Rethinking high-rise egress, top to bottom

In the wake of Sept. 11, designers devise more efficient ways to get building occupants out—and first responders in.

By Scott Siddens, Senior Editor -- Consulting-Specifying Engineer, 1/1/2008 1:00:00 AM

Good egress design was fairly simple when high-rises first became popular: Provide enough stairways and doors for people to get out, and designers were set. Not true anymore—Sept. 11 changed all that.

Now engineers must think about reinforced stairways, evacuation by elevator, and mass notification systems.

Engineers can't talk about fire and life safety in high-rises these days without first addressing the issues of Sept. 11 and the subsequent report from Gaithersburg, Md.-based National Institute of Standards and Technology (NIST), which analyzes disasters and provides guidelines for the future.

NIST's final report, released in April 2005, on the World Trade Center (WTC) disaster, “Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Final Report of the National Construction Safety Team on the Collapses of the World Trade Center Tower,” presented a list of 30 broad recommendations. Many of these recommendations involve structural issues, given the nature of the how the WTC towers collapsed, but some are germane to egress, evacuation, and mass notification:

- Improve active fire protection systems to provide performance, reliability, and redundancy. Designers need to develop advanced fire alarms and communications systems that provide continuous, reliable, and accurate information on life safety conditions.
- Improve the evacuation process to facilitate safe and rapid egress; methods for ensuring clear and timely emergency communications to occupants; and better occupant preparedness for evacuation during emergencies.

Two recommendations in particular have to do with egress: designing tall buildings to accommodate a total building evacuation of occupants if necessary, and maximizing the remoteness of egress components such as stairways and elevators without unduly increasing travel distances. In the original WTC towers, stairways were in close proximity, with the result that all egress stairways were destroyed by a single plane impact at each tower.

Tallest buildings now safer

Just as you cannot avoid a discussion of the NIST report, engineers also must look at the systems that are going into the new structures on the WTC site. Because of the unprecedented expense and amount of life safety design at the new site, no other structures can compare, and the site may well set many trends for the future. These are the most advanced life safety design schemes to date, and are likely the safest buildings in North America.

For example, in 7 WTC, a structure that replaced one of the buildings destroyed on Sept. 11, Skidmore, Owings & Merrill LLP (SOM), New York, included a core encased in reinforced cast-in-place concrete shear walls. The core has two 72-in. stairwells, a fire- and smoke-resistant refuge area on each floor, two-hour fire-rated doors, pressurized stair shafts, extra space at each stair landing for rescue assistance, and lighting systems with three power sources (normal, emergency, battery backup). Phosphorescent paint strips were applied throughout the core to improve visibility. Also, the stairwell doors are situated so that they open to the descending side in the direction of occupants descending the stairs to facilitate traffic flow. Proximity egress signs and marking systems near the stairwell doors were placed less than 2 ft. above the floor to maximize visibility.

The structural and life-safety features of 7 WTC go beyond current New York City building code requirements, parallel to many of the recommendations made by NIST, and in the design phase, anticipated many of the study's recommendations.

But “robust, hardened cores aren't cheap,” said Carl Galioto, FAIA, technical architecture partner, SOM. “Wider stairs alone decrease the amount of leasable building space by 1% to 2% at 7 WTC. Hardened cores are not appropriate for every building,” he said.

In short, most high-rise owners in the United States will not go to this same expense.

“Teams need to assess the safety risk factors, such as location, building function, and height, and then apply these strategies with discretion,” Galioto said. He suggested that jurisdictions encourage developers to include hardened cores and safety areas by deducting these spaces from the zoning areas so they can build more leasable area.

The fire and life safety designs for WTC Tower 1, or Freedom Tower, the centerpiece of the new WTC complex under construction in lower Manhattan, take it even further than 7 WTC in moving building occupants to safety and providing first responders with access.

New elevator models

“The emergency access core [in 1 WTC, or the Freedom Tower] contains the service elevators of the building, with one of the service elevators as a swing car,” Galioto said. “The swing car, under normal operation, could be used as a service car but has a second entrance within the car that is used by firefighters only. The elevator is similar to a firefighter's lift in the United Kingdom.

“In the United Kingdom, firefighters take small firefighter lifts up in high-rise buildings to two floors below a fire incident. They exit the elevator and go directly into a vestibule and then into a stair, where they walk up the remaining two floors to the incident floor,” Galioto said.

“We took the concept of an emergency response elevator and we used a service car to achieve it,” Galioto said. The elevator is a 4,000-lb. car with water-resistant equipment. The elevator is in its own hoistway, isolated from the other elevators by a fire-rated wall. The hoistway is pressurized so that in emergency mode, like a pressurized stair, it prevents smoke intrusion into the hoistway. The door used by emergency responders opens onto a pressurized vestibule and then to a stair dedicated through all the office floors that is only for use by emergency responders. It is not counted in the egress calculations and is purely for use by emergency responders. Responders get off several floors below an incident, go into a vestibule, walk up the stairs and when they arrive at the incident floor, they are in another fire-rated, pressurized enclosure and can go out onto the floor.

“Within the vestibule, we have included a standpipe and hose rack for use by firefighters,” Galioto said. “That is an enhancement well beyond what we have at 7 WTC and well beyond anything else in North America. It's close to the proposed European code for high-rise buildings.

But it does go one step further. There is a dedicated stair, whereas the proposed European code allows one to use one of the required exit stairs.

“We're using separate voluntary stairs not counted in terms of the egress calculation,” Galioto said. “The purpose is to allow the occupants of the building to come down the two stairs and move in a continuous flow without having a counterflow by emergency responders. It allows firefighters or any other emergency responders to walk up without being impeded by occupants egressing.”

Under some scenarios, Galioto explained, the other elevators can be used for evacuation. The other three are 6,000-lb. elevator cars, and can be used for an evacuation supervised by emergency responders.

“If firefighters found a large group of people who were injured or disabled, they could bring them down in the 6,000-lb. cars,” Galioto said. Designers separated the service vestibule from the office space by a series of doors that provide smoke separation. The elevator service lobby will be pressurized and use water-resistant equipment.

“It is not intended for building occupants to use those elevators to exit the building,” Galioto said. “The standard approach still exists that building occupants evacuate a floor of the building using stairs. We don't want to reeducate the public for this building.”

This touches on a point that is being explored by the code-making bodies and a major paradigm shift regarding elevator use for evacuation of occupants. Building occupants have traditionally been instructed not to use elevators in fire and similar emergencies.

“Use of elevators [for evacuation] has been studied for a number of years,” said Doug Evans, PE, fire protection engineer with Clark County, Nev. “We are moving more and more in that direction. Those who understand agree that elevators can provide a benefit for evacuating tall buildings. It hasn't gotten in the codes yet.”

“For tall buildings, people are thinking of using elevators now more than they did in the past,” said Jeffrey Tubbs, PE, associate principal with Arup Fire's Boston office. “It can be pretty arduous to walk down 100 or more stories of a building, so that's a pretty compelling argument to use elevator evacuation.”

Tubbs suggests two different ways that people are looking at the use of elevators. One is using elevators to take occupants directly off the floor. The other is for occupants to walk down a number of floors and use the elevators from there. “It gets into the whole discussion of refuge floors,” he said.

“We are working on a very tall building in Seoul, Korea, which is 1,800 ft tall. It is a multi-use building where there is retail, office space, restaurants, hotel, and observation deck and bar at the top of the building,” Galioto said. “So there's a whole stack of different uses. Given the height—close to 120 stories—we decided to compartmentalize the building vertically because it is unrealistic to expect people to walk down 120 floors.”

The designers came up with the concept of transitional refuge areas. Transitional refuge areas are fire-rated, pressurized spaces at various locations in super-tall high-rises where occupants can briefly rest in a protected environment before continuing their evacuation by stair or protected elevator.

But will all these robust designs become the conventional approach? Most buildings won't be designed to the specifications of WTC Tower 1, but the designs may well have an effect on building elsewhere.

“We do have other clients who are asking for these things,” Galioto said. “We are looking into a variation for other high-rise buildings—not to have the additional stair but to look toward the proposals that exist in Europe, and have the protected elevator open onto a vestibule that adjoins one of the primary exit stairs of the building. So I think that's the more standard case if we're considering a 50- or 60-story building.”

Stairways to safety

Another way in which 7 WTC went beyond the code minimums was stair width—with 72-in. wide stairs. “There's quite a bit of research which would support the notion that stairs, as they currently exist, are too narrow,” Galioto said. “We've found that the standard 44-in. wide stairs are just too narrow to allow two people to walk side by side. Most expert studies support the fact that instead of 44 in., the stairs should be in the range of 60 to 66 in. wide. That will allow two people to walk side by side comfortably, holding onto a handrail. That's a measure that we've taken in several buildings—the designs for several buildings not yet competed.”

The 2006 editions of NFPA 101, Life Safety Code, and NFPA 5000, Building Construction and Safety Code, already include text requiring 56-in. minimum stair widths for those stairs serving 2,000 or more occupants. This provision typically applies to buildings of 14 or more stories and serves to facilitate occupant egress and counterflow of emergency responders traveling up the stairs.

Another issue being addressed by recent code revisions is the required number of stairways in a high-rise building. “The 2007 Supplement to the International Building Code requires three stairways if the building is more than 420 ft. tall. And that's the only parameter,” said Raymond Grill, PE, principal at Arup and the leader of Arup Fire in the Americas. “There are many cases where three stairways are excessive and many are pushing to rescind the requirement.”

In addition, awareness of exits has become a major concern, especially horizontal transfer passageways from one staircase to another. It is proposed for the new codes that new provisions require that horizontal components of egress paths be marked by approved exit or directional signs.

Evolving codes

This brings us full circle back to the NIST study. The study is a point of departure in discussing ingress and egress system for tall buildings because of its profound effect on recent proposals and changes to the national building codes.

Jeffrey Tubbs puts it succinctly: “From a broader perspective, people are waiting to see where the codes are going to head. There have been a number of initiatives that have gone forward. For instance, the NFPA high-rise committee has been looking at recommendations and contemplating changes to codes, and the International Codes Council Code Technology Committee has a number of initiatives as well.”

The focus here has been on egress systems, but there is much more ground left to cover on all types of fire protection systems for tall buildings.

Total building evacuation

One recommendation from the National Institute of Standards and Technology (NIST) Sept. 11 study called for tall buildings to be designed to accommodate timely full-building evacuation. The codes currently permit total, phased, and partial evacuation, as well as defend-in-place methods. For protecting occupants from a fire event, owners and officials most likely will continue to use current code requirements.

“The 2006 International Building Code specifically requires that you evacuate the floor of origin, the floor above, and the floor below the event,” said Doug Evans, PE, fire protection engineer with Clark County, Nev. “And that's been standard for years. Since the stairs aren't designed to accommodate the entire occupant load, you can't really do anything more than that anyway.”

“You have to have a method for evacuating an entire building but it would be a phased type of system, depending on the height of the building,” said Jeffrey Tubbs, PE, associate principal with Arup Fire's Boston office. “Many incidents will be somewhat localized, thus the code mandates evacuating the floors that are most affected first, so that people in the most danger can evacuate to protected areas. However, there are events that would warrant evacuating the entire building. Evacuating the entire building can be a timely proposition. Elevators, used along with stairs, can help to reduce the overall evacuation times.”

“What we're trying to struggle with is what is the right phasing, what is the right sequencing to fully evacuate a building within a given event period. With buildings becoming taller and taller, it's not feasible to assume that occupants in a 100-story- plus building are going to be able to get into the stairwells and get out immediately,” said Brian Meacham, PE, formerly of Arup and now associate professor of fire protection engineering, Worcester Polytechnic Institute, Worcester, Mass. “You know you're going to have to do something different, either provide different levels of safety refuge or a phased evacuation by using elevators for part of the evacuation as well as the stairwells.”

Communication and notification

Efficient notification systems have been used for tall buildings for quite some time. “In a high-rise building, the codes typically require voice communication with general and selective paging on each floor. This allows broadcasting live voice messages selectively to floors or throughout the building,” said Jeffrey Tubbs, PE, associate principal with Arup Fire's Boston office. “In terms of notification for tall buildings, this capability has been included in high-rise design since the 1970s.”

But while the communication systems for building occupants hasn't changed much, the technologies to aid emergency responders has. “It is essential for emergency responders to have information,” said Carl Galioto, FAIA, technical architecture partner, Skidmore, Owings & Merrill LLP, New York. “Having cameras in stairways and key vestibules is very important so that from the security center or fire command center the person who is in command of emergency response operations can see what's actually going on in all these particular spaces. In 7 World Trade Center (WTC) we have numerous cameras in the stairs and various vestibules. One WTC will have cameras at all the service lobbies and stairs, so it will give more information to firefighters. There also is some new technology with regard to communication for emergency responders using coaxial cable so that their wireless communications systems function.”

“What we did in the last cycle in the 2007 edition of NFPA 72, National Fire Alarm Code, was to add an annex on mass notification to provide guidance for design and implementation of mass notification systems,” said Raymond Grill, PE, principal at Arup and the leader of Arup Fire in the Americas. “We also modified the body of the code to allow fire alarm emergency communication systems also to be used as mass notification systems so that they could actually serve dual purposes.”