

TEK 07-02

BALANCED DESIGN FIRE PROTECTION FOR MULTIFAMILY HOUSING

INTRODUCTION

The application of balanced design principles is particularly important in multifamily residential buildings. The risk of fires in apartments and condominiums is high because of the numerous kitchens, furnaces, hot water heaters, and other causes of residential fires. In addition, there is always a potential for sleeping occupants, children, and others who may be at a disadvantage for evacuating quickly.

Fire safety in multifamily housing requires an understanding of the hazards involved, so that both the potential for fire and the threat to life-safety during a fire are minimized. The purpose of balanced design is to protect life and property during a fire. Death and injury from fire is caused by asphyxiation from toxic smoke and fumes; burns from direct exposure to the fire; heart attacks caused by stress and exertion; and impact due to structural collapse, explosion and falls. Life safety in multifamily housing is influenced by the design of the building, its fire protection features, and by the materials, building contents, quality of construction, and maintenance.

BALANCED DESIGN

Balanced design relies on three complementary life safety systems to reduce the risk of death due to fire:

- a detection system to warn occupants of a fire
- a containment system to limit the extent of fire and smoke
- an automatic suppression system to control the fire until it can be extinguished.

Each of these essential systems contributes to lowering the risk of death and injury from fire in multifamily housing. The three balanced design components complement each other by providing fire protection features that are not provided by the other components. Some features of each balanced design component are intended to be redundant, so that in

the event that one system is breached, or fails to perform, the other components continue to provide safety.

Although not a tangible element in fire protection, a strong education program should be an integral part of any good fire protection plan in addition to the physical components of a balanced design system.

DETECTION

Accurate early warning is the first line of defense against the slow smoldering fire, typical in dwelling units with a low heat release rate that doesn't activate a sprinkler head. Detectors that respond to light smoke are important from a life-safety standpoint to alert occupants so they can evacuate.

Other detection or alarm systems may be used to notify the fire department, thus decreasing response time, expediting rescue operations, and limiting the resulting fire spread and property damage. Detectors wired to a central alarm and installed in corridors and common areas notify all building occupants, permit timely and orderly evacuation, and decrease the potential for injury and death.

The National Fire Protection Association (NFPA) National Fire Alarm Code, NFPA 72 (ref. 3), covers minimum performance, location, installation, testing and maintenance of detectors. The Standard includes heat, smoke, flame and gas sensing fire detectors.

The most common detector used in multifamily housing is the smoke sensing fire detector. Detectors should be wired into a continuous power supply. Their location in multifamily housing is determined in accordance with the building code.

Each dwelling unit should be equipped with detectors in all sleeping rooms and in areas adjacent to all sleeping rooms, and on each level of the building, including the basement. The amount of air movement and obstructions within the space, such as partitions, ceiling height, and other factors, will guide the fire protection engineer in the proper selection of the detector location.

The performance of detectors is vulnerable to unpredictable malfunctions, among which are lack of maintenance due to human error and neglect, faulty power supply, and even acts of sabotage by arsonists. Young children, the disabled, elderly, and the deaf may not be able to respond to auditory alarms. Tests on smoke detectors (ref. 4) indicate the need for a regularly scheduled maintenance and testing program, as well as the periodic replacement of some components.

SUPPRESSION

The function of automatic sprinkler systems is to control a fire at the point of origin. While not designed to extinguish a fire, residential sprinklers have been shown to be very reliable and effective in controlling a fire in the room of origin until it can be extinguished. Sprinklers reduce the likelihood of flashover. Flashover, the rapid ignition of volatile gasses, is particularly hazardous in exit corridors. Suppression of a fire allows access to the building to permit rescue and fire fighting efforts to proceed. Sprinklers are credited with preventing multiple deaths in fires.

The NFPA maintains minimum standards for the design and installation of sprinkler systems. Sprinkler systems for multifamily housing more than four stories in height are covered by NFPA Standard 13 (ref. 1). NFPA Standard 13R (ref. 2) covers the installation of sprinkler systems in multifamily housing up to and including four stories in height. When the interior construction or building contents contain a large amount of combustibles, sprinkler systems should meet the NFPA 13 Standard, regardless of height, to ensure protection in attics, closets, and other concealed spaces built with combustible materials, and to provide additional suppression in all areas due to the higher fuel loadings.

The NFPA Standards cover the design, installation, acceptance testing, and maintenance of sprinkler systems. In addition, there are specific spaces which are not required by NFPA 13R to be sprinklered. The Standards require an adequate water supply and a piping system designed to deliver sufficient water to the sprinkler head. Sprinkler head requirements ensure proper water coverage based on the room dimensions, area to be covered, and fuel loading. The Standards also list exceptions for specific spaces which are not required to be sprinklered. Once installation is complete, the Standards require inspection and acceptance of the system's piping, valves, pumps and tanks. Testing also includes verification of adequate water flow to the sprinkler heads. After the sprinkler system is in use, it must be maintained; however, specific maintenance requirements and frequency of maintenance are not specified by the Standards.

Performance of automatic sprinklers can be vulnerable to system failures due to inadequate maintenance and inspection, or inadequate water supply. Sprinklers are not intended to control electrical and mechanical equipment fires or fires of external origin, such as fires from adjacent buildings, trash fires, and brush fires. Fires in concealed spaces, including some attics, closets, flues, shafts, ducts, and other spaces where sprinkler heads are not required to be installed, can compromise life-safety due to the spread of toxic fumes and smoke. Inadequate water supply can occur due to low pressure in the municipal water system, broken pipes due to earthquakes or excavation equipment, explosions, freezing temperatures, closed valves due to human error, arson or vandalism, corrosion of valves, pump failure due to electrical outage, and lack of system maintenance.

COMPARTMENTATION

Compartmentation contains a fire until it can be brought under control by fire fighters as illustrated in Figure 1. Compartmentation limits the extent of fire by dividing a building

into fire compartments enclosed by fire walls or fire separation wall assemblies, and by fire rated floors and ceilings. Compartments also minimize the spread of toxic fumes and smoke to adjacent areas of a building. Conflagrations beyond the fire compartment are prevented by limiting the total fuel load contributing to the fire. Compartmentation provides safe areas of refuge for handicapped, young, elderly, incapacitated and other occupants who may not be capable of unassisted evacuation. Compartmentation also provides safe areas of refuge for extended periods, where evacuation is precluded due to smoke filled exit ways or blocked exits. Compartmented construction provides protection for fire and rescue operations. Highly hazardous areas, such as mechanical, electrical or storage rooms, can be isolated by fire walls from other occupied areas of a building. Fire separation walls and floor/ceiling assemblies between dwelling units in multifamily housing afford protection from fires caused by the carelessness of other occupants.

Each compartment is enclosed by fire resistive components. Floor and wall elements forming the boundaries of each compartment should have a fire resistance rating of at least two hours, and should be constructed of noncombustible materials that are capable of preserving the structural integrity of the building throughout the duration of the fire. Openings through compartment boundaries should be protected openings. Doors should be self closing when fire or smoke is detected. In multifamily housing, each dwelling unit should form a separate compartment. In addition, interior exit ways, as well as storage, electrical, and mechanical rooms, should be separate compartments. Exterior walls should be fire rated to form a barrier to the penetration of exterior fires and to contain interior fires.

The value of compartmentation could be reduced when joints between floors and walls, typically exterior curtain walls, or between walls and ceilings, are not properly fire-stopped. Damage caused by equipment, abuse, or the installation of utilities which are not properly sealed, can allow the passage of smoke and gas. Unsealed openings around penetrations can also allow the convective spread of smoke. Self-closing mechanisms on doors in compartment walls may fail if not maintained, or if blocked open.



📷 Figure 1—Compartmentation Provided by Masonry Walls Contains a Fire until Brought under Control

The initial cost of providing fire safety can be significant; however, balanced design offers

PROPERTY PROTECTION

advantages which offset initial costs. The higher level of protection for both the structure and its contents limits the potential loss due to fire. Immediate and long term savings will be reflected in lower insurance rates for both the building and its furnishings. Balanced design limits both fire and smoke damage of the building's contents to the compartment of fire origin. Noncombustible compartment boundaries limit damage to the structure itself and reduce repair time following a fire. Repair is generally nonstructural, but may include the replacement of doors and windows; electrical outlets, switches and wiring; heating ducts and registers; and floor, wall and ceiling coverings.

SUMMARY

Fire protection engineering is as much an art as it is a science. The number of unknowns and potential fire propagation scenarios are numerous. Fire protection is, therefore, generally based more on risk assessment than precise calculation. Currently, building code prescriptive criteria, (ref. 5, 6) along with an understanding of the science of fire protection, guides the designer in addressing fire safety.

Some of the more significant fire safety issues requiring consideration are listed in Table 1, along with the effectiveness of each component of balanced design. As shown by the table, there may be more than one component which is considered effective in mitigating a particular hazard. Since none of the components are fail-safe, overlapping functions are needed to provide the required level of safety. In addition, there are some functions listed in the table which are addressed by only one component of balanced design. The appendix of NFPA Standard 13R (ref. 2) also recognizes the need for compartmentation and detection, along with sprinklers, to ensure a reasonable degree of life-safety protection.

There is a general agreement among the engineering and scientific communities that the desired approach to improving fire safety in buildings is through computer modeling. Limited success to date has been achieved in developing a system (ref. 7) that will assess risk and design protection levels for each of the three components of balanced design. Future efforts will be directed through the government and the private sector in a cooperative effort to develop this tool.

Table 1—Fire Safety Function of Balanced Design Concept			
Function	Automatic Detection	Compartmentation	Automatic Suppression
Controls fire/limits fire growth	○	●	●
Provides smoke, toxic fume barrier	○	●	○
Provides fire barrier	○	●	○
Limits generation of smoke/toxic fume	○	◐	●
Allows safe egress	◐	●	◐
Provides refuge	○	●	○
Assists fire fighting efforts	○	◐	◐
Reduces fire & rescue response time	●	○	○
Difficult to vandalize/arson	○	●	○
Performance requires little maintenance	○	●	○
Property Protection Functions and Costs of Balanced Design Component			
Limits the extent of contents damage	◐	◐	◐
Limits the extent of structure damage	◐	●	◐
Low installation costs	●	◐	○
Low maintenance costs	◐	●	○
Limits repair time due to fire damage	◐	●	●
<p>● Considered to be effective</p> <p>◐ Considered to be partially effective</p> <p>○ Considered to be ineffective or only slightly effective</p>			

Table 1—Fire Safety Function of Balanced Design Concept

References

1. Installation of Sprinkler Systems, NFPA 13, National Fire Protection Association, 2007.
2. Standard for the Installation of Sprinkler Systems in Residential Occupancies up to and Including Four Stories in Height, NFPA 13R, National Fire Protection Association, 2007.
3. National Fire Alarm Code, NFPA 72 National Fire Protection Association, 2007.
4. Why We Need to Test Smoke Detectors, Leon Cooper, Fire Journal, National Fire Protection Association, November 1986.
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7. Fire Hazard Assessment Method, Hazard I, NIST Handbook No. 146, National Institute of Standards and Technology, U.S. Department of Commerce, 1989.

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Keywords

balanced design

compartmentation

containment

detection

fire walls

multifamily housing

residential

smoke

suppression