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NIST GCR 04-872:
"FIRE PROTECTION OF STRUCTURAL STEEL
IN HIGH-RISE BUILDINGS"-Part 1

By Richard Schulte

A report titled "**Fire Protection of Structural Steel in High-Rise Buildings**" developed for the National Institute of Standards and Technology (NIST) by the Civil Engineering Research Foundation contains a "treasure-trove" of information on structural fire protection. This report, dated July 2004, should be of interest to many in the fire protection field. The following are excerpts from various sections of this report.

The Forward section of the report, written by Paul D. Domich of the Building and Fire Research Laboratory (BFRL) at NIST includes the following excerpts:

> "*The National Institute of Standards and Technology (NIST) develops and promotes measurement, standards, and technology to enhance productivity, facilitate trade, and improve quality of life. In the aftermath of the attacks of September 11, 2001, NIST has taken a key role in enhancing the nation's homeland security. . .*" (Page *iii*)

"*In the aftermath of the attacks of September 11, 2001, NIST has taken a key role in enhancing the nation's homeland security.*"

> "*. . .A key element of that mission is BFRL's commitment to homeland security. Specifically, the goal of BFRL's homeland security effort is to develop and implement the standards, technology, and practices needed for cost-effective improvements to the safety and security of buildings and building occupants, including evacuation, emergency response procedures, and threat mitigation.*" (Page *iii*)

> "*This report, prepared for NIST by the Civil Engineering Research Foundation, was funded by DTAP* [Dissemination and Technical Assistance Program]*. This report discusses three important topics in the Fire Protection of Structural Steel in High-Rise Buildings.*" (Page *iii*)

"*An earlier workshop also sponsored by the National Institute of Standards and Technology's Building and Fire Research Laboratory was held on October 2 & 3, 2003, in Baltimore, MD, and was titled "**National R&D Roadmap for Structural Fire Safety Design and Retrofit of Structures: A Report of a Workshop Sponsored by the National Institute of Standards and Technology**". The conclusions and recommendations from these two studies provide important perspectives in understanding the future work that is needed for developing and implementing new technologies, materials, and systems for the protection of structural steel in high-rise buildings; and better guidelines and practices for their design development.*" (Page *iii*)

The following excerpts are from the Executive Summary section of the report.

"*Although history has shown that the statistical risk of life and limb from fire in structural steel high-rise buildings is very small, we now know with certainty that fires, including those in high-rise steel frame buildings, may also be the consequence of other hazards, both natural and man-instigated. The horrific but, as yet, singular example of this is the fire component of the 2001 World Trade Center terrorist attack.*" (Page 2)

"*Although history has shown that the statistical risk of life and limb from fire in structural steel high-rise buildings is very small, we now know with certainty that fires, including those in high-rise steel frame buildings, may also be the consequence of other hazards, both natural and man-instigated. The horrific but, as yet, singular example of this is the fire component of the 2001 World Trade Center terrorist attack.*"

"*There is a need to take a holistic approach to integrating thermal loads and effects of fire into the analysis and design of steel structures. . .Methods should be developed with the fire protection engineering community such that the response of the entire structural system to design fire scenarios would be considered. Such methods should be developed as a component of a Multi-Hazard design approach, and requires collaboration among architects, structural engineers, fire protection engineers, and other professionals in the design process.*" (Page 3)

"*The current approach provides a set of barriers to innovation. The overly simplistic 'fire rating' system is not useable for many new systems and products. It also does not support the need to conduct holistic modelling of combined performance (protection system and entire structure) under varying types of fire conditions. Codes also are too simplistic for special buildings. . .*" (Page 3)

"*Workshop participants observed that there are not only problems of quality in the installation of fire protection systems that severely compromise their effectiveness, but also problems of maintaining these systems through the life-cycle of the building.*" (Page 3)

"*Through history there have been incentive systems promulgated by the indemnity industry to encourage building owners to make their buildings safer. The workshop participants encouraged development of a rating system that would take into account, design to a higher fire resistance level. The concept is that such investment by the building owner to achieve additional protection warrants a reduction in building insurance premiums consistent with the reduction in risk. This effort should be a collaboration among the owners, the insurers, and the design professionals.*" (Page 4)

"*The current approach provides a set of barriers to innovation. The overly simplistic 'fire rating' system is not useable for many new systems and products. It also does not support the need to conduct holistic modelling of combined performance (protection system and entire structure) under varying types of fire conditions. Codes also are too simplistic for special buildings. . .*"

Commentary: The fire insurance premiums for fire resistive buildings with a light hazard occupancy (as defined by NFPA 13) are already minimal. This means that the fire insurance premium credit for the installation of a sprinkler system in this type of building is minimal. Any further credits beyond that provided for the combination of light hazard occupancy, fire resistive building construction and sprinkler protection would be essentially non-existent.

"*In summary, only the will to proceed is required for action. The National Institute of Standards and Technology must support these actions through their funding and as a catalyst and facilitator for change.*" (Page 4)

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"*Unlike so many other adverse aspects of human life, the incidence and consequences of fires has not lessened, in aggregate, as technology and knowledge have advanced.*" (Page 6)

"*We now know with certainty that fires, including those in high-rise steel frame buildings, may also be the consequence of other hazards, both natural and man-instigated. The horrific but, as yet, singular example of this is the fire component of the 2001 World Trade Center terrorist attack.*" (Page 7)

"*Given the intrinsic concern about fire and the potential devastating impact of fires in high-rise steel framed buildings, does past experience and the future prognosis, including multiple-hazard scenarios, mandate actions to improve the fire safety protection for this class of structures?*" (Page 7)

Commentary: High rise buildings protected throughout by a sprinkler system are the "safest" buildings which we build. A major fire has never occurred in a high rise building protected throughout by a sprinkler system in the United States since we first began providing sprinkler protection in high rise buildings in the early 1970's. Based upon the historical record of high rise building fire safety, the answer to the question posed above is obviously no.

The collapse of the World Trade Center (WTC) Towers and other buildings at the WTC site does not change the answer to this question. The World Trade Center towers collapsed as a result of a missile attack on each building-the hi-jacked aircraft were utilized as missiles. Preventing the collapse of a high rise building subjected to a missile attack is simply not economically feasible. The sole purpose of a missile attack on a building is to destroy the target.

The following are excerpts from a paper authored by Chris Marrion, P.E., Richard L. P. Custer, Matt Johann, and Brian Meacham, Ph.D., P.E., of Ove Arup & Partners Consulting Engineers PC:

"*It is suggested that by increasing the mass of steel in the basic design of the structure, the need for fire resisting assemblies or spray-applied coverings could be eliminated. It is also suggested that the incremental cost of the additional steel may be less than the cost of the additional fire resistant materials and installation. Such an approach should be investigated as a performance-based alternative solution.*" (Page 17)

"*It should also be remembered that bare steel has some degree of fire resistance. As temperatures increase, steel's yield stress decreases. It approaches 50% of its room temperature yield stress at approximately 550°C. Depending on fire conditions, loading, connections, end restraints, geometry of the space, etc. bare steel may be shown to provide sufficient resistance to the design fire(s) deemed credible for that space.*" (Page 17)

"*Structural fire resistant steel alloys have been developed that retain two thirds (2/3) of the specified room temperature yield strength at 600°C. This is accomplished with additive elements such as molybdenum that affect the yield strength. A number of structures have been constructed using this material.*" (Page 17)

"*It may be said that the prescriptive code basis for structural fire resistance requirements relies upon test methods that do not accurately portray actual building fire conditions (construction, heating, etc.) in the modern built environment. The field of structural fire engineering has sprung from this and other similar observations.*" (Page 18)

"*. . .Depending on fire conditions, loading, connections, end restraints, geometry of the space, etc. bare steel may be shown to provide sufficient resistance to the design fire(s) deemed credible for that space.*"

"*A common approach to designing safe and robust, yet economical, buildings is to eliminate fire protection materials in areas where they are not necessary. Considering the inherent high temperature strength of structural members or assemblies can do this. For example, recent tests and analyses have shown the potential benefits of considering catenary action within concrete floor slabs supported by steel joists. By redistributing loads throughout a properly supported concrete slab, a structure can remain stable even after individual steel members have failed locally. Thus, protective material can often be eliminated from specific members. Other structural mechanisms can be used in similar analyses, potentially with similar results. This is just one of the numerous examples of how structural fire engineering can be used to more efficiently and effectively protect buildings from fires and other hazard events.*" (Page 18)

"*Although sprinkler systems have been used for decades to protect against fire, direct application of water to structural elements is a relatively new approach in the US. Frequently, since most new buildings include fire sprinkler systems already, addition of sprinkler coverage for critical structural elements is not overly expensive or difficult. By drenching critical structural elements in water, a system can keep these elements cool for an extended period of time, and also can help prevent direct flame impingement upon the structural material.*" (Page 19)

Commentary: Standard spray sprinklers are specifically designed to lower temperatures at the ceiling of a space which protects the building structural system. If the sprinkler system is properly installed and the sprinkler protection is properly maintained, the there is no need to discharge water directly at structural members to provide protection for the structural members (except, perhaps, in storage occupancies). If the same water supply piping is used to supply standard sprinkler protection and special nozzles which will discharge water on structural members, this protection is not redundant. If the water supply to the standard sprinkler protection fails, then the water supply to the special nozzles will also fail. Typically, the purpose of providing both sprinkler protection and structural fire protection is to provide redundant fire protection for the structural system in the event of a failure of the sprinkler system.

"*At the present time, there is not a groundswell of research and development regarding fire protection technologies for structural steel. Although some research is underway with respect to fire protection materials, and with respect to fire resisting steel formulations, the bulk of the current research and development effort is focused on engineered (performance-based) analysis and design approaches for structural fire safety design.*" (Page 19)

"*Demand for new technologies in fire protection materials is not great. The general industry opinion seems to be that the material technologies that are currently available perform well and are sufficient to meet the needs of the building industry in most cases.*" (Page 20)

"*Demand for new technologies in fire protection materials is not great.*"

"*The past ten years have seen the emergence of new steel formulations resulting from innovative research and improved production practices. These new steels have seen limited use in Japan and other Asian countries, although they have not yet made their way to the United States. Referred to as fire-resistant steels, these materials have caught the attention of some within the industry.*" (Page 21)

"*Significant barriers to the widespread application of structural fire engineering currently exist, and numerous research efforts are required to this end. These needs are discussed below. A general, accepted framework for structural fire engineering is lacking and will be critical in guiding future research efforts.*" (Page 22)

The following excerpts are from a portion of the report authored by Dr. Frederick Mowrer of the fire protection engineering department at the University of Maryland:

"*It has long been recognized by knowledgeable fire safety professionals that fire resistance ratings derived from standard fire resistance tests should not be construed literally despite the fact that they are expressed in terms of hourly ratings. In other words, a 2-hour fire resistance rating represents the period of time that a rated element or assembly withstands the standard fire resistance test without exceeding any of the failure criteria specified in the test standard. It does not represent the period of time that the same element or assembly will perform acceptably in the field. Differences between test and field performance may occur due to differences in fire exposure conditions, connection details and construction methods. This distinction is important with respect to performance requirements for the fire resistance of structures.*" (Page 27)

"*Significant barriers to the widespread application of structural fire engineering currently exist, and numerous research efforts are required to this end. These needs are discussed below. A general, accepted framework for structural fire engineering is lacking and will be critical in guiding future research efforts.*"

"*Within the fire safety engineering profession, there has been increasing interest in performance-based design in recent years. With this increasing interest, there is increasing demand for analytical methods that address performance in terms of physically valid objectives and quantitative performance criteria. Structural design for fire safety is one aspect of performance-based fire safety analysis and design of buildings. Over the past decade, there has been considerable interest in performance-based structural design for fire, particularly internationally. With the total progressive collapse of three steel-frame high-rise buildings at the World Trade Center in New York City on September 11, 2001, there has been increased interest in this topic within the United States as well. This report presents a proposed framework for addressing structural fire design from both deterministic and probabilistic perspectives.*" (Page 27)

"*Requirements for fire resistance of tall buildings have existed for more than 100 years and have been standardized in virtually their current form for more than 75 years. In light of the World Trade Center disaster, it is ironic but not surprising that some of the earliest requirements for fire resistance of tall buildings were imposed in New York City, "necessitated by the rapid development of the skyscraper" around the turn of the last century. Efforts to establish an acceptable test procedure were initiated at that time by Professor Ira H. Woolson of Columbia University and Rudolph P. Miller, chief engineer, Building Bureau, New York City.*" (Page 27)

"*Following the Baltimore conflagration of 1905, the ASTM established a committee to standardize the fire test method, with Prof. Woolson as chairman and Mr. Miller as secretary. ASTM adopted a test method for floor constructions in 1907 and a procedure for testing wall and partition constructions in 1909. After a new committee composed of representatives of eleven engineering societies was organized in 1916, the fire test standard was revised and adopted as a tentative standard, ASTM Standard C19T, in 1917, and as a full standard, C19, in 1918. The primary features of the standard, including the fire test furnace and the standard temperature time exposure curve, remain unchanged to the present version of ASTM E119.*" (Pages 27 and 28)

"*The primary features of the standard, including the fire test furnace and the standard temperature time exposure curve, remain unchanged to the present version of ASTM E119.*"

"*From the start, it has been recognized that the standard temperature-time curve used in the ASTM E119 test standard represents only one fire exposure condition, albeit a relatively severe one. Almost immediately after the temperature-time curve was standardized, S. H. Ingberg, a research scientist at the National Bureau of Standards, began to develop methods to normalize the severity of the standard exposure condition with expected exposure conditions in the field. By 1928, Ingberg had developed the "fire load concept," which suggested that there was a relationship between the amount of combustibles present within a space and the fire severity, which is a term used as a measure of the intensity and the duration of a fire. Despite shortcomings in the fire load concept, some of which Ingberg recognized as he developed the concept, the fire load concept continues to serve as one of the primary implicit bases for evaluating expected fire severities and, consequently, required fire resistances in buildings.*" (Page 28)

"*The 1927 UBC would have required very tall buildings (greater than 85 feet or 8 stories) to be of Type I construction, with not less than four-hour fire-resistive protection for columns, beams and girders and three-hour fire-resistive protection for floors. These requirements generally exceed the requirements contained in the current model building codes. This begs the question: Were these requirements too conservative, have building fires become less severe or are safety margins simply being reduced to decrease building construction costs*?" (Page 30)

"*This begs the question: Were these requirements too conservative, have building fires become less severe or are safety margins simply being reduced to decrease building construction costs*?"

Commentary: To put Dr. Mowrer's question in other words, are columns and horizontal members which frame into columns with a 4 hour fire resistance rating and floors with a 3 hour fire resistance rating necessary to prevent the collapse of a building which is greater than 8 stories or 85 feet in height? Of course, the answer to that question depends upon the occupancy of the building. Typically, most high rise buildings are either office buildings or contain residential occupancies (*i.e.*, apartment buildings or hotels). Given the combustible loading in office and residential occupancies, it would seem that building structural elements with a two hour fire resistance rating would be more than adequate to prevent the collapse of these types of buildings assuming sprinkler system failure and no manual fire fighting efforts. Since all new high rise buildings are required to be protected throughout by a sprinkler system and the reliability of manual fire fighting operations has improved since 1927, providing structural elements with a 2 hour fire resistance rating should be more than adequate to prevent the collapse of high rise office and residential buildings with sprinkler protection and manual fire fighting operations providing factors of safety against collapse.

"*In 1942, the Subcommittee on Fire-Resistance Classifications of the Central Housing Committee on Research, Design, and Construction published its Report BMS92 on "Fire-Resistance Classifications of Building Constructions." This report was published (with a cover price of 30 cents!) by the National Bureau of Standards, the predecessor organization to the National Institute of Standards and Technology. . .*" (Page 30)

"*Report BMS92 outlined the "relations between combustible contents, fire severity, and fireresistance ratings" and provided "a method of evaluating the combustible contents of a building." In this way, this document attempts to lay out a rational basis for fire resistance requirements in buildings. Unfortunately, once this rational basis was outlined and fire resistance requirements were established from this basis, the connection between the performance objective and the design concept became implicit rather than explicit. In other words, once the fire severities and fire resistance requirements for different occupancies were established, the design objective became "meet the required fire resistance rating" rather than "provide a level of fire resistance sufficient to withstand the full fire severity.*" (Page 31)

Table 1. Relationship between combustible loading and fire severity from BMS92.

Avg. Weight of Combustibles lb/ft^2	5	7.5	10	15	20	30	40	50	60
Fire severity hours	0.5	0.75	1	1.5	2	3	4.5	6	7.5

(Page 31)

"*Knowledgeable fire safety professionals have recognized for many years that the fuel load concept developed by Ingberg has technical shortcomings. Ingberg himself recognized some of the shortcomings in the fuel load concept even as he developed and promoted it. As noted in the commentary to the ASTM E119 standard, "It is now generally conceded that fire severity as well as the temperature-time relationship of a fire depends on several factors, including:*

1. *Fire load-Amount and type.*
2. *Distribution of this fire load.*
3. *Specific surface characteristics of the fire load.*
4. *Ventilation, as determined by the size and shape of openings.*
5. *Geometry of the fire compartment—Size and shape.*
6. *Thermal characteristics of the enclosure boundaries.*
7. *Relative humidity of the atmosphere.*"

(Page 31)

"*The fuel load concept explicitly addresses only the first of these factors and implicitly addresses the second. Despite this recognition of its shortcomings, the fuel load concept continues to be widely used, and is even referenced in the ASTM E119 Standard right after the reference to these potential factors that can influence fire severity: "For the purposes of this commentary, fire severity is defined as a measure of the fire intensity (temperature) and fire duration. It is expressed in terms of minutes or hours of fire exposure and in Test Methods E 119 is assumed to be equivalent to that defined by the standard temperature-time (T-t) Curve, that is, the area under the T-t curve.""* (Page 32)

"*Despite this recognition of its shortcomings, the fuel load concept continues to be widely used, and is even referenced in the ASTM E119 Standard right after the reference to these potential factors that can influence fire severity. . .*"

"*BMS92 notes that height restrictions are not generally applied to buildings of Fireproof construction, except in occupancies deemed specially hazardous. "This may be justified on the basis that the building should withstand a fire completely consuming all combustible contents and trim without collapse of structural members, or that for the higher amounts of combustible contents, the fire resistance incorporated in the building, in combination with its fire extinguishing equipments and the public fire protection, is deemed adequate to prevent such collapse.*" (Page 34)

"*This statement is interesting for two reasons. First, it reiterates that buildings of Fireproof construction should be designed to prevent collapse resulting from fire, either by withstanding complete burnout of all combustible contents or through a combination of fire resistance, automatic and manual fire suppression. Second, this discussion recognizes "tradeoffs" for fire resistance, but only if they are adequate to prevent collapse.*" (Page 34)

"*While building codes such as the 1927 UBC were generally requiring fire resistance ratings of 4-hours for primary structural members, BMS92 suggested that such levels of fire resistance might not be justified. "For buildings generally associated with the lower range in combustible contents, such as residential and office buildings, it does not appear justifiable even from this standpoint to apply an unduly large factor of safety. Where the expected fire severity is in the range ½ to 1½ hr, a 2-hr requirement for high buildings should give good assurance of stability under fire conditions.""* (Page 35)

"*Part of the rationale for this statement was the fire resistance inherent in larger structural members and in continuous structural frames. "It is noted that fire-resistance ratings are based on the performance of members near the lower range in size. For the larger size of members used in all but the upper stories of such high buildings, there would be considerable increase in fire resistance above the nominal ratings for the same kind and thickness of protecting materials. Also, the structural continuity inherent in the type of construction increases the margin of safety on stability above that indicated in test furnaces for comparable fire exposure and loading of segregated columns, beams, and floor and wall assemblies."*" (Page 35)

"*BMS92, a report published more than 60 years ago, lays out a number of rational performance objectives for the fire resistance of buildings of different types of construction that are still relevant today. BMS92 is useful from the standpoint that it explicitly discusses the rationale for different restrictions and limitations based on types of construction that have become implicit, and therefore less clear, in the intervening years. Of particular note, for "fireproof" buildings BMS92 identifies the same performance objective noted by Buchanan, which is that the fire resistance of a structure, or part thereof, should be greater than the fire severity to which the building, or part thereof, is expected to be exposed.*" (Page 35)

"*While the performance objectives described throughout BMS92 remain relevant today, the approach to achieving these performance objectives outlined in BMS92 has technical shortcomings. These shortcomings include reliance on Ingberg's fire load concept as the means to establish the expected fire severity in a building and reliance on occupancy classifications as a means to establish the expected fire loads.*" (Page 36)

"*Unfortunately, this only demonstrates code compliance, which may bear little correlation with actual field performance and does not address the serviceability of a building or the structural elements and assemblies following a fire.*"

"*Unfortunately, this only demonstrates code compliance, which may bear little correlation with actual field performance and does not address the serviceability of a building or the structural elements and assemblies following a fire.*" (Page 37)

"*In a probabilistic performance-based design environment, evaluation of fire resistance depends on a number of factors, including the likelihood and severity of different expected fire scenarios, the expected thermal and structural responses of fire resistant assemblies and structural frames to these fire scenarios and the performance criteria being used to judge the adequacy of a design.*" (Pages 37 and 38)

"*For tall buildings, the structural fire resistance performance objective has implicitly been to prevent the collapse of the building with complete burnout of combustibles within the building, i.e., for the fire resistance of the structure to exceed the expected fire severity, as noted in Section 1.0. This could also be stated as an explicit performance objective.*" (Page 38)

"*In a probabilistic framework, the same deterministic performance objectives can be used along with statements of expected success probabilities. For example, the deterministic performance objectives could be expressed as:*

> *Prevent the total or partial collapse of a building to a specified level of confidence;*
>
> *Limit the spread of fire within a building to a specified level of confidence;*
>
> *Limit the spread of fire between buildings to a specified level of confidence.*"

(Page 39)

"*While this probabilistic approach introduces the concept of reliability that is lacking in the deterministic approach, it is still based on single occupancy importance factors and tolerable damage performance levels for all buildings.*" (Page 39)

"*As the collapse of the World Trade Center buildings so vividly demonstrated, the collapse of large buildings in urban areas can have devastating effects on surrounding buildings, on the local and regional infrastructure as well as on the local, regional and even on national and international economies.*" (Pages 39 and 40)

Commentary: It should be recalled that the events of September 11th were more than just the collapse of a single tall building. The collapse of the towers was preceded by the hi-jacking of 4 aircraft nearly simultaneously and then flying three of the hi-jacked aircraft into buildings. Obviously, the effects of the scenario which played out on September 11th would have been expected to encompass more than just the collapse of a single tall building.

September 11th was similar to the Japanese attack on Pearl Harbor on December 7, 1941 and the effects of September 11th were also similar to the effects of the Pearl Harbor attack. Like the attack on Pearl Harbor, the missile attack on the World Trade Center towers was an act of war, and nine years later the United States is still involved in the war which resulted from the attacks on the World Trade Center towers.

"*Due to the technological and intrinsic nature of fire, neither the frequency nor the magnitude of a fire incident will be independent of the building design. The frequency of fire depends on a number of factors, including compliance with recognized standards for the installation of utilities, good ignition prevention practices, and the potential for arson and other terrorist acts, which may be related to building security design and management. The magnitude of fire incidents also depends on a number of building design factors, including the flammability properties, quantity and distribution of combustible materials, fire detection and alarm notification, automatic and manual fire suppression systems and activities, and fire confinement and ventilation. To a large extent, the magnitude and severity of a fire incident depends on the fire intervention strategies and their timing.*" (Page 44)

"*. . .To a large extent, the magnitude and severity of a fire incident depends on the fire intervention strategies and their timing.*"

"*Within a deterministic design framework, this would entail the selection of a combination of fire protection features and systems that would maintain the probabilities of exceeding the tolerable damage states within acceptable limits. Statistics on the effectiveness and reliabilities of different fire protection features and systems are needed to support this approach. Within a probabilistic design framework, the same fire protection feature and system selection process would be used along with a more detailed analysis of system reliabilities and probability distribution functions for fire severities and fire resistances of different building elements and assemblies.*" (Page 44)

"*Statistics on the effectiveness and reliabilities of different fire protection features and systems are needed to support this approach.*"

"*Within a deterministic design framework, the designer would select the fire protection features and systems needed to meet the design performance objectives. Either more fire protection features or higher safety factors, or both, would be included for buildings with higher importance factors. In some respects, this is already done implicitly in the model building codes. For example, in hospitals, which are included in Occupancy Type IV, it is common to control combustibles, to include early detection and alarm systems, to provide automatic fire suppression and to provide a high level of fire resistance and compartmentation of the building. It would be instructive to map the current fire protection requirements for different buildings onto the occupancy important factors to determine how extensive such implicit connections might be.*" (Page 44)

"*As noted previously, large buildings located in urban areas could be classified in higher performance groups than similar buildings located in less concentrated areas, thus justifying higher fire resistances for buildings located in concentrated urban areas. While the severity of the fires in such similar buildings would be expected to be similar regardless of the building location, the potential consequences of building collapse would be different based on the building location. Consequently, it would be reasonable to require a higher level of fire resistance for buildings located in urban areas than for similar buildings in isolated locations.*" (Page 45)

"*In order to apply a "stress"-"strength" interference model to the issue of fire severity versus fire resistance, it will be necessary to develop appropriate probability distributions for fire severities as well as for the fire resistances of different structural elements and assemblies. In turn, this would require that fire severities be addressed in terms of all the variables that influence fire severities, not just the fire load concept upon which fire severity has traditionally been based. . .*" (Page 46)

"*Implementation of the proposed framework for structural fire design will require consideration of a number of factors in addition to those already addressed. It will also require research to further develop the framework and to develop the data and models needed to support the framework. Some of these factors and research needs are discussed in this section.*" (Page 46)

"*Implementation of the proposed framework for structural fire design will require consideration of a number of factors in addition to those already addressed. It will also require research to further develop the framework and to develop the data and models needed to support the framework. Some of these factors and research needs are discussed in this section.*"

"*The treatment of multi-hazard scenarios needs to be considered in the development of a comprehensive framework for structural fire design. . .With the increase in terrorist activity over the past decade, such extreme events are now recognized to be significant threats to structural integrity. Methods similar to those used in LFRD structural design could be developed with fire as either a load or a resistance factor to address multi-hazard scenarios. How to combine load factors, including traditional loads, extreme events and fire, requires further consideration.*" (Page 46)

Commentary: It appears that Dr. Mowrer is suggesting that buildings be designed to address terrorism. It seems reasonable to question whether or not it is both possible to design buildings to be "terrorism-resistant" and whether or not it is economically feasible.

Another question with regard to "terrorist-resistant" buildings is whether or not regulations should be adopted for the retro-fit of existing buildings. It seems obvious that terrorists could simply choose to target buildings constructed prior to the adoption of "terrorist-resistant" regulations if existing buildings are not retro-fitted to comply with "terrorist-resistant" building requirements. It is my opinion that Dr. Mowrer's suggestion regarding the adoption of "terrorist-resistant" provisions for building construction will likely bankrupt the United States.

As with many problems, sometimes "the best defense is a good offense". Eliminating the terrorist threat is more likely to be an effective measure, than trying to minimize the damage caused by terrorist activity. At present, it doesn't appear that the United States has the financial resources to pursue both approaches to the problem of terrorism.

"Fool me once, shame on you. Fool me twice, shame on me."

"*A multi-hazard approach to design that includes fire as a design parameter provides the opportunity to enhance the fire performance of buildings while improving their performance against other hazards as well. For example, it may prove cost-effective to improve fire performance through structural enhancements that also improve earthquake and wind performance rather than through thermal enhancements that do not affect these other hazards. Such structural enhancements may also improve building comfort, for example by reducing building sway and vibrations felt by building occupants.*" (Page 47)

Commentary: The "multi-hazard" design concept has been mentioned several times above, however, this concept has never been defined. Without a precise definition of what is meant by this term, the proposal to adopt this approach as a design concept is "fuzzy"-no doubt, intentionally so. "Fuzzy" concepts to be defined at some later date are what has gotten this country in the economic "mess" we find ourselves in at the present. Proponents of the "multi-hazard" design concept need to lay out exactly what they have in mind before we proceed in adopting and implementing this concept.

"Fool me once, shame on you. Fool me twice, shame on me."

We have already been fooled by NIST once into thinking that the NIST World Trade Center towers collapse investigation would address the issue of terrorism (as promised by Dr. Arden Bement, the director of NIST, in order to gain funding from Congress for NIST's investigation into the collapse at the Congressional Science Committee hearing held on March 6, 2002). Let's not get fooled again by NIST into adopting NIST's "multi-hazard" design concept without knowing how this concept is actually going to be defined.

Editor's Note: The discussion of this NIST document will continue in Part 2 of this article.

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