Fire Protection

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Opposing Viewpoints on the WTC Collapse

The fire protection column in the August, 2002 *Plumbing Engineer* (page 8) reviewed the Federal Emergency Management Agency (FEMA) report titled "World Trade Center Building Performance Study: Data Collection, Preliminary Observations, and Recommendations" issued in May, 2002. The August column included a brief timeline of the events and excerpts from the executive summary of the FEMAreport, as well as criticism of some of the report's recommendations. While the FEMAreport is the "official" report on the attack on the World Trade Center, other organizations and individuals have also addressed this incident. This month's column addresses some of the "unofficial" commentary on the World Trade Center incident.

On the morning of September 11, 2001, each of the World Trade Center (WTC) towers was struck by commercial aircraft intentionally flown into the buildings. The impact of the aircraft caused extensive damage to the structural systems of each of the buildings, however, each tower remained standing. Immediately following the impact, fuel onboard the aircraft ignited and a massive fire ensued in each tower. The fires caused additional damage to the structural systems of the towers and within a relatively short time both towers collapsed. The north tower collapsed 103 minutes after the aircraft struck the building, while the south tower collapsed 56 minutes after being struck by the aircraft.

As might be expected, the collapse of the two towers has generated considerable discussion as to whether the high rise provisions presently contained in building codes are adequate to protect both the occupants of the building and emergency response personnel. There are a number of organizations pressing for more restrictive code requirements. One of these organizations is the Skyscraper Safety Campaign (SSC), an organization of families of firefighters, emergency personnel and civilians who died in the attack on the World Trade Center. Another organization is the Voices of September 11, an organization of family members of victims of the attack on the World Trade Center, the Pentagon and also passengers on board the hijacked airliner that crashed in Pennsylvania.

The Web site for the Skyscraper Safety Campaign (*www.skyscrapersafety.org*) indicates that the goals of the organization are as follows:

- *"To have a Federal Comprehensive Investigation, with subpoena power, into the collapse of the WTC, including design, construction, evacuation procedures and fire fighting techniques.*
- *"To reform Building Codes in New York City and nationwide, thereby safeguarding Firefighters, as well as persons who must live and work in skyscrapers.*
- *"To reform 'codes groups' by allowing the Fire Service to have more input into writing Building Codes. We call for at least 50% of all codes groups to be composed of representatives of the Fire Service and the academic field of Fire Science Engineering. (Existing groups are composed of builders, developers, financiers and bureaucrats who know little about Fire and Life Safety.)*
- *"To prohibit building construction by the Port Authority that is immune from City and State Building Codes, such as was the case with the WTC. To require the Port Authority of New York and New Jersey to rebuild the WTC according to the New York State International Code, and not 'its own codes.'*
- *"To insure that all future WTC development be characterized by quality, safety, security and code compliance."*

The SSC Web site also includes transcript of the testimony given at various hearings. The following is an excerpt from testimony of Ms. Monica Gabrielle, co-chairperson of the SSC, on June 24, 2002:

> *"What we need is the boot end of a knee jerk reaction to expeditiously kick out the despicable building code provisions that allow 10 story buildings to be treated the same as 100 story buildings!*
>
> *"We need to ensure that new high rise buildings are structures of quality, safety, and security ... not the same old bare minimum codes and structural requirements. And we need to have it on the fast track!"*

The Voices of September 11 Web site (*www.voicesofsept11.org*) also contains transcripts of meetings. The following is an excerpt from testimony by Ms. Beverly Eckert, also on June 24, 2002:

> *"The Towers of the World Trade Center were deathtraps. Fire, not planes, brought them down. I've heard the structural engineer and the builder speak with pride of the innovative design of the buildings—how they made them economically viable to build and to rent, by making their interior structure lightweight and open. They used trusses and bolts to hold the house of cards together.*
>
> *"I wish the engineer and builder could have listened to my husband die, the way I did. I wish they could have*

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heard the sound he made when those lightweight trusses melted and those flimsy bolts sheared ... and the floor fell out from under - neath him. I wish that they could hear—just once—the sound that will haunt me forever."

Another excerpt from remarks by Ms. Eckert on August 13, 2002 is as follows:

"And it also needs to be acknowledged that the efforts of the firefighters trying to rescue the occupants were cut short because of the premature collapse of the building. And that happened because the building lacked ade - quate fire-proofing, had limited fire suppression systems and was constructed with trusses and brackets that made the building lit - tle better than a house of cards."

The fact that the towers were able to absorb these tremendous blows without immediately collapsing is actually a testament to the resiliency of the structural systems of these two buildings.

Another Web site which addresses the collapse of the World Trade Center is the Web site of Chief Vincent Dunn (*vincentdunn.com*). Chief Dunn, a former deputy chief with the New York Fire Department, writes:

"The computer has allowed engineers to reduce the mass of a structure by its ability to more accurately determine the load bearing capability of structural framework. Years ago before the computer, builders were not sure of a structural elements load bear - ing capability, so they over built by using a so called 'safety factor.' This built in safety factor could result in a structure with twice the required load bearing strength. Because of computer calculation this no longer occurs. The older buildings use[d] to have built in a so called 'safety factor' of two-to-one. Not so today, if the building code requires a load bearing fac - tor of 40 pounds per square foot that is exactly what you get. There is no margin for error."

Chief Dunn also writes:

"Since the end of WWII builders designed most of the con - crete from the modern high-rise constriction. First concrete they eliminated was the stone exterior wall. They replace them with the 'curtain walls' of glass, sheet steel, or plastics. This curtain wall acted as a lightweight skin to enclose the structure from the out - side elements. Next the 8-inch thick concrete floors went. They were replaced with a combination of 2 or 3 inches of concrete on top of thin corrugated steel sheets. Next the masonry enclosure for stairs and elevators were replaced with several layers of sheet rock. Then the masonry smoke proof tower was eliminated in the 1968 building code. It contained too much concrete weight and took up valuable floor space. Then the solid steel beam was replace by the steel truss. And finally the con - crete and brick encasement of steel columns girders and floor supports was eliminated. A light - weight spray-on coating of asbestos or mineral fiber was sprayed over the steel. This coat - ing provided fireproofing. After asbestos was discovered haz - ardous vermiculite or volcanic rock ash substance was used as a spray-on coating for steel. Outside of the foundation walls and a thin 2 or 3 inches of floors surface, concrete has almost been elimi - nated from high-rise office build - ing construction. If you look at the WTC rubble at ground zero you see very little concrete and lots of twisted steel.

"How did lightweight high-rise construction evolve since WWII? It evolved with the help of the so-called performance code. After WWII the builders complained about building codes. They said they were too restrictive and spec - ified every detail of construction. They called the old building codes 'specification codes.' They com - plained the codes specified the size and type and some times even the make of a product used in con - struction. They decried the specifi - cation code as old fashion. They wanted the building codes changed to what they called 'per - formance codes.'They wanted the building codes to specify the per - formance requirements only; and, not specify the size and type of building material to use. For example, with fire resistive requirements they wanted the code to state just the hours of fire resis - tance (one, two, three or four hours) required by law; and not to state the specific type and materi - al used to protect structural steel and enclosures for stairways and elevators shafts. For example, a performance building code states: the steel has to be protected against heat of flames for one, two, three or four hours during a fire. It does not state what to use as a fire resisting material. This performance code signaled the end to concrete encasement fire protection and allowed a spray on fire protection for steel and plas - terboard enclosed stairs and ele - vator shafts. Builders hailed the New York City building code of 1968 as a good performance code. However, some fire chiefs decried it as a law that substituted frills for real construction safety. The asbestos spray on coating of steel trusses used in the WTC towers was considered by Chief of the New York City Fire Department, at the time, John T. O'Hagan to be inferior to concrete encasement of steel."

Chief Dunn's Web site includes recommendations for the construction of

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the replacement buildings at the World Trade Center site. The following are Chief Dunn's "recommendations for constructing the new high rise buildings on ground zero":

- *"The steel columns, girders and floor beams should be encased in masonry or other more effective fire retarding material. Spray-on fire retarding is ineffective. Post fire investigations reveals the spray on fire retardant has scaled off and steel beams and concrete and steel floor slabs crack and allow flame spread.*
- *"Lightweight bar joists should not be used to support floors in high-rise buildings. The National Fire Protection Association has shown unprotected steel bar joist fail after five or ten minutes of fire exposure.*
- *"For life safety in high-rise buildings bring back the smoke proof tower. This allows people to escape fire using smoke free stairways.*
- *"Stairs and elevator shaft ways should be enclosed in masonry to prevent smoke spread.*
- *"Heating ventilation and air con - dition HVAC systems should be provided by unit system serving only one or two floors. Central air system serving 10 or 20 floors creates shaft ways and duct sys - tems that penetrate fire rated floors walls partitions and ceil - ings. Smoke spreads throughout ducts of central HVAC systems.*
- *"The high rise building frame - work should be skeleton steel framing not center core steel col - umn framing. There should be no bearing wall high rise construc - tion. Reduce the size of open floor design.*
- *"Increase the thickness of con - crete in floor construction. The two or three inches of concrete over corrugated steel fails during most serious high rise fires and must be replaced.*
- *"Automatic sprinklers should protect all high rise buildings. Firefighters can extinguish approximately 2,500 square foot of fire with one hose line. Two hose steams may quench 5,000 square feet of fire. The World Trade Center floor areas were 40,000 square feet in area."*

Tempering reaction with logic

The response to the terrorist attack on the World Trade Center towers by the relatives of the victims of the attacks is rather interesting, and, perhaps, understandable. The reason for the collapse of the WTC towers seems rather obvious, even to those who are not engineers—buildings are simply not designed to be struck by aircraft. The enormous fire that ensued as a result of the impact of the aircraft fur-

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ther damaged the building structure and, as a result, both of the towers collapsed. From the general public's standpoint, there is little mystery surrounding the collapse of the towers.

Of course, an engineer's view of the collapse is a little more sophisticated than the simple explanation given above. The planes that struck the World Trade Center towers were large aircraft traveling at high rates of speed when they struck the towers. The FEMA report on the incident indicates that the speed of the plane that struck the north tower was estimated to be 470 miles per hour, while the speed of the airplane which struck the south tower was estimated to be 590 miles an hour. The FEMA report also indicates that the weight of each of the airplanes which struck the towers was approximately 274,000 pounds.

As would be expected, each of the aircraft inflicted massive damage on the building structure. The plane which struck the north tower damaged the structural system on five stories of the building, while the plane that struck the south tower damaged the structural system on seven stories of the building. While the towers were described as being a "house of cards" held together by "flimsy bolts" by Ms. Eckert, the fact that the towers were able to absorb these tremendous blows without immediately collapsing is actually a testament to the resiliency of the structural systems of these two buildings.

Because the buildings were not specifically engineered to absorb the high-speed impact of a large aircraft, one cannot credit the architects, engineers and contractors for purposely designing and constructing the building to resist collapse under the conditions the buildings were exposed to on the morning of September 11, but certainly condemning the design and construction teams for not anticipating this event is ludicrous. The statements referring to the World Trade Center towers as being a "house of cards" and being "flimsy" can perhaps be best described as hysterical and were certainly intended to be inflammatory.

While the World Trade Center towers were able to absorb the initial impact of the aircraft and remain standing, the ignition of the aviation fuel in the planes caused massive fires within each tower and increased the stress the already crippled structural systems were under. As the airplanes slid through each of the buildings, they no doubt compromised the building fire protection systems, including the structural fire protection (on the floors where the impact occurred), the sprinkler system, the standpipe system, the exit stair enclosures, the elevator hoistway enclosures and other floor opening enclosures. With all of the building fire safety systems compromised to one degree or another, the flammable liquids fire roared out of control. Given this, the collapse of each tower was more or less a forgone conclusion. The only question remaining to be answered that morning was how long the buildings could remain standing.

According to the FEMA report, the answer to that question was long enough for most of the people in the World Trade Center complex located below the impact floors to evacuate. Of the 58,000 people estimated to be in the World Trade Center complex that morning, roughly 95 percent of them escaped. According to the FEMA report, most of the building occupants who died in the collapse were located on or above the floors where the aircraft struck the buildings. Despite the fact that the buildings had not been designed and constructed to withstand the impact of a large commercial airliner and the enormous flammable liquids fires that would ensue, the towers' structural performance was nothing short of astounding. Yes, roughly 3,000 people lost their lives in the collapse, but it was very fortunate indeed that the death toll was not far greater.

Rethinking goals

One of the goals of the Skyscraper Safety Campaign is to have a comprehensive investigation of the terrorist attack on the World Trade Center towers. The SSC would like this investigation to include a review of the design and construction of the World Trade Center, firefighting operations and evacuation procedures. Of course, an investigation into the design and construction of the World Trade Center makes sense if you regard the design and construction of the building as the principal reason for the collapse of the towers. However, it should be obvious to most engineers (and the general public) that the towers' performance was far more than adequate given that the buildings were not designed to withstand the impact of large aircraft, let alone an exposure to the enormous flammable liquids fires which followed. The real culprit in the collapse of the World Trade Center towers was not the building construction, but the terrorists who flew the airplanes into the buildings. Do we really need a taxpayer funded investigation of the obvious?

NFPA statistics on fire fatalities in high rise office buildings tell us clearly that high rise office buildings are not dangerous buildings, regardless of whether they are 10 stories or 100 stories.

Do we need an investigation into the evacuation procedures? Again, with the knowledge that 95 percent of the occupants of the World Trade Center complex escaped and that most of the occupants who died were located on or above the floors where the airplanes struck the towers, it seems obvious what the evacuation problems were. The airplanes sheared off the evacuation routes, the stairs and eleva-

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tors, and the occupants above the impact floors had no viable escape route from the building. Again, do we need a taxpayer-funded high cost investigation of the obvious?

Another goal of the Skyscraper Safety Campaign is to reform the [model] "code groups" so that 50 percent of the representatives writing codes are either from the fire service or are academics in the field of fire science engineering. The goals of the SSC also state that the present model building code groups are mainly composed builders, developers, financiers and bureaucrats who know little about fire safety.

The statement of this goal is rather interesting given that the two organizations who now develop model building codes in the United States, the International Code Council (ICC) and the National Fire Protection Association (NFPA), are not dominated by members of either the construction industry or the real estate industry. In fact, the International Code Council only permits governmental representatives to vote on code change proposals. Neither the by-laws governing the ICC or the NFPA prohibit fire service participation and, in fact, many members of the fire service already actively participate in the code development process. Similarly, these two organizations do not prohibit the participation of academics in the code development process.

It should be noted that the statement of the goal of the participation of the fire service and academics in the code development process presumes that the fire service and academics are the most knowledgeable people in the field of building fire protection. Speaking from my own personal experience (as a former fire protection engineer employed by City of San Jose Fire Department), few in the fire service actually have a genuine understanding or interest in building fire protection. Generally speaking, the fire prevention bureau (code enforcement) is the "step-child" of most fire departments. Given this, it is obvious that the Skyscraper Safety Campaign has been misinformed about the fire service's interest in building codes.

Return to past practices?

Chief Dunn's comments regarding the collapse of the World Trade Center towers and the need for changes to the building codes to prevent another such occurrence are interesting from the perspective that Chief Dunn advocates a return to past (pre-World War II) building construction practices. Are high rise buildings constructed in the past actually "safer" buildings from a fire safety standpoint than more modern (post-World War II) high rise buildings?

In particular, Chief Dunn has criticized modern high rise buildings constructed using structural steel framing. If you review the modern construction practices, you will find that high rise office buildings are typically constructed with structural steel framing, while residential buildings are typically constructed using concrete structural framing. Hence, the fire safety statistics for high rise office buildings are of particular interest. Statistics on fire fatalities in high rise office buildings published by the National Fire Protection Association for the 14-year period between 1985 and 1998 are as follows:

U.S. Office Building Fire Fatalities

1985	1	1992	1
1986	1	1993	0
1987	4	1994	0
1988	0	1995	0
1989	0	1996	0
1990	0	1997	0
1991	0	1998	0

Total: 7

These statistics are not only for high rise office buildings in New York City, Chicago or Los Angeles, but are for every high rise office building in the United States. These statistics are also not only for sprinklered high rise buildings, but for both sprinklered and non-sprinklered high rise buildings. To put these statistics in perspective, it is estimated that roughly 75 people in the United States die as a result of being struck by lightning each year. In other words, 10 times as many Americans die as a result of being struck by lightning each year as the total number of Americans who died as a result of fire in high rise office buildings in the 14-year period between 1985 and 1998. Are modern high rise office buildings really "dangerous" buildings?

Not only do the NFPA statistics not support Chief Dunn's assertions about modern steel-framed high rise buildings, but information provided in the executive summary of the FEMAstudy on the collapse of the World Trade Center towers also contradicts Chief Dunn. The executive summary of the FEMA report states "The collapse of these structures [referring to Buildings WTC 5 and WTC 7 in the World Trade Center complex] is particularly significant in that, prior to these events, no protected steel-frame structure, the most common form of large commercial construction in the United States, had ever experienced a fire-induced collapse." An interesting fact considering Chief Dunn's comments regarding the "dangers" of modern (post-WW II) steel-framed high rise buildings.

Although the fire record of modern steel-framed high rise buildings is nearly perfect, let's examine the premise that steel-framed high rise buildings could be made even "safer" by incorporating archaic methods of construction, such as the use of masonry and plaster as a means of providing fireproofing for the structural frame and enclosing stairs and elevator hoistways. Although the premise seems logical, a close examination of many older high rise buildings shows that the masonry used to provide fire protection is not brick or concrete masonry units (CMU), but is often hollow clay tile. In many cases, the combination of hollow clay tile and plaster results in fire resistance ratings for columns and beams of 1 hour or less, not the 3 or 4 hour fire resistance ratings anticipated by Chief Dunn. In some older high rise buildings, clay tile units are used as forms to create concrete joist floor construction similar to "pan-joist" concrete floor construction. Although the floors may have a total thickness of 8 inches (including the thickness of the clay tile forms), the actual thickness of the concrete used in the floor construction is far less. While there is a perception that pre-World War II steel-framed high rise buildings are more fire resistive than more modern steel-framed high rise

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building, this is, in fact, not necessarily the case.

Finally, would substituting masonry stair and elevator hoistway enclosures for gypsum wallboard enclosures in the World Trade Center towers have made any difference on the morning of September 11? Typically, 8-inch-thick concrete masonry units are required to achieve a 2 or 3 hour wall fire resistance ratings. Is 8-inch-thick concrete masonry wall construction capable of absorbing a blow from a 274,000-pound aircraft traveling at a speed of 490 miles per hour and still remaining intact? You don't have to be a structural engineer to answer that question. Even if the stair and elevator enclosures had been masonry, the enclosures would have been sheared off at the floors of impact and the building occupants above the impact point would have been trapped. Smokeproof enclosures, regardless of whether the enclosures were constructed of gypsum wallboard or masonry, would have suffered the same fate.

The NFPA statistics on fire fatalities in high rise office buildings tell us clearly that high rise office buildings are not dangerous buildings, regardless of whether the buildings are 10 stories or 100 stories in height. Incorporating Chief Dunn's recommendations into the construction of World Trade Center towers would likely have had little impact on the results of the attack of the World Trade Center towers. However, the adoption of these recommendations would certainly have a major impact on cost of constructing high rise buildings. Increasing the cost of constructing high rise buildings in the name of fire safety, without actually increasing the level of safety provided in these buildings, is foolishness. The events of September 11 were tragic, but adopting new more restrictive, but unnecessary, code requirements will simply compound the tragedy. □

About the Author

Richard Schulte is a 1976 graduate of the fire protection engineering program at the Illinois Institute of Technology. His experience includes work with the Insurance Services Office of Illinois, the Joint Commission on the Accreditation of Healthcare Organizations, Building Officials and Code Administrators, International, Grinnell Fire Protection Systems Company and Schirmer Engineering Corporation. Mr. Schulte formed Schulte & Associates in 1988. His consulting experience includes work on the Sears Tower, the Minneapolis Convention Center, the Philadelphia Convention Center, Milwaukee Center, New Orleans Center and the New Orleans Distribution Center. Mr. Schulte has also acted as an expert witness in the litigation involving the fire at the New Orleans Distribution Center. Mr. Schulte can be contacted by sending email to rschulte@plumbingengineer.com.