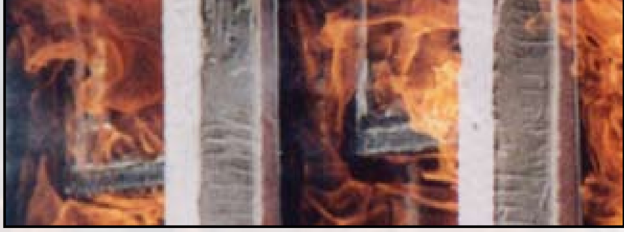

# Structural Design for Fire Conditions

## Who Is Responsible?

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### Structural Engineering: A "Performance-Based Culture"

Structural engineering practice uses a performance-based process to make design decisions. It utilizes a design-by-analysis approach, founded on a consistent, integrated library of documents that defines the design loads, uses engineering methods to analyze and understand structural performance, and applies design standards to provide allowable measures of performance. The elements of modern practice began to fall in place in the early Twentieth Century, in the period from about 1900 to 1930. Educated in mechanics and structural theory, structural engineers had evaluation methods to calculate strength, stability, and deformations for structural members, while building codes identified allowable loads, design stresses, and serviceability requirements. Standards were just emerging with the first reinforced concrete design standard appearing in 1912 and the first structural steel design standard in 1923.

Contemporary technology and research, combined with experience and judgment based on understanding performance from a large group of practitioners and educational institutions were used to solve emerging structural problems and to foster advancements in design and analysis. As the structural engineering profession promoted and developed confidence with the tools for design of structures for performance loadings, the prescriptive portions of the building code evolved into performance-based provisions.

Current building code performance requirements and industry design standards form a consistent system with the analytical methods that are an important element of structural engineering education. Expectations involving structural engineering practice are clearly understood; the building code recognizes that structural engineers assume responsibility for structural safety by designing in accordance with current practice.

### A "Code Culture"

Building codes have contributed to and maintained a major philosophical division between the practice of fire safety and structural safety. Although both fire protection engineers and structural engineers may refer to the same document, their interpretations of "the code" and thought processes are very different. A brief look at the history of building fire safety helps us to understand these differences and their implications in the practice of structural design for fire conditions.

About the time of World War I, the fire problem in the United States placed an enormous human and financial burden on society, and the building industry was expected to respond. The number of complex and dynamic factors involved in a building's fire protection system is manifold: the fire, sprinklers, fire department operations, life safety, barrier performance, structural collapse, smoke, and a variety of risks. With limited fire technology, very few practitioners and researchers, and only one university program, an expedient solution was forced: fire regulations were incorporated into building codes as legislated prescriptive requirements that were enforced by building code officials. Consequently, the building code assumed responsibility for fire safety, and this regulatory thinking produced a "code culture" in the fire community.

*Photo by Brenda K. Schwartz*

The code culture that was used for the structural aspect of fire design has a very weak technical base with regard to understanding structural performance during a fire. The level of risk associated with current prescriptive building code provisions is indeterminate. In addition, the expedience of using ASTM E-119 hourly ratings and their code relationships has little bearing on contemporary knowledge of structural performance during a fire.

### Structural Design for Fire Conditions

In recent years, fire protection engineers have been developing procedures to transition towards performance-based design. Structural design for fire is an area where the two disciplines of fire protection engineering and structural engineering interface. Each has a role in performance-based design for fire. The Society of Fire Protection Engineers (SFPE) recently updated its position statement entitled "The Engineer and the Technician Designing Fire Protection Systems." The SFPE document clearly delineates the roles and responsibilities of licensed fire protection engineers and certified fire protection technicians in the design of active systems for detection, alarm, control and extinguishment. However, the document is nearly silent on the roles and responsibilities of licensed fire protection engineers and structural engineers in the design of the structural frame as part of a building's passive fire protection.

Although structural engineers investigate and proportion building structures for acceptable performance for gravity loads as well as abnormal loadings, such as severe wind and seismic events, most structural analyses and design decisions are based on non-fire environment temperatures. Fire introduces environmental conditions for which sufficient strength and structural stability must be assured. The heat of a fire reduces the load capacity and stiffness of structural materials. The rate and manner in which the properties of a material deteriorate are dependent on the time-temperature conditions of the fire environment, the structural insulation protection, and the structural material itself. In addition to the behavior of individual members, the integrity of the fire protection system depends on the performance of the structure as a system. For example, thermal expansion of beams and girders may contribute to premature collapse of walls or columns due to beam-column or $P$-$\Delta$ effects.

Existing knowledge of structural engineering incorporating international research on structural behavior at elevated temperatures and materials for structural protection provides a technical capability to evaluate performance. Knowing the structural frame sizes and layout, the insulation system, and the time-temperature environment, it is possible to determine if the frame will endure the fire conditions. It is also possible to characterize objectively the changes in structural performance with changes in insulation systems, time-temperature environments, and costs. Thus, a performance-based approach to structural design for fire conditions can add value to the building industry. Who will assume responsibility?

Performance-based design for fire is integral with structural safety, not an add-on requirement. Although the fire protection engineer (FPE) has tools to establish compartment temperatures in the fire environment, the profession does not dedicate attention to the full range of knowledge about structures and behavior that is provided by the structural engineering methods of analysis and design. In addition, an FPE is not involved in and cannot lend insight to the consideration of the structural system of the building that integrates the gravity loads and extreme loads with the form and function of the architecture.

## Conclusions

The fire protection engineer and the structural engineer each have professional skills that relate to aspects of building design. The interface between these professions is with the structural framing. Code culture-based ASTM E-119 test results and their building code association have little to do with performance-based structural design for fire. With the information, knowledge, and technology that are available today, the structural engineering profession can develop a consistent system for performance-based design for fire in a manner similar to the way in which gravity loads, engineering methods, and structural standards were handled during the first few decades of the $20^{th}$ Century. The FPE is in a good position to provide information about the fire environment for a variety of conditions; these involve fuel, ventilation, compartment insulation, and compartment geometry. The structural engineer can develop standards similar to those for other structural conditions for professional applications. In this way, each profession can take advantage of and contribute its technical strengths, and the responsibility for professional design can remain within the current practices. ▪

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