# *Reconsidering Fire Resistance Requirements for Tall Buildings*

*By Ramon Gilsanz, P.E., S.E.*



*Recent tragedies involving tall building collapse due to fire have prompted many building design professionals to reconsider whether current fire resistance requirements for such structures are sufficient. When a building taller than 420 feet collapses due to fire, its occupants and emergency responders are placed at risk, and there is potential for great economic loss to the building, to neighboring structures, and to the city. While the number of tall buildings that have collapsed due to fire is very small, the consequences are severe. In recent tragic disasters of all types, the public has demonstrated intolerance to large losses of life despite the infrequency of such events. This reality has generated renewed interest in returning to the concept of fireproof construction for tall buildings.*

*The debris field resulting from the collapse of WTC 7.*

Fireproof construction is the design concept that a building should survive total burnout without collapse. Total burnout occurs when a fire continues until all combustible material is consumed. The concept of fireproof construction formed the basis of early fire codes. The 1942 report, *Building Materials and Structures: Fire Resistance Classifications of Building Constructions*, issued by the National Bureau of Standards, defined fireproof construction as a design where "the structural elements are of incombustible materials with fire resistance ratings sufficient to withstand the fire severity resulting from the complete combustion of the contents and finish involved in the intended occupancy." The minimum required resistance was four hours.

The current International Building Code is based solely on a prescriptive fire resistance rating. The code requires that tall buildings be designed to resist fire for a duration of three hours. No additional calculations are required based on framing style or combustible content. In order to determine whether these reductions in the required fire resistance rating and the repeal of building specific analysis were warranted, it is helpful to look back at the development of the current standards along with contemporary examples of building fires.

## Historical Overview

At the beginning of the 20th century, fire engineering was created to save lives and to avoid the total collapse of a building due to a fire burnout. Fire engineers and structural engineers worked together and, through experimental testing and common sense, developed a set of prescriptive rules that satisfied their goal so successfully that no additional testing was required.

As the initial challenge was solved, fire and structural engineering professionals focused their efforts on further endeavors to protect building occupants and contents. The development of sprinklers and other fire suppression and compartmentalization measures have been very effective, saving lives, controlling the spread of fire, and limiting economic losses. These efforts were helped by The Society of Fire Protection Engineers (SFPE), created in 1950, which has as one of its goals "applying scientific and engineering principles to protect people and the environment from destructive fire."

However, the prescriptive requirements developed in the early 1900s may no longer be accurate indicators of building safety during fire. Over time, they have been expanded for application to new materials and assemblies. Behavior of these new components and materials is determined through testing. The response of the entire system is then extrapolated from the component behavior. Although this approach is usually reasonable, its validity for new methods of construction – such as those using larger bay sizes, different and lighter materials, and different connections – is unclear. The assembly may react differently than what is predicted from the behaviors of its individual components considered independently. Unfortunately, the American Society for Testing and Materials (ASTM), which details procedures for fire testing of components, does not address the impact of fire on the integrated structural system.

Our European counterparts have conducted full-size fire tests in Cardington, UK, demonstrating the satisfactory behavior of steel structures under total fire burnout. Unfortunately, in the US, steel connection types differ from, and

The International Code Council will review proposals to amend the International Building Code between February 18th and March 2nd, 2008. Among the new proposals are two which would require more stringent fire resistance guidelines for buildings over 420 feet in height. The first proposal, G51-07/08, requires that a design fire be calculated, using the total amount of combustibles in a building. The building must be capable of withstanding this design fire and must also have at least a three-hour fire rating. This proposal was submitted by the Terrorism Resistant Building (TRB) Ad-Hoc Committee. The second proposal, G52-07/08, is a variation of the first, but with an aim at giving the designer more flexibility. This proposal was submitted by Ramon Gilsanz. It gives the designer the option to use the same type of analysis required by TRB proposal. However, it also provides the alternative of using an increased fire resistance requirement of four hours, the value from the original code requirements and research. It is believed that this rating is conservative, and most buildings will have a fire load below this level. Acceptance of these proposals would increase fire resistance requirements of tall buildings when necessary, and leave them at current levels when the fire load is less than the minimum resistance.

are not as strong as, the British connections that have axial strength requirements. Therefore, the UK tests cannot be applied directly to structures in the US. To date, full-size building tests have not been conducted in the US. Such tests could verify whether current design practices are sufficient protection in the event of a total burnout. They could also reveal the strengths and weaknesses in common building design practices.

The early 1900s prescriptive requirements have also been relaxed with time due to the installation of fire suppression systems and the limited number of significant fires in large buildings. Over the years, the minimum fire resistance of major structural elements has been progressively reduced from an original requirement of four hours to as low as one-hour resistance when tested using the ASTM E119 procedures. Whether relaxing the prescriptive requirements for an economic reason was correct is yet to be technically confirmed. This places a heavy reliance on sprinklers and other fire suppression systems, with the assumption that they will be properly maintained and fully operational at the time of a fire. The IBC already specifies that, for tall buildings, the required fire resistance of three hours cannot be reduced, even though the building has a fire suppression system. Fire suppression systems are important life-saving devices, and the intent is not to replace them with burnout design. Rather, structural design for total burnout should supplement fire suppression systems; both should be required.

## Recent Examples

On September 11th, the failure of towers 1 and 2 of the World Trade Center (WTC) proved that buildings that are structurally damaged can collapse due to fire. The partial collapse of WTC 5 from fire was due to a particular steel framing system, and the total collapse of WTC 7 may be attributed in large measure to the fire in the building. The high rise building fire at One Meridian Plaza, Philadelphia, in 1991, burned 9 of the 38 floors, but the structure did not collapse. In all these buildings, the fire suppression system was not operational or was only partially operational at the time of the fire.

The uncertainty in the structural performance of buildings under total fire burnout has also been witnessed in other countries. A fire in the year 2000 in the 540-meter (1,772-foot) Ostankino TV tower in Moscow, Russia started at 440 meters (1,443 feet) and burned down to 100 meters (328 feet) above ground, tilted the spire 2 meters (6.5 feet), and lasted 24 hours. As the authorities were uncertain whether the tower would collapse, they

## Prescriptive Assemblies or Engineered Solutions?

*By Charlie Carter, P.E., S.E.*


*Courtesy of Brenda Schwartz.*

For many decades, fire engineering consultants have designed fire and life safety into the architectural and structural systems used on high-profile projects. More routine projects – the majority of buildings – have been protected with rated assemblies, often with sprinkler systems added as the only feature that increased their statistical level of life safety. Both approaches have performed well.

As design becomes more innovative and less routine, though, engineered fire and life safety systems may be much more common and needed. Fortunately, provisions now exist to assist in implementing this direction: Appendix 4 (Structural Design for Fire Conditions) in AISC 360-05, *Specification for Structural Steel Buildings*. This Appendix provides for both the prescriptive approach using rated assemblies and an engineered approach in which the fire exposures and risks are considered and addressed systematically. AISC 360-05 is available as a free download at **www.aisc.org/epubs**.

With intumescent coatings developing as a viable alternative to the more traditional spray-applied fire-resistive materials, technology is also advancing. Interest today is in the shop application of engineered intumescent systems, which provides a significant cost benefit.

Regardless of the system used, an engineered solution is the always the best way both to define the performance goals and to achieve them.

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*Windsor Building in Madrid, Spain after fire burnout – a portion of the building that experienced partial collapse. Courtesy of Vicent Pons.*

created a 700-meter (2,296-foot) exclusion zone around the tower and removed fuel from nearby stations. In 2004, a fire collapsed a 12-story building in Nasr, Egypt after only three hours, and in 2005, the Windsor building in Madrid, Spain burned for 18 hours, suffered a very significant partial collapse and was later demolished. These losses, their varying burn times, and the degree of structural failure, reflect the uncertainty of whether our current designs can withstand the threat of total burnout.

## Design Considerations

The lack of information on the fire resistance of current buildings, extension of the prescriptive requirements of a historic fire code to a new era of structures, and the reliance on fire suppression systems to supplant structural design for fire, all demonstrate the need for a contemporary analysis of building fire safety.

The renewed interest in building performance during fire was presented at the World Trade Center Building Code Task Force Public Forum in New York City on August 13, 2002. At this forum, it was stated that a goal of the structural engineering community is "to design buildings to resist collapse from fire in a manner similar to designing buildings to resist collapse when exposed to other loads (i.e. gravity, earthquakes, wind, etc.)". Under the current fire standards, it is unclear that this goal is being met.

Engineers design structures to withstand a number of potentially damaging events. These events cause losses of different magnitudes, give varying levels of warning to the public, and occur with different frequencies. An earthquake does not give any warning, whereas the public is forewarned about a flood. We know that the economic loss due to a flood or an earthquake can be comparable, but because of the difference in warning times, a flood may lead to a smaller loss of human life than an earthquake.

The frequency of occurrence of each event is characterized by the probability of that event happening in any given year, and the probability of occurrence is measured by the return period. The code earthquake loads have a 2,500-year return period, which means that the probability that an earthquake of the design intensity happens in a given year is 1 in 2,500. The code wind load has a 500-year return period. The code flood loads have a 100-year return period. Events that give the public more warning have smaller return periods because they present a lesser threat to human life. A flood that has an annual probability of 1 in 100 would be of less severity than one with an annual probability of 1 in 500 or 1 in 2,500. The return period therefore determines the magnitude of loads that the structure is designed to withstand.

Fires occur without warning and can cause significant economic and human loss. Fire statistics of the past 30 to 40 years for buildings less than 100 years old may not provide a complete picture of the risk that the public faces or the potential economic loss. Engineers and building professionals need to establish the proper return period for fire design, the risks of building collapse due to fire, and the associated losses. Society should then evaluate whether the benefits of greater fire protection justify the costs. As an example, seismic design is mandatory in New York City, even though there have been no significant losses in the city due to earthquake. The fire threat may elicit a similar decision among residents of major cities once the risks are evaluated.

## Implementation Steps

A return to fireproof construction practices would require that several technical issues and questions be addressed, including: How can we correctly predict that a building will stand up in case of a total burnout? What is the fire load that has to be considered for the burnout? What is the responsibility of each design professional involved in the design of buildings with respect to burnout design? Should every kind of building resist burnout, or should it depend on occupancy, size, or number of stories? What is the associated economic cost?

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The answers to these questions and the tools necessary to conduct the underlying technical analyses are still being established. There are ongoing efforts to provide design professionals with the means to conduct analyses of fire loading and structure response in situations where the prescriptive requirements of the past do not suffice, or when the team wants a more in-depth study.

The analysis required in the design of fireproof structures involves three steps: (1) estimate the fire exposure; (2) estimate the thermal response of the structure to the fire exposure; and, (3) estimate the structural response given the thermal response of the structure.

To estimate fire exposure for the first step, one must first determine the amount of combustibles available to burn; this amount, together with the amount of oxygen present, determines the amount of heat generated in a fire. The National Fire Protection Association is in the process of developing a standard (NFPA 557) that would identify how to determine the amount of combustibles. SFPE is working on another standard for the first step that is presently available for public review and comment on that organization's website (**www.sfpe.org**).

With respect to the second and third steps, the SFPE is also developing a standard to estimate thermal response, and the American Society of Civil Engineers (ASCE) intends to develop a standard to estimate structural response, although this effort has not yet begun.

The cost of requiring fireproof construction is currently unknown. As present designs may not collapse under total burnout, it is possible that implementing fireproof construction, particularly in the case of new buildings, may have little or no cost impact. In other cases, particularly when an existing building is involved, there could be a significant upgrade cost to ensure adequate behavior of buildings under fire. The cost of implementation must be considered in relation to the potential risks.

## Conclusion

In summary, the ability of our modern constructions to withstand a total burnout fire is uncertain. The codes and standards of the past may no longer be accurate indicators of building performance and expected loadings. It would behoove us to face the potential challenges that may arise with the testing and development of a new set of fire resistance requirements. The advantages of having buildings that remain standing after burnout could far outweigh the associated costs.▪

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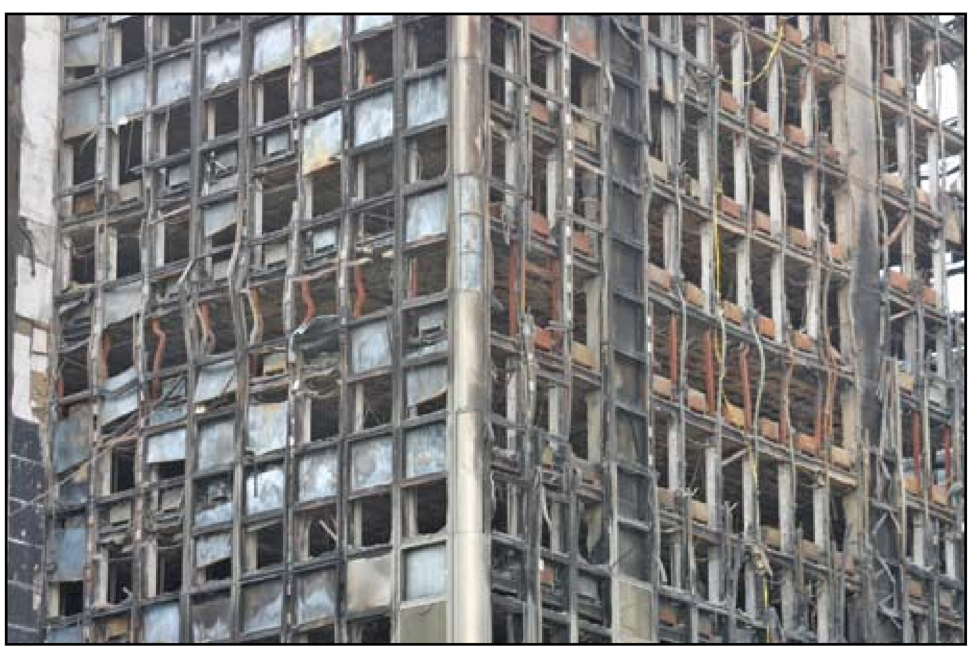

*Windsor Building in Madrid, Spain after fire burnout – a portion of the building that withstood the fire. Courtesy of Ramon Gilsanz.*

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