and Technology (NIST) in 1988.

Tests were also conducted in actual buildings scheduled for demolition, the most notable being an old five-story building in Washington [D.C.] in 1928 in an area being cleared for the Federal Triangle. The spectacular collapse of this building convinced city officials to ban further experimentation in the downtown area. [Steven] Inberg's landmark 1928 article relating to the severity of fire with magnitude of the combustible contents or "fire load" still forms the underlying basis for the building code requirements which are prescribed in terms of hourly ratings according to the standard fire endurance test exposure[4].

Research with these materials and methods was translated into early building and fire codes that matched the success of their tests. If a successful test revealed that a 4-inch thick masonry wall resisted fire spread for a specific period of time, the codes included that detailed construction method. Over time, the specific requirements for masonry, block, concrete, tile, or other materials were replaced by a "performance" requirement that walls, ceilings, floors and roofs resist fire for a measured period of time. The methods and materials to achieve that goal were left up to the building designer and contractor, as long as they were approved by the local building and fire officials or – in some cases-- insurance underwriters.

Likewise, a number of famous, tragic fires resulted in changes to the building and fire codes as show in Figure 1.

[4] Gross, Daniel. "Fire Research at NBS: The First 75 Years," National Institute of Standards and Technology, Gaithersburg, MD. 1991.

Fire Incident	Date	Lives Lost	Predominant Code Issue
Iroquois Theater Chicago, IL	12/30/1903	602	Exit doors swing in direction of egress Fire retardant decorations
Triangle Shirtwaist Factory New York, NY	3/25/1911	145	Inadequate and locked exits Accumulations of combustibles
Cleveland Clinic Cleveland, OH	5/15/1929	125	Storage of cellulose nitrate films
Ohio State Penitentiary Columbus, OH	4/21/1930	320	Inadequate egress supervision Lack of fire protection equipment
Cocoanut Grove Boston, MA	11/28/1942	492	Number of exits Exit door swing Combustibility of decorations
LaSalle Hotel Chicago, IL	6/5/1946	61	Corridor protection Enclosure of vertical openings
Winecoff Hotel Atlanta, GA	12/7/1946	127	Enclosure of vertical openings Early notification (fire alarm) Recognition that “fire proof” does not exist
GM Transmission Plant Livonia, MI	8/12/1953	3	Concealed combustible spaces Unprotected steel columns Lack of fire separations Lack of sprinklers Large quantities of heated combustible liquids
Hartford Hospital Hartford, CT	12/8/1961	16	Combustible ceiling tile and glue Delayed fire reporting Open doors onto corridors
Golden Age Nursing Home Fitchville, OH	11/23/1963	63	Lack of fire separations Lack of fire protection equipment

Figure 1
Some Famous Fires and Related Code Issues

Even when less famous tragedies occur, fire and building officials often are motivated to initiate local changes to their codes. It may be as simple as a retrofit law for the installation of fire doors or fire alarm systems, or as comprehensive as the installation of fire sprinkler systems in all high-rise hotels as occurred in Nevada after the MGM Grand and Hilton Hotel fires in 1980.

Finally, whether or not we like to admit it, some code changes occur simply in a political environment. Many of these national and local changes occur without any specific evaluation of their adequacy, excessiveness, or conflicts with other requirements. This has resulted in many code provisions that are based primarily on empiricism (observed events), experience and judgment, or past results rather than on current scientific understanding of the principles of fire and life safety.

Once adopted, these prescriptive codes effectively establish the minimum level of risk that we are willing to accept as a community. Building designers, contractors and authorities having jurisdiction place great emphasis on "code compliance." If it meets the code, they argue, it must be safe.

However, not all buildings constructed under the mantle of prescriptive codes meet absolutely every detailed fire protection and life safety requirement. We know people still die or are injured in these structures, so sometimes it is difficult to describe them as "safe."

The prescriptive code writers have recognized for a long time that there may be specific circumstances that arise in a project design or construction that cannot meet the mandates of prescriptive design, so the codes allow "equivalencies" or "alternate designs" when approved by the local building or fire official. As you look around at your community and identify historic structures, architecturally unique buildings, and designs that are creative, exciting and new, you realize they cannot always meet requirements outlined in currently adopted prescriptive codes. "Equivalencies" or "alternate designs" give architects and code officials the latitude to explore alternate ways to solve complex code problems as long as the solution meets some agreed-upon minimum standard of life safety and fire protection, and the intent of the code.

The principal challenge with "equivalencies" or "alternate designs" is that they put the burden on the code enforcement official to define the criteria by which the equivalency will be considered "successful." While the codes require that the proponent submit the design solution and supporting documentation, the final decision rests with the code official as to its effectiveness. Unfortunately, the prescriptive codes give us no tools or evaluative methods to assess proposed alternates to determine if they provide equivalent levels of safety.

About the Author

Robert Neale currently serves as the Deputy Superintendent for the United States Fire Administration National Fire Academy in Emmitsburg, Maryland. He is responsible for curriculum development aimed at improving the professionalism of America's fire service.

Prior to his current assignment, Mr. Neale for six years managed the National Fire Academy's Technical Fire Prevention curriculum; including fire inspection techniques, prescriptive and performance-based fire and building code interpretation and application, fire protection systems function, design, installation and standards, and plan review for fire inspection personnel.

In 2009, Mr. Neale represented the United States Fire Administration in an analysis of the Fire Department of New York's "Comprehensive Building Inspection and Data Analysis System." In 2001, Mr. Neale served on the Federal Emergency Management Agency, World Trade Center Building Performance Assessment Team.