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NIST GCR 04-872:
"FIRE PROTECTION OF STRUCTURAL STEEL
IN HIGH-RISE BUILDINGS"-Part 2

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.

This document published by NIST contains a number of papers written by various authors. Part 1 of this article included excerpts from two papers, one paper written 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 and the other paper authored by Dr. Frederick Mowrer of the fire protection engineering department at the University of Maryland, as well as excerpts from the Forward and Executive Summary.

The following are excerpts from a paper authored by Robert Berhinig of Underwriters Laboratories, Inc.:

> "*The methods and performance criteria used to quantify the fire endurance of building systems have changed little over the last 50 years in Europe and North America. During this period, improvements have focused on sample selection, data collection, accuracy of the data and reproducibility of results on an inter-laboratory basis and the application of data. In 2003, the National Institute of Standards and Technology (NIST) published a report that summarized the features of twenty-seven test facilities used to determine the fire resistance of building assemblies.*" (Page 49)

> "*Numerous papers have been written identifying concerns regarding the present test methods such as ASTM E119 and ISO 834 and the application of results from these tests in determining the fire endurance of building structures.*" (Page 49)

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"*During the past 75 years, these prescriptive approaches have been successful. In the NIST report, six occurrences of collapse in steel framed structures were cited. Four of these six were at the World Trade Center site. It would appear this performance has resulted from a balance of redundancy in structural design and the conservatism in the assessment of fire test data.*" (Page 50)

"*Specialized structures have been constructed in addition to the standardized testing equipment. Two examples include one at NIST and one at the Cardington facility of the British Research Establishment. Both were steel structures with the focus being to obtain information on the redistribution of loads within the frame during a fire exposure. Unlike the standardized equipment, these facilities have had a short life in terms of being used for a relatively few fire exposures*." (Page 50)

"*Current performance criteria for testing equipment are somewhat limited. Both standards include tolerances with respect to variation from prescribed temperature levels. The ISO 834 standard provides criteria in addition to that specified in ASTM E119. The ISO standard specifies the minimum thickness and density of the furnace lining material, the pressure conditions within the furnace chamber and the minimum stiffness of the restraining frame into which test samples are constructed. ASTM E119 is silent on all these topics.*" (Page 50)

"*Neither of the test methods addresses the type or amount of heat flux received by the sample or the magnitude of the restraint applied by the testing equipment to the sample during the fire test.*" (Page 50)

"*During the past 75 years, these prescriptive approaches have been successful. In the NIST report, six occurrences of collapse in steel framed structures were cited. Four of these six were at the World Trade Center site. It would appear this performance has resulted from a balance of redundancy in structural design and the conservatism in the assessment of fire test data.*"

"*Work is underway in ASTM to further define specifications for testing equipment and the testing environment. The focus in ASTM is presently directed towards the operation of test equipment with respect to monitoring pressure conditions.*" (Page 51)

"*Results from specially built steel frame structures have demonstrated that a degree of load redistribution occurs within the frame because of the frame's stiffness and thus its ability to resist the resulting thermal expansion. Today, test frames do not include a mechanism to quantify the thermal thrust developed by the expansion of the assembly under test or a means to apply a level of resistance or restraint that would be representative of a structural frame. Is this data desirable? How should it be accomplished? During the 1960's, fire test facilities operated by the Portland Cement Association had horizontal test frames that included perimeter hydraulic jacking.*" (Page 52)

"*Results from specially built steel frame structures have demonstrated that a degree of load redistribution occurs within the frame because of the frame's stiffness and thus its ability to resist the resulting thermal expansion.*"

"*At times the recommendations were conflicting. For example, it was recommended that the fire test be conducted until structural failure occurred and that data be provided documenting the performance of the test assembly during the "cool-down" phase.*" (Page 53)

"*It was also suggested that revisions be made to ASTM E119 to provide guidance in the scaling of the test assembly to be better representative of "as-built" construction.*" (Page 53)

The following excerpts were "synthesized" by the Civil Engineering Research Foundation based upon comments of participants at the workshop:

"*It is tempting to say that the concerns with fireproofing of steel structures that were discussed in this workshop are solely a consequence of the collapse of the World Trade Center; and therefore, since that was a singular event, reality suggests that our response should be directed at preventing terrorists from hijacking airplanes and flying them into buildings. In fact, the workshop experts did recognize that while more can be done to improve fire protection safety in high-rise structural steel buildings, it is not feasible to design for such events as occurred on 9/11. As one breakout group noted, "Fire hazard mitigation should be a top priority, instead of focusing on products to protect from worst case scenarios."*" (Page 55)

"*A particularly important pre-existing life-safety issue stems from the fact that fire protection standards for high-rise buildings have been liberalized in the current building codes. As Mowrer notes in his white paper: "there has been a general reduction in fire resistance requirements in recent years"*" (Page 55)

> "*In fact, the workshop experts did recognize that while more can be done to improve fire protection safety in high-rise structural steel buildings, it is not feasible to design for such events as occurred on 9/11.*"

Commentary: One of the reasons for collecting fire safety statistics is so that we have a "yardstick" with which we can measure progress. Have we made progress against the hazard of fire over the years? There is little doubt that we have.

Over the years, we have come to realize that the most effective means of providing fire protection for both buildings and building occupants is sprinkler protection. According to the National Fire Protection Association (NFPA), the installation of sprinkler protection throughout a building reduces property losses by 40-70 percent and cuts the number of fire fatalities by 83 percent in dwellings protected by a wet pipe system when compared with buildings which are not protected by a sprinkler system.

We also know that the installation of sprinkler protection is effective against fire in 1- and 2-family dwellings.

Is sprinkler protection a reliable form of building fire protection? You bet ya it is. While statistics show that, on average, sprinkler systems fail to control 9 percent of fires (large enough to activate sprinklers), failures of dry sprinkler systems are far more common than wet sprinkler systems.

The statistics on sprinkler system reliability also tell us that the occupancies where sprinkler systems are most likely to fail are industrial and storage occupancies and that systems protecting occupancies classified as light hazard (by NFPA 13) are far more reliable than the average reliability statistic would indicate.

Not only do sprinklers protect building occupants, as well as provide property protection, but sprinkler protection also makes fire fighting much safer. Statistics collected and published by the NFPA tell us that the number of fire fighter fatalities which occur annually in buildings protected by sprinkler systems is typically zero (0) or one (1).

Given the facts above, it makes sense that provisions which recognize the value of providing sprinkler protection in buildings have been included in building codes utilized in the United States. These provisions are usually referred to as "sprinkler trade-offs". Given the capability of sprinkler systems to protect both life and property, as well as making fire fighting operations safer, and also the reliability of sprinkler systems, the preferred method for providing building fire protection in every occupancy, including 1- and 2-family dwellings, is sprinkler protection.

Based upon the above, it should be obvious why the requirements for fire resistance have been either reduced or, in many cases, eliminated in buildings codes over the last 40 years.

"*The technical bases for these apparent reductions and trade-offs in fire protection have not been established.*" (Page 55)

Commentary: It should be noted that 40 years ago, another agency of the United States Government, the General Services Administration (GSA), was a leading proponent of reductions in passive fire protection where sprinkler protection was provided.

> "*A particularly important pre-existing life-safety issue stems from the fact that fire protection standards for high-rise buildings have been liberalized in the current building codes. As Mowrer notes in his white paper: "there has been a general reduction in fire resistance requirements in recent years""*

At that time, Harold Nelson, the fire protection engineer for the General Services Administration proposed or supported numerous reductions in the passive fire protection requirements for a government office building being designed and constructed in Seattle in an effort to make the installation of sprinkler protection reasonably economical for that building. The reductions in passive fire protection supported by the General Services Administration back then included the following:

- Reduction in fire protection ratings for structural elements
- Reduction in shaft enclosure ratings
- Elimination of fire dampers at ventilation system penetrations of shaft enclosures
- Substitution of pressurized stairs as an alternative to smokeproof enclosures
- Elimination of horizontal exit requirements for each floor
- Elimination of the requirement for 1 hour spandrels/flame barriers
- Elimination of 1 hour corridor wall rating requirements

Obviously, it would seem that Harold Nelson and the General Services Administration thought that the protection provided by sprinkler systems was sufficiently reliable to justify reductions in passive fire protection provisions if the GSA both proposed and supported these reductions in the early 1970's.

Interestingly enough, one of the consultants employed by NIST on the World Trade Center towers and the WTC 7 Building collapse investigations was Harold Nelson, the same fire protection engineer who worked at GSA in the early 1970's.

It would appear that NIST has an "institutional memory" problem.

It would appear that whoever wrote the statement that there is no basis for the reductions in passive fire protection permitted when sprinkler protection is provided in a building was unaware of the Federal Government's involvement in developing the "sprinkler trade-offs" included in the model building codes used in the United States. It would also appear that whoever wrote the statement was unaware of the extensive discussions on "sprinkler trade-offs" in high rise buildings which took place in the late 1960's and early 1970's. Many of those discussions which took place were sponsored by the General Services Administration.

To say that there is no basis for the "sprinkler trade-offs" for high rise buildings included in the three regional model building codes and the early editions of the International Building Code and the NFPA 5000 means that NIST is essentially contradicting the General Services Administration. In other words, the United States Government is contradicting itself.

It would appear that NIST has an "institutional memory" problem.

"*The professions' inability to establish a sound technical basis for changes in codes and/or standards, or to provide guidance to the authorities having jurisdiction, follows directly from Mowrer's statement that current design objectives have focused on "meet(ing) the required fire resistance rating" even though fire safety professionals have "long recognized" that ratings derived from standard fire resistance tests do not accurately predict how that building element or assembly will perform "in situ".*" (Page 56)

Commentary: This statement makes the assumption that there is no "*sound technical basis*" for the required fire resistance ratings contained in the International Building Code, yet Mowrer's paper reviewed the technical basis for allowing structural elements in high rise buildings to have a two hour fire resistance rating, rather than a 3 or 4 hour fire resistance rating. Dr. Mowrer's paper includes the following passage:

“*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)

BMS92 was published by a Federal Government agency, the National Bureau of Standards (NBS). This agency is now known as the National Institute of Standards and Technology. Given this, we can say that it appears that NIST is now contradicting NBS. In other words, NIST is contradicting itself.

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Is a two hour fire resistance rating adequate for the structural elements of a high rise office or residential building? According to BMS92, the answer to that question is yes. Two hour structural fire protection, along with sprinkler protection and manual fire fighting operations, is more than adequate for high rise office and residential buildings. In fact, the BOCA Code permitted two hour structural fire resistance ratings for high rise office and residential buildings of any height for close to a quarter century (1975-1999).

Given that a major fire has never occurred in a high rise building protected throughout by a sprinkler system, the two hour structural fire protection permitted by the BOCA Code has never been actually challenged in a typical fire which occurs in high rise office and residential buildings (without sprinkler protection). What this fact demonstrates is the reliability of sprinkler protection.

“*A general conclusion from their study was that the inherent ability of steel structures to effectively redistribute load justifies the elimination or reduction of fireproofing to below the requirements of the then-current British standard. While the concept of reducing the fireproofing on the steel frame without compromising its integrity was nicely demonstrated, generalization of these results and the development of sound guidance for moving in this direction will take considerably more effort. However, the economic payoff could be considerable.*” (Page 56)

"*The simple and obvious statement that the benefit (or reduction in risk) of any change in materials, methods, or regulations should outweigh the cost (or increase in risk) of implementing the change belies the complexity of quantifying the true benefits, the full costs, and the multiple perspectives of the many interest groups as to their specific risk (or cost) and benefit. The huge risk associated with a singular event such as the collapse of the World Trade Center needs to be somehow combined with what may be a minimal risk based upon the historical record. In the end, however, the perception of risk to an individual or organizational stakeholder is more important than the actual risk.*" (Page 56)

Commentary: In essence, the statement above is an admission that the "problem" being discussed is really a non-problem. If the proponents of structural fire engineering can't verbalize the rationalization for the need for structural fire engineering, it is probably a "safe bet" that there is really no pressing need for structural fire engineering. In other words, despite the criticisms of ASTM E119, ASTM E119 works. In the Midwest we have a saying, "don't fix it if it ain't broke".

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Once again, the proponents of structural fire engineering make reference to the collapse of the World Trade Center (WTC) towers as a rationale for the need for structural fire engineering. And once again, it needs to be pointed out that the collapse of the WTC towers was initiated by a missile attack on the buildings-the aircraft were utilized as missiles. Should we design buildings to be collapse-resistant in the event of a missile attack? Aside from the fact that this is not possible (due to the fact that the destructive capability of missiles is constantly being improved), it is not economically feasible.

Of course, our governmental budget problems are a security risk. One way for NIST to assist in our collective homeland security efforts would be for NIST to volunteer to curtail some of its research projects. Research into structural fire engineering is probably a project which can be curtailed without too much harm to homeland security and this would, in effect, advance NIST's interest in homeland security.

"*An innovative, multi-dimensional approach is suggested, involving better, performance-based understanding of fire protection materials, both old and new. New insights, through research, are needed relative to the thermal, mechanical and durability properties of both fire protection and structural components, acting separately and in combination. Such new knowledge and technologies can be applied both to increase benefits and help reduce the actual and perceived risks, and not just in high-rise structural steel buildings, but across the built environment.*" (Page 56)

Commentary: It appears that the statement above indicates that further research is required into the concept of structural fire engineering. If so, how did NIST perform its structural fire engineering analysis on the World Trade Center towers and the WTC 7 Building?

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"*Two institutional "barriers" that impede this proposed effort are noted: first, the current lack of a generally accepted framework for structural fire engineering and, second, the inescapable fact that progress invariably requires consensus by all stakeholders, perhaps especially among owners, architects, engineers, and others with responsibility for ensuring the safety of the public.*" (Page 57)

Commentary: At the present time, there does not appear to be a consensus that research on structural fire engineering is a priority. It would be helpful if NIST would provide a rationale on why such research should be a priority. In absence of a justification on why such research should be given priority in these economic times, it appears that there simply is no justification for the expenditure of capital on this research. Perhaps in rosier economic times, the expenditures on the proposed research could be justified, but it appears that its time to begin trimming the "fat" from the Federal budget. Research on structural fire engineering would definitely be considered to be "fat".

In the early 1970's, Harold Nelson and many others, including Chester Schirmer and Rolf Jensen, figured out how to best protect high rise buildings from fire. Forty years ago, the answer to the problem was to provide sprinkler protection for these buildings. The lack of any adverse experience with sprinkler protection in high rise buildings since then, except as a result of a terrorist attack, clearly demonstrates that Nelson, Schirmer, Jensen and many others were correct.

"*Those silly Americans-what will they think of next? It's going to be easier to bankrupt America than I thought, thanks to NIST.*" OBL

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