7.1 OVERVIEW

The previous chapters have focused on the protective design of office buildings because this occupancy is one that has been of most concern within the public and private sectors to date. The concepts discussed, however, are largely applicable to any type of civilian building serving large numbers of people on a daily basis. This chapter considers the unique challenges associated with three other high-occupancy building types: multi-family residential buildings, commercial retail buildings, and light-industrial buildings. Protection of schools and hospitals is addressed in other FEMA reports and is not explicitly addressed here.

The uniqueness of these other occupancy types from the perspective of protective design is a function of many factors, including hours of peak usage, dominant population, size of building, and construction type.

For dual-use facilities such as those that incorporate both retail and commercial office uses, two important recommendations for the HVAC are:

- to provide separate HVAC zones; and
- to strictly adhere to isolation principles (that is, to treat any public area as equivalent to an entrance lobby in a single-use building).

7.2 MULTI-FAMILY RESIDENTIAL OCCUPANCY

Multi-family residential buildings are unique because they tend to house more elderly, handicapped, and children than do office buildings, which tend to have more able-bodied occupants within working age (18-65). Office buildings of course can have a certain percentage of less-able-bodied populations, depending on the tenancy (e.g., medical offices, social services, or child care centers), and such populations need to be accounted for in the design of these buildings as well. In any case, the occupancy will have a major effect on the evacuation and rescue efforts.

For multi-family residential buildings, it becomes more imperative that primary egress routes, including hallways leading to stairwells, remain as clear of debris and smoke as possible during the evacuation period. This criterion demands a higher level of protection than has been discussed for office buildings. Some recommendations for providing

enhanced protection to facilitate evacuation and rescue of distressed populations are listed below.

- Place hallways in a protected location away from the building exterior.
- Do not use glass in the hallways used for primary egress.
- Egress routes should lead to exits that are as far as possible from high-risk areas such as the lobby, mail room, and delivery entrance.
- Create pressurized safe havens in elevator vestibules and stairwells using tightly constructed, air-tight enclosures placed in a protected core area of the building.
- Emergency exits should be easily accessible by emergency vehicles and should be spacious enough to accommodate rescue workers entering the building as well as injured persons exiting the building.
- The side(s) of the building with emergency exits should be free of any canopies, overhanging balconies, or other ornamentation that may fall and block the exits.
- Emergency power should provide sufficient lighting and or phosphorescence to lead persons safely out of the building.
- Avoid using false ceilings in hallways. These can become falling debris that interferes with evacuation.
- Attach light fixtures to the floor system above to avoid hazardous debris in the exit path and to provide emergency lighting.

Multi-family residential construction is more likely than office building construction to incorporate flat plate/slab or pre-fabricated components and therefore tends to be more structurally vulnerable. To improve performance, robust connection detailing becomes paramount to ensure that the connections are not weaker than the members to which they are attached. Also, balconies are more common in multi-family residential buildings. These present a debris hazard due to their inherent instability and connection weakness.

7.3 COMMERCIAL RETAIL SPACE OCCUPANCY

Commercial retail space such as malls, movie theatres, hotels, night clubs, casinos, and other spaces that house large public populations gathering for shopping or entertainment have their own unique features that increase their vulnerability compared with that of office buildings. Often, these spaces are low-rise buildings that have large interior spaces with high, laterally unsupported walls, long-span roofs, and interior columns spaced relatively far apart. They are generally constructed

using lightweight construction and may be prefabricated. This type of construction has little if any redundancy, which increases the structural vulnerability significantly.

The primary goal for this type of construction is to prevent progressive collapse of the building in response to a large-scale attack. Where possible, floor-to-floor height and bay spacing should be reduced, and lateral bracing of the columns and roof joists should be provided. Connections should be designed to be at least as strong as the members. Secondary structural framing systems further enhance protection. To limit laceration injuries, lamination of glass is recommended. Consider structural partition walls or shelving units placed within the space that will stop the roof system from falling directly on the occupants in the event of collapse. If this approach is used, take care that the partitions have sufficient lateral support so that they do not topple over.

In these large spaces, it is virtually impossible to isolate HVAC to protect against CBR-type threats. In this case, negative zone pressurization or smoke-evacuation methods become critically important. Also, mechanical areas should be protected with restricted access and a hardened shell (walls, ceiling and floor). It is also recommended to have centralized redundant control stations, easily accessible by appropriate personnel. Consideration should be given to providing additional, clearly marked, easily located egress routes to facilitate mass evacuation. If there are business offices serving these buildings with a sizable workforce, consider relocating these and other mixed-use functions to a separate, offsite location.

7.4 LIGHT INDUSTRIAL BUILDINGS

Light industrial buildings are used through out the United States for offices, light manufacturing, laboratories, warehouses, and other commercial purposes. Typically, these buildings are low-rise buildings three to five stories high, often using tilt-up concrete construction. Typically, they are located in industrial or commercial complexes and may have significant setbacks from public streets. They are serviced by surface parking lots or parking structures outside the building. Security may vary widely depending on the use of the building. For a building used for laboratories or manufacturing, there may be already be significant security measures at the perimeter and inside the building. For office buildings, security may be light to negligible.

The main focus of this section is on light industrial buildings that house office space, because these are the buildings with potentially high popu-

lations, and therefore, life safety is a primary concern. For warehouses and manufacturing plants, the primary objective is more likely to be protection of the contents and processes. For laboratories, the primary objectives are to prevent release or deflagration of hazardous materials and to protect processes.

Office parks inherently have an open character with medium-to-large setbacks from the street and public parking. In this environment, the most effective way to protect the building from moving vehicle threats is to use landscaping methods between public streets and parking to prevent the intrusion of vehicles. Devices such as ponds, fountains, berms, and ditches can be very effective in reducing the accessibility of the building exterior to high-speed vehicles.

Parking should be placed as far as practical from the building. Driveways leading directly to the building entrance should have a meandering path from the public streets that does not permit high velocities to be achieved. Separation between the driveway and building may be achieved through a number of devices such as a pond with a bridge leading to the entrance, a knee wall with foliage in front, or other landscape features.

The design of parking structures servicing these buildings should fulfill two main objectives to prevent explosions in the parking structure from seriously damaging the main office building. The first is to control the lines of sight between the parking structure and the building to limit air-blast effects on the building. One solution is to use a solid wall that is bermed and landscaped on the side of the parking structure facing the building. Second, design the parking structure to withstand the design-level explosion without structural failure in order to reduce the potential for debris from a parking structure failure damaging the office building. This second objective can be achieved while still allowing the parking structure to sustain significant levels of damage.

For the tilt-up walls, use continuous vertical reinforcement with staggered splices, preferably on both sides of the wall to resist large lateral loads. It may be advantageous to consider designs that permit the wall to bear against floor diaphragms to resist loads. Connections between the walls and structural frame should be able to accept large rebound forces to prevent the wall from being pulled off the exterior. Care should be taken to prevent the wall from bearing directly against exterior columns to limit the opportunity for progressive collapse. Using laminated glass on the exterior reduces the potential for laceration inju-

ries. For the roof, a concrete slab with or without decking is preferred over a solution using metal decking only.

7.5 FURTHER READING

FEMA, 1988, *Seismic Considerations: Office Buildings, FEMA 153, Earthquake Hazards Reduction Series 38,* Federal Emergency Management Agency, Washington, D.C.

FEMA, 1988, *Seismic Considerations: Apartment Buildings, FEMA 152, Earthquake Hazards Reduction Series 37.* Federal Emergency Management Agency, Washington, D.C.