Tall Building Fire Safety — Post 9/11

Joe Zicherman

Fire safety is a most crucial issue associated with tall building design and technology. The importance of fire safety issues has been acknowledged by The Council on Tall Buildings and Urban Habitat (CTBUH) in a number of ways. One of these has been through the periodic preparation of monographs on fire safety, the latest of which was published in 1992 (Zicherman, 1992).

However, nowhere in that 1992 monograph -which includes 15 chapters on diverse subjects, which include amongst others smoke control, fire service operations and discussions of evacuation & human behavior issues - does the text address emergency response under extreme conditions or mitigation of problems posed by acts of terrorism.

Now, in 2003 we may ask ourselves “why are we so surprised at what transpired on 9/11 and the impact of that incident?” One reason that is clear to this author is that in the early 1990’s terrorist assaults of the magnitudes we have seen in the last decade in Oklahoma City, Nigeria and most recently at the World Trade Center were not considered foreseeable by the majority of the community whose job it was to assess safety levels in such buildings. Certainly, some can argue that the signs were there, beginning with the destruction of buildings in Lebanon and with the initial bombing attempt at WTC in 1993. However, hindsight is always 20:20.

1 Since 9/11 a CTBUH task group has prepared two handbooks, “Building Safety Assessment Guidebook” and “Building Safety Enhancement Guidebook” (CTBUH, 2002), for use by building owners and managers that provide enhanced emergency assessment information and methodologies.
Currently, we do know that the rules and the playing field have changed in terms of safety issues and tall buildings. Now we are beginning to apply a new set of rules to address emergency response issues for both existing and new building designs. In the fire safety community we will be challenged in particular to address access and evacuation issues for existing buildings designed with long, relatively safe histories until the onset of the class of incidents listed above.

It is the objective of this paper to address evacuation issues under extreme conditions, which are a component of this problem area.

**Background**

Looking back at watershed events, a series of fire incidents occurred through the 1970’s and early 1980’s that suggested problems with evacuation designs and facilities in complex tall buildings. While none of these led to losses of life that approach those created by terrorist attacks since then, unexpected substandard performance of exiting facilities has led to an awareness that increased vigilance is important not just in building design but in pre-fire planning and building management and administration.

High profile examples of these can be found in the cases of the MGM Grand fire in Las Vegas in 1980 (Klem, 1980) and the DuPont Plaza fire in San Juan in 1986 (Bryan, 1986). In both cases, life losses occurred remote from the fire locations and in both cases rescuers attempted helicopter evacuations when conventional means of egress proved inadequate. Less well known are other incidents where fire department access became limited and occupants of tall buildings were trapped due to blockages of stairways and other means of egress. These are described in articles by Isner (1988) and Lathrop (1976).

By definition it is this author’s opinion that when events occur, which result in [such] breakdowns in the emergency exiting facilities mandated for such buildings, then those designs are inadequate. In fairness to the tall buildings community, increased vigilance led, after those incidents of the late 1970’s and early 1980’s to improved levels of fire safety in such buildings until the community was confronted by the large-scale events beginning in the USA with the Oklahoma City bombing.

Looking prospectively, new tall building designs will doubtless encompass new structural designs and arrangements of features for emergency exiting so that these are isolated from one another. Survivability of facilities, not considered heretofore will become part of the design process. However, for existing buildings there must be total reliance on existing exiting facilities and ways to complement these exist as well. These complementary alternatives are available in the form of unconventional exiting systems which are being either re-examined by potential users or examined for the first time. Some are also just now being developed in response to the realities of the changing political landscape.

Before the September 11, 2001 terrorist attack in New York City, the World Trade Center had already withstood a number of insults, including two fires in 1975 (Lathrop, 1976) and a terrorist bombing in 1993. Those incidents led to perhaps the most intensive fire safety planning of any high rise building worldwide and given the nature and extent of the insult which the towers absorbed, it can be argued convincingly that building occupants below the impact floors - while exposed to grave conditions - evacuated effectively and in an orderly fashion. What was not foreseen in the preparations made were conditions developing above incident floors which became so severe that building occupants there had no means of escape and emergency access facilities. They exist currently in the three formats listed below and each has particular strengths and weaknesses:

- Lowering Devices
- Chutes and Slides
- Airfoils

One reason that discussion of these proposed evacuation methods has become relevant, are suggestions that deployment of some of these devices and systems could
have helped on 9/11 at the WTC. It is up to the reader to consider whether, had they been available to occupants of WTC floors above the aircraft impact zones, their presence might have led to the safe escape of some of the people trapped there?

To date unconventional means of egress have not been included in design processes, emergency planning or regulatory reviews for tall buildings in the U.S. Overseas, various systems are available and have been deployed for some years. Certain of these systems however, are not unknown in the US where evacuation chutes and slides are addressed – albeit to a limited extent - in the NFPA 101 “Life Safety Code”. ²

The common feature of all of these systems is the necessity to address dissipation of kinetic energy generated when a body – in this case in the form of an evacuee – moves from a high elevation to a lower one. In all cases, the systems designed for unconventional evacuation account for dissipation of that kinetic energy in one way or another, be it by reducing descent speed – as through use of friction and reduction of velocity when descending in tube like devices, use of an air resistance with some of the descending devices and air-foils as with parachutes and finally use of friction and counterweights with some of the older pulley based devices.

Discussion

There are numerous important issues that need to be addressed when assessing the applicability of these alternative existing methods in emergency situations. These include planning and risk issues, human factors related issues and regulatory issues, amongst others.

Planning and Risk Issues

Critics of alternative means of exiting raise a number of important issues when discussions of this subject take place. Most of these have merit and warrant careful consideration. At the head of the list, this author believes, is how we perceive emergency planning – including the economic impact of such systems - in the future.

We can, as noted earlier, point to a certain history of failures of emergency response systems in tall buildings in previous years – not just in major fires – but also in serious fires which involved fewer people. As such, we can point to issues of preparation and performance by building managers, security guards and planners that contributed to the outcome of these situations.

If we add another layer of cost – for the purchase, training and maintenance of this new class of exiting devices – what will this do to tall buildings safety budgets? Might we do better spending these resources on existing, state of the art systems? This is an important issue.

What about the final levels of safety and performance attained? What is the threshold of acceptable performance for these systems? As with conventional

² These sorts of systems have been deployed for some years for rapid evacuation of industrial facilities such as oil cracking towers or aircraft control towers on military bases.
Exiting systems, we would hope and strive for 100% success in evacuation using the unconventional systems. However extraneous and uncontrollable factors such as the nature and impact of the emergency on a given structure, winds, nature of the evacuating population, etc., all will have an impact on levels of success attained. At the end of the day, if we can save 80% of those exposed to what would have been certain death – an outcome that would have been welcomed on 9/11 - one would also have to assume that representatives of the other 20% would call for damages and file lawsuits. Thus, expectations for success and conversely liability issues associated with any failures need to be addressed before such systems are deployed for use.

**Human Factors and Human Behavior**

In spite of demonstrations of the technical feasibility of these systems, this author does not believe that human factor issues associated with use of these devices and evacuation approaches have been adequately addressed to date. A reasonable test in this case would involve considering and somehow testing – and perhaps demonstrating the likelihood that a population encompassing the ages and physical abilities of those that use existing tall buildings today, would be able and/or agreeable to using these methods. If not, how do we address this situation?

More conventional questions of human behavior can be considered baselines in considering application of these unconventional exiting approaches. A telling, anecdotal example of human behavior issues – that touches on behavior of both occupants and first responders can be found in “Rescuing the Occupants”, an article that discusses the difficulties encountered during a high rise fire in January 1988 at 135 East 50 St. in New York City (Isner, 1988).

More conventional treatments about how people move and respond to fires during emergencies in tall buildings are available in Chapters 12-14 of the most recent SFPE handbook (Bryan, 2002).

Emphasis on issues related to human behavior in Hotels – many of which are tall buildings – as well as evacuations procedures in other tall buildings have also been addressed by Bryan and Pauls in the earlier SFPE handbook and in the NFPA Fire Journal including references from 1982 and 1983. The same issues have been addressed in detail in reports from Europe including those which provide descriptions of times required for high rise evacuations during drills (Kendik, 1983).

**Regulatory Issues**

**Codes and Standards**

As with any life-safety measure, regulatory issues to address expanded use of emergency building evacuation systems are significant. Of primary importance and as suggested previously, it should be acknowledged that application and use of unconventional existing methods to new and existing building designs must not supercede or lead to downgrading of the design, maintenance and training of conventional pressurized stair ways in emergencies. As such it must be acknowledged that controlled descent devices are only intended as a last resort for use when conventional exits are no longer serviceable.

In addition, expansions of existing high rise fire safety regulations – as in the model codes- to address unconventional exiting must define and include a new set of expectations for conditions and risks under which these systems may be used and these must be developed by a consensus process. These regulations must also address the significantly different expectations for exposures to risk in these situations when compared to expectations under conventional emergency exiting strategies.

Precedent for use and application of unconventional exiting approaches already exists in regulations. The NFPA 101 Life Safety Code includes examples which can be found in Sections 7.2 as well as Chapters 11 and 40. It can be anticipated that similar text will be developed for other model codes in the future and standards addressing component performance can be readily developed to supplement existing ad hoc approaches being applied by groups such as Underwriters Laboratories to existing systems.
Listing Issues

References in existing regulations for unconventional exiting components already exist which carry the familiar reference to “approved systems,” a term which suggests third party review and possible listing of these systems and/or their components.

Some of the components and devices described above are already listed by Underwriters Laboratories and are subject to the ongoing UL inspection programs to maintain those listings. UL’s description of the product category “Controlled Descent Devices” [EIXI] for example describes these items as, “reusable Controlled Descent Devices intended primarily for controlled lowering of persons from various heights during emergency situations.”

Most important though, that description notes that the devices have been evaluated for mechanical operation only and [they] are not intended for use as a means of egress during fire situations.

The latter disclaimer from UL is consistent with the absence of ANSI, NFPA or UL standard protocols providing guidance for the systematic evaluation of unconventional evacuation systems. Factors needing to be addressed in the development of such standards should include measures of overall performance, human factors aspects and safety of these systems. Third party evaluations conducted to date address specific properties such as descent speed, capacity and durability-resistance to corrosion. However, rating and qualifying the performance of these systems under emergency conditions needs to be addressed and realistic expectations for their effectiveness should be established if they are to be accepted for widespread use.

Emergency Exiting Technology Review

A survey of specific, available systems and devices follows for those unfamiliar with the concept being discussed here. It is recommended that readers interested in obtaining additional information review web site data.
how their braking is controlled separates the various systems available. Of interest is the fact that one of the older lowering device concepts available; the Oriro Decenter has been in use in Japan, for over 30 years with over 100,000 units in the field. This system includes a friction-based braking system with a maximum descent rate of approximately 3 feet per second. Designed and manufactured in Japan, it operates like a controlled pulley, with woven cotton harnesses at each end of a steel rescue cable that passes through the device. In the event of an emergency, an evacuee puts on a harness and steps away from the side of building and is lowered to the ground. The manufacturer reports that the device has been used to help evacuate victims during fire incidents in Asia, although there are no statistics available describing the number of times it has been used and outcomes of use during emergencies. The Decenter is listed by Underwrites Laboratories, and it has been certified for use by the Japanese government (www.evacuation.net).

A device similar to the Decenter and manufactured in the U.S. is the BEST Rescue System (BRS). The main difference between this and the Oriro system is in the type of harness used to lower an evacuee to safety. Instead of cotton harnesses, the BRS unit employs two fire resistant suits. These suits extend above an evacuee’s head and attaches to the pulley above. The suit’s design is intended to reduce the evacuee’s exposure to heat, and to possibly ease their anxiety by not allowing them to see the ground below. Commercially available since 1999, approximately 200 are reported to been sold. www.bestrescue.com

The SafirRosetti ResQline system is the newest and represents perhaps the most sophisticated lowering approach available. Developed in Israel, this system differs from the preceding products in that it doesn’t use a centrifugal friction brake to control descent speed. Rather, an air turbine system is employed to dissipate kinetic energy generated during lowering. To use the ResQline system, in the event of an emergency, an evacuee puts on a harness which is attached to a cartridge which includes a spool of pre-cut cable. After attaching the spool to the axle of the turbine, the evacuee steps away from the building, and descends as the turbine spins to control their descent. Descend speeds can be as fast as 15 feet per second. In addition to higher, safe rates of descent, the ResQline system includes has been designed for use on multiple floors and demonstrated successfully evacuating disabled personnel in high rise applications. In addition portable versions of this unit are available and have been deployed by fire services.

According to recent information ResQline systems have already been installed in small number of high-rise buildings in the City of New York as well as in one high rise in Tel-Aviv. Bezeq On Line, a subsidiary of the largest telecommunication company in Israel, has installed the ResQline solution and has provided all its employees with the ResQline personal safety gear. The U.S government has completed its analysis process and as of January 1, 2003, ResQline will be listed on the GSA schedule. www.ResQline.com.

Chutes and Slides

A second type of alternative evacuation system involves chute and slide devices which typically feature a fabric tube deployed in a variety of ways from evacuation locations which may be as high as up 30 stories above the ground. Use of these chutes requires run-out room to allow for an evacuee to slow down prior to exiting.
The most widely used escape-chute-type device is the Baker Life Chute (BLC), made by Baker Safety Equipment. The Baker Life Chute is composed of a tube of nylon netting attached to 3’ diameter metal rings located at each end. During use, one ring is secured to the structure from which the evacuation is taking place and the other end which has been secured to a fixed object on the ground as part of pre-use deployment. Evacuees escape by sliding down though the tubular net, slowing themselves down as needed by applying outward pressure on the net with their feet and hands. The BLC is reported to be capable of carrying a continuous flow of as many as 30 people at one time. Several models are available and have been demonstrated, including one that can be airlifted to the top of a building during an emergency, and another that can be attached to the bucket of a fire department rescue ladder. The BLC has been commercially available since the mid-1980's, and approximately 40 are reported to be in use today in the U.S., Europe, and Japan. Roughly 80% of the units sold have been installed for use in air traffic control towers and NASA tested and approved the BLC for use on its shuttle platforms, though none are currently used in that specific application. A number of other BLC systems have been sold for rapid evacuation of facilities such as oil cracking towers and other high industrial platforms where emergency conditions can develop rapidly. www.lifechute.com.

Another chute system, developed recently by AES in Israel is the Advanced Modular Evacuation System (AMES) made. This system is based on an enclosed chute made of fire resistant material that is automatically deployed from a portal inside a building. During a fire, the fire alarm triggers automatic chute deployment to a pre-designated location either on the ground or at an adjacent building. Evacuees slide down the chute to safety, with flat sections in the slide serving to control descent speed, allowing the evacuee to be deposited onto a cushioned landing pad. After evacuees have been safely evacuated, rescue personnel can also enter the building using a winch system built into the chute hardware. www.aes-systems.com.
**Parachute Systems**

The last category under discussion is the parachute system. These present the greatest challenge for safe use in that even trained personnel acknowledge that use of parachutes in urban environments is accompanied with major safety issues.

The Executive Chute is made in the US by the Destiny Aircraft Corporation. This chute is deployed by a static line, which requires the evacuee to secure the ripcord to a fixed object within the building before jumping. This is intended to minimize operator error and to allow the parachute to deploy even in the event that the evacuee loses consciousness during free fall. Currently 200 Executive Chutes have reportedly been sold although there have not been any documented cases of this system having been used in a highrise emergencies. Private individuals have purchased the majority of these devices. Executivechute.com.

The Evacuchute, made by Emergency Evacuation Systems is another parachute evacuation system currently available. The Evacuchute employs a cone-shaped canopy design to provide forward movement away from an affected building, to give the evacuee steering capability, and to give added stability. Two models are available, one designed for civilian use, and the other is designed for rescue professionals. The civilian chute is not fire-resistant, while the rescue chute has a fire-resistant harness. These devices have been commercially available since July of 2002, though none are yet reported to be in use (Evacuchute.com).

**Summary**

While the technical and engineering aspects of the available controlled descent systems appear reasonable, their application to large structures represents an untried concept especially when human behavior must be taken into account. It is the author’s opinion that these unconventional exiting systems will become part of the accepted tools available for tall building emergency response. This may take the form of use by first responders only in portable form which is progressing already. More comprehensive solutions may prove acceptable to regulators, and building designers and owners with increased familiarity and research.

There is obviously a lot work to be done and development of a sufficient knowledge base as well as well defined codes and standards to address the performance of these systems presents a formidable challenge.

**References**


**About the Author**

Joe Zicherman is a fire scientist with Fire Cause Analysis of Point Richmond, California. He received his Ph.D. degree from the University of California in 1978, and his work in the fire safety community has included editing the last “tall building fire safety monograph” published by CTBUH in the 1990s. Joe’s consulting work involves a mix of fire safety design and research work, investigative work and participation in fire safety related forensic activities.