Chapter 5: Performance of Fire Protection and Life Safety Systems

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Introduction

The AEI Task Committee for the Study of the Aftermath of Hurricane Katrina surveyed a limited number of facilities in New Orleans to evaluate the performance of the architectural engineering systems during and after the storm. The facilities included East Jefferson General Hospital, Children's Hospital, the University of New Orleans, East Haven Care and Rehabilitation Center, and Lafon Home Nursing Facility. The task committee included representatives from a wide range of engineering disciplines with the intent of providing a complete evaluation of building performance. This chapter focuses on the impact on fire protection and life safety systems in healthcare facilities, eldercare facilities, and community shelters before, during, and after the hurricane. The considerations of fire hazard in the continued operations of a critical facility following a hurricane are essential, as shown in Figure 5.1. The impact of damage created by the hurricane and subsequent flooding as well as the effects of actions taken by building operators and occupants are considered. Issues that may be considered in developing fire protection requirements for shelters were identified based their impact on fire protection and life safety.

Figure 5.1: Example of fire hazard following a hurricane (FEMA P-757, 2009)

Damage Observations

The condition and availability of buildings, including the structure, services, and systems, changed significantly during the course of the hurricane. Changes were caused by the storm, the actions of building owners and operators in preparation for or in response to the storm, and the actions of people sheltering in the building. A general discussion of each of these elements is provided below.

Hurricane

Sustained, high-speed winds are characteristic of hurricanes, but hurricanes may also generate tornadoes, push significant quantities of water ashore (storm surge), or cause torrential rains that result in flooding. Flooding may also result when flood controls fail, as occurred in New Orleans following Hurricane Katrina. These phenomena can result in loss of electrical power, municipal water supplies, or communication systems (landline and cellular); flooding of building floors; and damage to the building envelope. The impact of the hurricane on utilities and the building structure are discussed throughout the other chapters of this report.

During Hurricane Katrina, electrical power and municipal water supplies were unavailable, and the facilities were forced to rely on backup systems. The hospitals were each equipped with generators that provided backup power to the buildings used to provide shelter. The University of New Orleans had backup power capability, but it did not provide service to all buildings. A dormitory used by local residents as a shelter did not have power because the university did not intend to use it as a shelter. The two nursing homes surveyed had backup power generators, but they were evacuated before the storm and did not use the generators.

East Jefferson General Hospital had a deep well and a 500-gallons-per-minute (gpm) pump that provided a backup potable water supply. The backup supply was cross-connected to the sprinkler system but isolated from it by manual valves. The hospital had a response plan in place to manually respond to fire alarms and, in the event the fire could not be extinguished, to open the cross-connect valves and pressurize the sprinkler system.

Building operators interviewed during the survey indicated that communication systems were not reliable after the hurricane and that the presence of flood waters around the facilities would have significantly affected the response of municipal emergency services. However, some of the operators indicated that emergency service units had relocated to their facilities before the storm and were available to respond. For East Jefferson General Hospital, relocating the emergency services to their facility was part of a prearranged plan between the services and the hospital.

Facility and Staff Responses

In hurricane prone areas, building owners and operators formulate response plans to mitigate the damage to the building and its occupants. The response plans identify the actions required before, during, and after a storm. If the intention is to shutdown the facility before a storm hits the area, the plan may identify evacuation criteria and shutdown procedures for equipment and systems. If the intention is to occupy the facility but cease operation, the plan may identify who is permitted to use the facility as a shelter, procedures for securing specific systems or equipment not needed, modifications to building security to maintain access control, and a number of other actions.

Building operators interviewed during the recent Katrina survey identified a number of specific actions that were taken in response to the storm. Facilities that evacuated before and after the storm as well as a facility that was not evacuated were represented. Two of the facilities were hospitals that served as shelters during the storm and faced unique challenges because of the vulnerable condition of occupants prior to the storm. The other facility, the University of New Orleans, was evacuated prior to the storm but was used by local residents as a shelter after the storm.

Well patients were discharged from East Jefferson General Hospital before the storm to reduce the number of occupants. In addition, isolated buildings located on the hospital campus were evacuated and secured because they were not connected to the backup power and water systems. This reduced the number of people requiring care during the storm and concentrated those using the hospital as a shelter into fewer locations.

To control access to the building, East Jefferson General Hospital chained and locked exit doors that discharged outside to prevent people from gaining access. The plan called for staff to report to and open assigned doors if it was necessary to exit the building. Based on information provided at all of the sites, landline and cellular communications were not reliable in the days after the storm. Thus, staff depended on handheld radios for communication.

Building Occupants

In addition to the conditions created by the storm and the building operators, the actions of building occupants can also have an adverse effect on fire protection and life safety systems. This can include occupying building corridors, using open flames for cooking or heating, and participating in vandalism. In general, the facilities managed by staff during and after the storm limited damage by occupants; however, an instance of cooking on a hot plate resulted in a smoke alarm. The occupants of the university dormitory were not controlled, and the university staff reported significant vandalism.

Current Design Requirements

The current Louisiana building code is based on the International Building Code (IBC)–2003 edition (IBC 2003), which was adopted in December 2005. Although the facilities surveyed were built before the code was adopted, their systems and features were compliant to code requirements.

The facilities surveyed included hospitals and nursing homes, all of which are classified as Group I-2 occupancies by IBC. Some of the key fire protection features required for Group I-2 occupancies include

- provision of smoke barriers to subdivide stories used by patients for sleeping or treatment and other stories with an occupant load of 50 or more into at least two smoke compartments;
- installation of automatic sprinkler protection throughout smoke compartments containing sleeping units; and
- installation of a manual fire alarm system and an automatic fire detection system.

IBC references the National Fire Protection Association (NFPA) installation standards for automatic sprinkler and fire detection systems. NFPA 72, *National Fire Alarm Code* (NFPA 72, 2002), requires fire alarm systems to have a backup power supply capable of running the system for a minimum of 24 hours. This requirement is based on the assumption that the building will be

evacuated during a prolonged outage. If the building is intended for use as an emergency shelter, NFPA 72 indicates that additional secondary power should be required to address a prolonged outage, but it does not provide any specific requirements or guidance.

There are no requirements in NFPA 13, *Standard for the Installation of Automatic Sprinkler Systems* (NFPA 13, 2002), for backup water or power supplies for automatic sprinkler systems. However, IBC requires standby power for electric fire pumps and backup water supplies for new high-rise buildings in specific seismic areas. NFPA 20, *Standard for the Installation of Stationary Fire Pumps for Fire Protection* (NFPA 20, 2003), states that electric fire pumps are only required to have a secondary power supply when the primary power supply is considered unreliable by the authority having jurisdiction. If required, the secondary power supply may be provided by a second utility service, an on-site generator, or a redundant diesel engine-driven fire pump.

FEMA provides additional guidance for facilities intended to be used as shelters (FEMA 361, 2000). It defines community shelters as those designed and constructed to protect large numbers of people from natural disasters (FEMA 361, 2000). A shelter may be intended for use by the public or by specific individuals, such as employees. FEMA distinguishes community shelters, which are intended to provide protection for a relatively short time (less than 36 hours), from recovery shelters, which are intended to provide long-term housing for those whose homes have been damaged or destroyed.

The primary focus of FEMA's guidance on the design and construction of community shelters is structural design and resistance to debris impact to protect people from the effects of high-wind events. A limited discussion of fire protection and life safety requirements is provided, and the need to provide adequate means of egress for the shelter occupant load is identified. FEMA's guidance does not provide any additional requirements for fire protection systems and indicates that these systems will likely be limited to those required for occupancy during normal use.

Similar to FEMA and IBC, other model building codes do not provide additional fire protection or life safety requirements for buildings intended for use as community shelters. The lack of additional requirements appears to be based on the assumption that shelters are only need to provide short-term protection during a high wind event and that the shelter will not be used or required after the wind event has ended.

Discussion

The conditions created by the storm, building operators, and occupants, as discussed above, had a significant impact on the fire protection systems and life safety. The degradation or loss of required fire protection systems and features left occupants more vulnerable to fire emergencies. The effects of the conditions created by the storm and personnel response on key fire protection systems and features are discussed below.

Automatic Sprinkler

Automatic sprinkler systems are installed to suppress fires and, consequently, limit damage to the building and protect building occupants. The availability of an automatic sprinkler system is dependent on the integrity of the distribution piping, the water supply, and if a fire pump is included, the power supply to the fire pump. If the sprinkler system is unavailable, then any fires that occur will burn until they are manually extinguished.

The loss of the municipal water supply causes catastrophic failure because most sprinkler systems do not have an independent water supply. IBC only requires backup water supplies for new high-rise buildings in specific seismic areas. As noted previously, East Jefferson General Hospital had a backup potable water supply that was cross-connected to the sprinkler system. The sprinkler system connection was isolated by a closed valve that had to be manually opened. None of the other facilities had a backup water supply for the automatic sprinkler systems.

Similar to the loss of the municipal water supply, the loss of power to the fire pump would also render the sprinkler system ineffective. The loss of electric power disabled the University of New Orleans' electric fire pump because there was no secondary power source. Children's Hospital also had an electric fire pump, but secondary power was provided by a diesel generator. East Jefferson General Hospital had a 2000 gpm diesel fire pump. The two nursing homes did not have fire pumps. It is important to note that if the secondary power supply was a secondary municipal utility service, the pumps would not have been operational.

Fire Detection and Alarm

Fire detection and alarm systems provide early detection and alarm notification of fires and perform other control functions, such as closing dampers and releasing doors that are held open under normal conditions. The availability of the fire detection and alarm system is dependent on the availability of the power supply. If the fire detection and alarm system is unavailable, fires may not be detected and may not be reported to municipal fire department, and building occupants may not receive alarm notification.

For buildings intended to shelter occupants, the loss of utility power had little impact on the fire alarm systems because they had diesel generators to power these systems. However, as facilities were evacuated, the generators were either not activated or shutdown, and the fire alarm systems were forced to rely on battery backup power, which is only required to operate the system for 24 hours.

Fire Department

The municipal fire department responds to fire alarms, among other things, and if necessary, controls and extinguishes fires. Their ability to respond to an alarm is dependent on several factors:

- Communication systems must be available to notify available personnel of an event.
- Personnel and equipment must be available to respond to an incident.
- Road conditions must permit personnel and equipment to travel to the scene.
- Personnel must have access to the resources required to respond to an incident (for example, public water supplies to fire hydrants or standpipe systems required for firefighting).

Very little specific information was obtained during the surveys about the fire department response. Input was limited to a comment that flooding around the facilities would have made it difficult for the fire department to respond had there been a fire. However, it is apparent how the flooding and loss of key systems would affect the fire department response. First, the loss of communication systems would make it difficult for fire departments to receive alarm notification, either from a fire alarm system or from people. Flooding, as reported, would make it difficult to travel to many areas and impossible to travel to others. The loss of the municipal water supply would also affect the ability of emergency services to respond to fires because water would need

to be supplied by fire department apparatus or obtained from another source, such as a nearby river or pond.

Egress

In the event of a fire, building occupants need a sufficient means of egress so that they can escape buildings or travel to safe areas within buildings. If occupants are unable to exit hazardous areas, they may be exposed to the effects of fire, including smoke, heat, and toxic gases. During Hurricane Katrina, several conditions affected building egress. Several facilities reported flooding in and around buildings, which would have limited occupants' ability to exit had there been a fire. If the flood waters were sufficiently high, it may have been difficult to open exit doors, which could hinder egress. There is also the obvious hazard of exiting a building into flood waters.

An alternative to exiting a building is to egress to a separate area within it. Smoke barriers were provided in the hospitals and nursing homes as required by the International Building Code (IBC). The smoke barriers, which have a minimum 1-hour fire resistance rating, provide limited protection against fire that has spread into adjacent areas. In comparison, the fire resistance rating required for barriers separating adjacent building areas must be at least 2 hours if the barrier is being considered a horizontal exit. The horizontal exit requirement does not necessarily address situations where occupants cannot egress from the adjacent area to a public way.

The exit doors of one of the facilities were chained and locked to limit access to the building. The facility had a plan in place for staff to report to specific doors and unlock them in the event of a fire. Although special locking arrangements are permitted in IBC, this one is not allowed.

The loss of power and the subsequent loss of lighting can affect occupants' ability to locate an exit and egress from a building. This was not an issue in any of the surveyed facilities because all of the facilities had generators to provide backup power. In facilities without a generator this would be an issue for prolonged power outages because emergency lighting systems are only required to operate for 90 minutes.

Summary

Although the damage caused by Hurricane Katrina and the actions of building operators and occupants affected the performance of fire protection and life safety systems, it appeared that these systems operated in accord with the applicable codes and requirements. However, the existing codes and standards do not adequately address fire protection and life safety requirements for emergency shelters. They do not require a secondary water supply for automatic sprinkler systems, and although guidance is provided about the need for secondary power supplies for fire pumps and fire alarm systems, there are no specific requirements for emergency shelters.

Greater redundancy in the fire protection and life safety systems is desirable in facilities intended as community shelters, especially in areas where prolonged loss of municipal water and power supplies are possible. The overall goal should be to maintain the level of fire protection and life safety during emergency conditions to that provided during normal conditions. In light of the performance of systems during and after Hurricane Katrina, code committees should consider the unique needs and challenges of emergency shelters and develop appropriate requirements for fire protection systems. This may include provisions for secondary water supplies, secondary power supplies for fire pumps, fire alarm systems that are not dependent on utility power, and fire rated

separations to permit egress into separate areas of a building when it is not possible to egress from the building.

References

FEMA 361, *Design and Construction Guidance for Community Shelters*, First Edition, Federal Emergency Management Agency Mitigation Directorate, July 2000.

FEMA P-757, *Mitigation Assessment Team Report*: Hurricane Ike in Texas and Louisiana Building Performance Observations, Recommendations, and Technical Guidance, April 2009.

International Building Code, 2003 Edition, International Code Council, 2003.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 2002 Edition, National Fire Protection Association, Quincy, MA, 2002.

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Chapter 6: Performance of Communication Infrastructure

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Introduction

This chapter presents an overview of the impact of Hurricane Katrina on communication infrastructure in general, including recommendations of an independent panel to the Federal Communication Commission (FCC). It then discusses communication problems associated with Hurricane Katrina at two hospitals and one unintended shelter. It concludes with a brief description of the modifications these facilities have made to the communication aspects of their emergency plans.

Impact on the Region's Communication Infrastructure

Most of the region's communication infrastructure performed fairly well through Hurricane Katrina's wind and rain, with the exception of those facilities located right on the Gulf Coast. Most issues arose due to the aftermath of the storm: substantial flooding, widespread power outages of long-term duration, and serious security problems. Because Katrina affected such a huge geographic area for an extended time, every sector of the communications industry was affected.

Public Safety Networks

Public safety communication networks are generally built to be robust and reliable in extreme conditions. These systems are designed to withstand power outages and transmission, interconnection, and personal equipment failures. They are not designed to withstand widespread disasters of long duration, such as Hurricane Katrina.

In general, the antenna towers remained standing after the storm but were blown out of alignment and/or failed due to loss of power. However, some towers were structurally damaged by high winds, even though these are the most hardened of facilities built to withstand severe hurricanes (see Fig. 6.1). Many back-up generators were damaged because they were placed too low and were flooded by storm surge. Other power failures resulted from the extended duration of the disaster, which exceeded the capabilities of most back-up generators and fuel reserves (base station generators are typically designed to operate for 24 to 48 hours). Back-up batteries generally have an 8- to 10-hour duty cycle; without access to power, these batteries were not able to recharge and eventually ran out of power.

There were also training issues. Public safety personnel had to utilize unfamiliar, alternate communication technologies. For example, some personnel forced to use back-up satellite phones were unaware of their special dialing requirements. Additionally, since these alternative systems are rarely used, problems with their upkeep and maintenance were reported.

Fig. 6.1. Example of buckled antenna tower at Mississippi fire station (Source: FEMA 543, Design Guide for Improving Critical Facility Safety from Flooding and High Winds: Providing Protection to People and Buildings, 2007.)

Public Safety Answering Points (PSAPs)

Thirty-eight 911 call centers ceased to function as a result of the storm. Limited training and advance planning on rerouting emergency calls in this type of disaster hampered efforts to get these calls to the appropriate agencies.

Wireline

More than 3 million customer phone lines were knocked out in Louisiana, Mississippi, and Alabama. Lack of redundancy in high-volume routes was a severe problem. Critical tandem switches went down due to lack of fuel. Aerial fiber was at greater risk of being severed than underground fiber. After the storm passed, the lack of security for repair personnel greatly hampered recovery efforts. Additionally, repair personnel were not allowed into the affected area because of a lack of proper credentialing.

Cellular/PCS

The majority of the problems for wireless providers were due to a lack of commercial power or lack of transport connectivity to a wireless switch. Both of these failures require a site visit to return the affected base station to operational status. Site visits were problematic because personnel did not have the necessary credentials to access many of the affected locations that were under martial law, personnel did not have proper security when their intended destination proved unsafe due to unrest, and fuel could not be transported to or through flooded locations. Some locations remained flooded for six weeks.

Paging

Paging systems were more reliable because they use satellite networks rather than terrestrial networks for their backbone infrastructure. Paging technology is also inherently redundant; messages can be relayed if a transmitter or group of transmitters fails. Paging signals also penetrate buildings more easily than some other signals. Additionally, pager batteries have a longer life and, thus, remained operational longer than many other communication devices. They are also effective at both text messaging and broadcast messaging.

Satellite

Satellite networks were the least affected by the disaster. Both fixed and mobile satellite systems remained operational. Reported problems include specialized dialing (personnel must be trained to use these devices), line of sight issues, a general inability to work indoors, and the need to charge the batteries. Satellite data services were more robust than satellite voice services.

Broadcasting

Twenty-eight percent of television stations experienced down time, and only four of 41 radio stations remained on the air after the disaster. Some broadcasters returned to the airwaves after partnering with unaffected broadcasters (in many cases, a competitor). Very few tower losses were reported, but many antenna were blown out of alignment. Loss of power and lengthy outages that exceeded back-up resources were also issues. Additionally, lack of security for repair personnel hampered recovery efforts.

Fig. 6.2. Example of damage to cable infrastructure (Source: FEMA 543, Design Guide for Improving Critical Facility Safety from Flooding and High Winds: Providing Protection to People and Buildings, 2007.)