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"THE CURRENT FIRE RESISTIVE RATING SYSTEM . . .IS NOT CONSERVATIVE."

By Richard Schulte

The report on the NIST investigation into the collapse of the WTC 7 Building on September 11th was issued in November 2008. Of the two NIST reports on the collapse of buildings at the World Trade Center complex, the report on the WTC 7 Building is definitely the more interesting report.

From an engineering standpoint, the collapse of the WTC towers was pretty straightforward-buildings are simply not designed to resist high-speed impact of large commercial aircraft, but the WTC 7 Building was not struck by aircraft. Hence, the collapse of the WTC 7 Building has been somewhat of a mystery.

The NIST report on the collapse of the WTC 7 Building contains a "treasure-trove" of information on building fire protection. Excerpts from NIST's final report on the collapse of this building, NCSTAR 1-9 (Volume 2), include the following:

"*The collapse of WTC 7 represents the first known instance of the total collapse of a tall building primarily due to fires. The collapse could not have been prevented without controlling fires before most of the combustible building contents were consumed.*" (Page 617)

"*The collapse of WTC 7 represents the first known instance of the total collapse of a tall building primarily due to fires.*"

"*WTC 7 collapsed due to uncontrolled fires with characteristics similar to previous fires in tall buildings. The fires in WTC 7 were similar to those that have occurred previously in several tall buildings (One New York Plaza, 1970, First Interstate Bank, 1988, and One Meridian Plaza, 1991) where the automatic sprinklers did not function or were not present. However, because of differences between their structural designs and that of WTC 7, these three buildings did not collapse.*" (Page 617)

"*The passive fire resistance design of the WTC 7 structural system was based on catalogued ASTM E 119 test data. Practice today (and in the 1980's) for the fire resistance design of structures, based on the use of ASTM E 119 standard test method, is deficient since the method was not designed to include key fire effects that are critical to structural safety. Specifically, such practice does not capture: (a) important thermally-induced interactions between structural subsystems, elements, and connections-especially restraint conditions; (b) system-level interactions-especially those due to thermal expansion-since columns, girders, and floor subassemblies are tested separately; © the performance of connections under both gravity and thermal effects; and (d) scale effects in buildings with long span floor systems.*" (Page 620)

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"*The design of WTC 7 did not include any specific analysis of how the structural system might perform in a real fire. There is a critical gap in knowledge about how structures perform in real fires, particularly considering: the effects of the fire on the entire structural system; the interactions between the subsystems, elements, and connections; and scaling of fire test results to full-structures, (especially for structures with long floor systems).*" (Page 620)

"*The design of WTC 7 did not include any specific analysis of how the structural system might perform in a real fire.*"

"*NIST simulations showed that, for the heaviest columns in WTC 7, when properly insulated, it would have taken an exposure of about 7 h at post-flashover upper layer gas temperatures to raise the steel temperature to 600°C (1100°F)* [1112°F]*, the point at which the steel strength would have been reduced by half. A similar calculation indicated it would have taken about 4 h to reach this temperature for an insulated lighter column. These times are both far longer than the time over which post-flashover gas temperatures were sustained in the computed WTC 7 fires. For comparison, this steel temperature would have been reached in under one-half hour if the insulation were not applied.*" (Pages 628 and 629)

"It is unlikely that the collapse of WTC 7 would have been prevented had the insulation thickness on the floor beams been increased by 50 percent, from 13 mm (½ in.) to 19 mm (3/4 in.). NIST calculations indicated that the time to reach the steel temperature of 649°C (1200°F) would have increased by about 10 min to 20 min." (Page 629)

"*The ASTM E119 test does not capture critical behavior of structural systems, e.g., the effect of thermal expansion or sagging of floor beams on girders, connections, and/or columns. The thermal expansion of the WTC 7 floor beams that initiated the probable collapse sequence occurred primarily at temperatures below 400°C (750°F). Thus, to the extent that thermal expansion, rather than loss of structural strength, precipitates an unsafe condition, thermal expansion effects need to be evaluated. The current fire resistance rating system, which does not include thermal expansion effects, is not conservative.*" (Page 629)

> "*There is a critical gap in knowledge about how structures perform in real fires. . .*"

Discussion

The excerpts from NIST's NCSTAR 1-9 report present a number of topics which require further discussion.

> "*The current fire resistance rating system, which does not include thermal expansion effects, is not conservative.*"

First, with regard to the collapse of the WTC 7 Building being a first time event, the collapse of high rise buildings was indeed an unprecedented event from the standpoint of building fire protection. What is unstated in this commentary however, is that September 11th was itself an unprecedented event, and that the events which occurred on that day significantly influenced the collapse of the WTC 7 Building. In other words, the collapse of the WTC 7 Building was not an isolated event, but rather the final act of a drama which even nine years later affects the world in which we live.

If the fires which occurred in the WTC 7 Building were an isolated event which had occurred on September 10th, rather than on September 11th, would the WTC 7 Building have collapsed? It would seem that there is universal agreement that the answer to that question is no. Hence, it seems reasonable to conclude that the fires in the WTC 7 Building were unlike the fires which occurred in the One New York Plaza Building, the First Interstate Bank Building and the One Meridian Plaza Building. A comparison of the WTC 7 Building to the fires in these three buildings is misleading in that the comparison ignores the events which precipitated the occurrence of multiple fires in the building and the damage done to the fire protection infrastructure of Lower Manhattan on September 11th.

In the excerpts above, NIST attacks both building design practice and the fire resistance test standard, ASTM E119. Is building design practice really deficient because that practice utilizes ASTM E119? Given the results of the practice of utilizing ASTM E119 for purposes of determining structural fire resistance, one would have a difficult time trying to make a case against the use of ASTM E119. NIST's own statement with respect to the collapse of tall buildings (the first excerpt above) effectively rebuts the assertion that somehow building design practice is deficient due to its use of and reliance upon ASTM E119.

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Not only is NIST's statement regarding the use of ASTM E119 in the practice of architecture and engineering rebutted by NIST's own statement, but the statistics on the safety of high rise buildings in the United States is a further rebuttal. The safety record of high rise buildings protected by a sprinkler system is magnificent-a major fire has never occurred in a high rise building protected throughout by a sprinkler system in the United States since the construction of the Sears Tower in the early 1970's, with the exception of on September 11th. Given that record, it would be difficult for anyone to conclude that the use of ASTM E119 in the design of tall buildings constitutes deficient design practice, unless, of course, you ignore the safety record of sprinklered high rise buildings (and that's exactly what NIST did in both of its WTC investigation reports).

With respect to NIST's commentary on the ASTM fire test standard, much of what NIST says regarding the standard is correct. However, NIST states that there are "critical gaps" in our knowledge about how elevated temperatures generated by fires affect the entire structure of a building. NIST's point regarding "critical gaps" is indeed correct and, given this, how can building designers rely on alternate methodologies being suggested by NIST? Is the use of alternative technologies with known "critical gaps" in our knowledge advisable if the alternatives are not considered to be standard engineering practice?

While many in the fire protection field would agree with NIST's commentary on ASTM E119, the weaknesses of ASTM E119 standard being pointed out by NIST are really nothing new. The problem is that we have yet to devise an alternative to the use of ASTM E119 which is universally accepted. Not everyone involved in the design and construction of buildings has the knowledge base to be capable of understanding the alternative methodology that NIST is proposing. Given that, perhaps the "KISS" ("keep it simple stupid") concept is applicable here.

> Is the use of alternative technologies with known "critical gaps" in our knowledge advisable if the alternatives are not considered to be standard engineering practice?

While the ASTM E119 methodology is by no means perfect, and by no means simple to apply, it does have the advantage of being simpler than the methodology being proposed by NIST. Is simpler better? When it comes to fire protection, there is no doubt that the answer to that question is yes. The most effective means of providing building fire protection, sprinkler protection, is a relatively simple concept and the fire safety record of tall buildings protected by sprinklers bears out the fact that the sprinkler protection is a highly effective means of providing building fire protection. Simple, effective and relatively inexpensive is always better than the complex.

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Lastly, NIST's statement that *"the current fire resistance rating system, which does not include thermal expansion effects, is not conservative*" is simply an erroneous statement. Our experience with utilizing fire resistance designs based upon testing per ASTM E119 for more than 80 years tells us that this is the case. NIST's observation that "*the collapse of WTC 7 represents the first known instance of the total collapse of a tall building primarily due to fires*" provides us with all the evidence that we need to determine that NIST is mistaken. With respect to structural fire protection, it is safe to say that the "whole (building structure) is stronger than the sum of its parts".

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In the middle-to-late 1970's, a concept referred to the "systems approach" to fire protection was introduced. The "systems approach" took a look at the purpose of each of the fire protection features provided in a building to see if unnecessary redundancies existed in the protection scheme provided for a building.

The primary fire protection feature provided to protect the occupants of a tall building is sprinkler protection. Sprinkler protection is not only capable of protecting the occupants of a building from both heat and smoke generated by a fire, but is also capable of protecting a building structure by reducing the temperatures to which the structural elements of a building are exposed. If the sprinkler protection successfully controls (or extinguishes) a fire, then there is no need to provide structural fire protection for the building.

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In addition to sprinkler protection, all tall buildings are provided with a standpipe system. The standpipe system facilitates fire department operations in the event that sprinkler protection only controls a fire, rather than completely extinguishes a fire. A standpipe system is also provided in tall buildings as a backup to the sprinkler system in the event of sprinkler system failure. To facilitate the safe use of the standpipe system in the event of sprinkler system failure, the building structure must posses some degree of fire resistance.

While the purpose of providing a standpipe system in a tall building is to facilitate manual fire extinguishment, the application of hose streams on the fire also provides a degree of protection for the structural elements of the building. The application of water on the fire reduces the temperatures to which the structural elements of the building are exposed, hence, enhancing the structural fire resistance of the building.

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Given the above, it can be stated that the structural elements of a tall building provided with both sprinkler protection and a standpipe system, as well as structural fire protection (determined by code requirements which reference testing per ASTM E119), are provided with three different types of fire protection for the building structure. When considering the standard fire protection for a tall building as a system of protection, it would be difficult to say that "*the current fire resistive rating system. . .is not conservative*". This statement can only be made if the structural fire protection provided by sprinkler protection and manual fire fighting are ignored. In effect, NIST is suggesting that the protection provided by sprinkler and standpipe systems be ignored with this statement, despite the historical record of reliability of both automatic and manual fire suppression.

The historical record of the high degree of reliability of sprinkler protection in high rise buildings is undeniable. Similarly, the high degree of reliability of manual fire fighting in high rise buildings is, likewise, undeniable. It will be the rare case indeed where the structural fire protection for building structural elements will be of any importance whatsoever.

In the early 1970's, the General Services Administration (GSA) urged that sprinkler protection be installed in high rise buildings. At that time, the GSA went so far as to suggest that reductions in passive fire protection features be proposed to encourage the installation of sprinkler protection in high rise buildings. For the General Services Administration to make this recommendation, the GSA must have been convinced that sprinkler protection was a highly reliable form of fire protection.

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Nearly 40 years later, it appears that we have come “full circle” with another agency of the Federal Government, the National Institute of Standards and Technology, now recommending that we ignore the protection provided by sprinkler and standpipe systems in the design of tall buildings. Are tall buildings provided with sprinkler and standpipe systems and structural fire protection determined per ASTM E119 “safe”? Given the historical fire safety record of high rise buildings protected by a sprinkler system, it would be difficult to conclude anything but that sprinklered high rise buildings are “safe”. Since NIST has provided no rationale why the high level of “safety” provided by sprinkler protection and standpipe system installations should be ignored, it seems only rational that NIST’s recommendation on this issue should be ignored, at least until NIST can provide a rational argument supporting their position.

Forty years ago, the General Services Administration provided a rationale which supported the reduction in passive fire protection to encourage the installation of sprinkler protection in tall buildings. GSA’s rationale is as valid today as it was 40 years ago, and nothing has really changed to invalidate that rationale. (Even NIST has conceded that making tall buildings “terrorist-proof” or even “terrorist-resistant” is not economically feasible. Hence, the 9/11 terrorist attack is irrelevant to this discussion.)

Conclusion

NIST’s statement that “*the current fire resistive rating system. . .is not conservative*” is simply in error. In making this statement, it is apparent that NIST doesn’t want to acknowledge the safety record of tall buildings. Nor does NIST want to acknowledge that there are more pressing safety issues in America besides high rise building safety.

It is my opinion that the high rise building safety issue was addressed by the General Services Administration (i.e., Harold Nelson, now a consultant to NIST) and many others, including Chester Schirmer and Rolf Jensen, in the early 1970's. It is time to move on to more pressing safety issues in United States.

Given the state of the economy today, in particular the construction industry, serious consideration needs to be given to removing "roadblocks" which restrain the economy. The NIST recommendations, and the code provisions which have resulted from these recommendations, are one of those "roadblocks" and are an impediment to getting the US economy "back on track".

The effects of the NIST recommendations on the (lack of) construction of new tall buildings is just one more example of the "law of unintended consequences".

"Stealing" capital from the economy to address the issue of tall building "safety" not only makes it more difficult to address real safety issues, but also takes capital necessary to maintain fire safety features away from owners of existing buildings. Implementing the NIST recommendations won't make tall buildings any "safer", but it will certainly make tall buildings far more costly to construct and that's bad news for unemployed construction workers in the United States.

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