6 Observations on Personal Protection and Sheltering

Existing and new construction can be strengthened to better resist wind forces associated with inflow winds of tornadoes and weak tornado vortices; however, sometimes more protection is required. To survive a violent or severe tornado directly beneath or adjacent to the vortex or to minimize potential loss of life for any tornadic event, a hardened aboveground or belowground shelter specifically designed and constructed to provide near absolute protection is the best alternative.

However, a shelter or safe room is not effective if ample warning time is not provided. The NOAA/NWS "Service Assessment" for the May 3, 1999 Tornado Outbreak (see Appendix E) provides information on the warning times for the May 3, 1999 tornadoes. Tornado warnings for smaller tornadoes is typically 5-10 minutes. For the tornadoes studied in the "Service Assessment", the warning times ranged from 13-65 minutes. These warnings allowed those individuals with access to shelters time to take refuge. Additional lives would have been lost by individuals attempting to seek refuge in shelters if this ample warning time had not been provided.

6.1 Shelters

Engineered shelters not only provide the best protection against loss of life for individuals subjected to a tornado, but also furnish the only protection reliably capable of providing survivable places of refuge. This section presents observations on the types of shelters observed by the BPAT.

6.1.1 Types of Shelters

Both aboveground in-resident shelters and belowground shelters were successfully utilized in the May 3 storms in Oklahoma and Kansas, and were responsible for saving many lives. The aboveground in-residence shelters observed were constructed of cast-in-place concrete. Figure 6-1 shows an aboveground in-residence shelter located in Del City, Oklahoma, that consists of a reinforced concrete room (including a roof slab) located behind the brick veneer that was affected by inflow winds and was about 100 feet from the vortex of a violent tornado. Figure 6-2 shows the extent of damage the tornado caused on the homes surrounding the shelter. Homes in the foreground were hit by the tornado vortex and were located behind the home shown in Figure 6-1. The other type of residential aboveground shelter observed is an insulated concrete formed (ICF) shelter shown in Figure 6-3 that was hit by inflow winds of a violent tornado in Bridge Creek, Oklahoma.

FIGURE 6-1: Aboveground in-residence shelter hit by strong inflow winds near the vortex of a violent tornado in Del City, Oklahoma. Arrows indicate the extent of this reinforced concrete shelter that cannot be seen due to the brick veneer.

FIGURE 6-2: Damage to houses near the home in Figure 6-1. This photo is taken from the roof of the concrete shelter.

FIGURE 6-3: Entrance to the ICF shelter in Bridge Creek, Oklahoma. This residence and shelter were on the periphery of the inflow winds of a strong tornado, and damage was limited to light missile impacts.

Belowground shelters included shelters constructed in basements as well as self-contained shelters located out of the building footprint, sometimes known as storm cellars. Basements were typically constructed of cast-in place concrete or CMU walls, and ceilings were normally wood framed structures constituting the structure for the floor above. Basements intended for occupancy and normal use contained windows, some of which were planned for egress from sleeping spaces. A basement may function as a place of refuge, but can not be considered an engineered shelter unless it has been designed to perform as a shelter. Refer to Section 6.2.1 for use of typical basements for refuge. The storm cellars observed by the BPAT were constructed of cast-in-place or precast concrete (Figure 6-4), and prefabricated steel with a concrete roof slab (Figure 6-5). The BPAT did not observe fiberglass or steel tank storm cellars, although numerous proprietary storm cellar systems are available that are constructed of these materials.

FIGURE 6-4: This precast concrete storm cellar was located immediately behind a single-family residence in Sedgwick County, Kansas. This residence and shelter were on the periphery of a violent tornado path.

FIGURE 6-5: Del City storm cellar constructed of welded steel sheets with a concrete roof slab. This area was directly struck by the vortex of a violent tornado.

6.1.2 Use of Shelters

Shelters observed by the BPAT appeared to be constructed and located by occupant type. Family-size shelters situated near or in the residence for immediate use in the case of danger were evident throughout Oklahoma and Kansas. In Oklahoma, the BPAT observed a few aboveground in-residence shelters that had been added to existing homes or incorporated into the construction of new homes. In Kansas, no aboveground in-residence shelters damaged by the tornadoes were inspected by the BPAT. However, the BPAT did inspect new reinforced concrete aboveground in-residence shelters that were being constructed in Wichita, Kansas (Figure 6-6).

FIGURE 6-6: Aboveground in-residence shelters under construction in Wichita, Kansas.

The second type of shelters observed by the BPAT were designed to accommodate small groups of people. The group shelters inspected by the team were located relatively close to the individuals for which the shelter was provided or within the actual building in which individuals were located. A group-sized shelter located within a plastics manufacturing plant in Haysville, Kansas, is intended to accommodate factory workers (Figure 6-7). The plant's shelter functioned daily as a conference room and lunchroom for employees. Although a violent tornado damaged other buildings on the plant site, the building containing this shelter received damage only in one isolated area, where a partial roof collapse occurred. Other smaller group-sized shelters were observed at a new manufactured home rental development, which provided precast concrete shelters (1 per 4 homes) (Figure 6-8). None of the group-size shelters observed by the BPAT were directly impacted by a tornado on May 3, 1999.

Deficiencies and vulnerabilities were observed in the group shelter presented in Figures 6-7 and 6-8. The shelters in both figures are only accessible by stairs and, depending upon the emergency plan, are possibly non-compliant by ADA requirements. The interior of the shelter in Figure 6-7 was also very damp, signifying a moisture problem that may be a problem for long duration stays within the shelter. The group shelter in Figure 6-8 has a vent on the top that is

FIGURE 6-7: Entrance to the plastics manufacturing plant group shelter in Haysville, Kansas.

FIGURE 6-8: Group shelters at a manufactured home rental community in Wichita, Kansas.

very susceptible to damage and removal by wind and windborne debris. The door, specifically the latch mechanism, is vulnerable to windborne debris. Damage to either of these two elements would result in experiencing wind, windborne debris, and hail and rain from a storm event within the shelter.

Community-sized or mass shelters were also inspected by the BPAT. Community or mass shelters are designed to accommodate over 100 individuals and may often be located up to ½ mile from the individuals requiring use of the shelter. A manufactured home community shelter in Wichita, Kansas, was constructed partially underground and located at one end of the large development. The shelter was intended to house all residents of the development (Figure 6-9). Approximately 200 people reportedly sought shelter in this building during the May 3 tornadoes. Another community-sized shelter was located underground and under the concrete bleachers in the Midwest High School gymnasium in Midwest City, Oklahoma (Figure 6-10). Approximately 500 people sought shelter here during the May 3 tornadoes (the shelter has a capacity of 3,500). A similar shelter is located at Del City, Oklahoma High School in Del City . Members of the community are generally aware of the location of these shelters. Interviews with residents of the manufactured home community indicated that parking was a problem at the community shelter. In contrast to the shelter at the manufactured home community, ample parking is available near the high school gymnasiums for those seeking shelter.

FIGURE 6-9: Partially belowground community shelter in a manufactured home park in Wichita, Kansas.

The shelter in Figure 6-10 had the following vulnerabilities. According to residents, the shelter was constructed in a flood-prone area that often causes access problems to the shelter and could result in the shelter being inundated by floodwaters. Residents also indicated that only a few people had keys to open the shelter and, during this event, other residents had to wait to gain access because they did not have keys. Similar to the shelters shown in Figures 6-7 and 6-8, access was limited to stairwells at each end of the shelter. Numerous windows along the sides of the building are vulnerable to damage. Finally, the roof covering of aggregate surfacing may become air-

FIGURE 6-10: Community shelter, Midwest High School gymnasium in Midwest City, Oklahoma.

borne during high-wind events and tornadoes. If this ballast becomes airborne, it could damage the windows of the facility and seriously injure individuals attempting to take refuge within the shelter.

6.1.3 Maintenance and Design Issues of Shelters

The BPAT observed deficiencies in some shelters inspected during the field investigation. Underground, partially underground shelters, or shelters located exterior to buildings were subject to moisture and the associated deterioration. Insufficient attention often was paid to these shelters with regard to waterproofing of walls and roofs and resulted in musty and damp environments. These conditions were perhaps merely an inconvenience for the family-size or small group shelter, but were potentially environmentally hazardous to occupants with allergies or respiratory ailments in the large group and community shelters.

In numerous cases, the BPAT observed that construction practices, the selection of materials, and maintenance can impact the effectiveness of shelters (Figure 6-11). Storm cellar doors observed by the BPAT were often covered with thin gauge sheet-metal and exhibited corrosion. The sheet-metal storm cellar doors were often backed with untreated plywood that was usually found to be rotted, delaminated, or otherwise deteriorated to the point where it was no longer useful in providing protection to the shelter opening.

Numerous other deficiencies were observed regarding shelter doors and hardware. Most of the storm cellar doors were of insufficient thickness to withstand tornadic wind forces and windborne missiles. Most shelter door latching devices were also insufficient to withstand wind forces and windborne

FIGURE 6-11: Door to underground shelter with rotting wood and corroded hinges.

missiles and one observed failure resulted in the door destruction and the partial filling of the storm cellar with debris (Figure 6-12). Widespread door failures were observed on the belowground shelters; this included both metal and wooden doors. The aboveground in-resident shelters observed had hollow metal doors and three hinges on one side and an insufficient single deadbolt locking device (Figure 6-13). The door metal skin thickness and the single lock would have probably been insufficient to secure the door had they experienced a direct strike from a high-energy windborne missile.

Other shortcomings of shelters were observed by the BPAT. The community shelter in Figure 6-14 produced a potential safety hazard to nearby buildings resulting from windborne missile generation from a fence and roof ballast. A security fence that surrounded this roof area was damaged and removed by the winds of the violent tornado that impacted the opposite side of this community. Aggregate ballast shown in the photo may become airborne during high wind events and cause damage to other properties and injure individuals attempting to access the shelter. In addition, the ventilation covers are inadequate to stop free-falling debris via the penetrations that are in the roof for ventilation.

FIGURE 6-12: Failed wooden door at a belowground shelter in Oklahoma. Note the medium-size debris (clothes dryer) immediately adjacent to the shelter access.

FIGURE 6-13: Shelter door of home in Del City, Oklahoma, showing an insufficient deadbolt locking device. The bottom circled area on the door frame is the catch for the only latching mechanism on the door. Note: the second opening in the door frame was not used to provide a second latching point (top circled area).

FIGURE 6-14: Ballast roof covering on a community shelter in Wichita, Kansas was a potential source of deadly windborne missiles to those seeking to access the shelter. Circles identify covers protecting roof penetrations intended for ventilation, but unable to provide adequate resistance to windborne debris.

6.1.4 Shelter Accessibility

The observed aboveground in-residence shelters were easily accessible by the home occupants. Observed door widths would have allowed access by wheelchair or otherwise disabled occupant. The group or community shelters observed by the BPAT had restrictive entrances that may have hampered access to the shelters by persons with disabilities. Although privately owned, residential below-grade shelters also were limited to stairs to provide access. Figure 6-15 shows stairs leading to the entrance of a community shelter in Kansas. Additionally, several of the community shelters were locked and required authorized admission. Access to the community shelter in Figure 6-15 was restricted to community members without pets and the travel distance from the far end of the development to the shelter was approximately several city blocks. The group shelters observed also require access via stairs at both the plastics manufacturing plant and the manufactured home rental development. Figure 6-16 shows the stairs required to access the group shelter at the manufactured home rental development.

The gymnasium community shelters required suitable storm warnings because of travel time, and time required to open the facility. In unincorporated Sedgwick County, Kansas, residents indicated that a wheelchair bound individual, who resided in a manufactured home, was unable to traverse the stairs into a neighbor's home and down into the basement. The individual attempted to take shelter back in his manufactured home and was killed by a violent tornado that destroyed the manufactured home.

FIGURE 6-15: Stairway leading to entrance of manufactured home community shelter, Wichita, Kansas. The only means of accessing this structure were this stairway and an identical one at the other side of the shelter.

6.1.5 Shelter Ventilation

The observed aboveground in-residence shelters did have ceiling and/or wall penetrations outlets for forced air ventilation from the home HVAC system; however, no other method of natural ventilation was included. All observed underground or partially underground shelters outside the building footprint had some means of natural passive ventilation. The most common types of ventilation mechanism observed were vent pipes (Figure 6-17) or turbine ventilators (Figure 6-8). The vent pipe in Figure 6-17 was sufficiently thick enough to not be broken by windborne debris and was capped to prevent the intrusion of debris. The turbine ventilator observed in Figure 6-8 was 8-in in diameter and made of light gauge metal. It would have been easily destroyed by flying debris if impacted by even a weak tornado, thereby allowing free-falling debris to enter the shelter through the 8-in diameter opening in the roof of the shelter, placing the safety of the occupants at considerable risk.

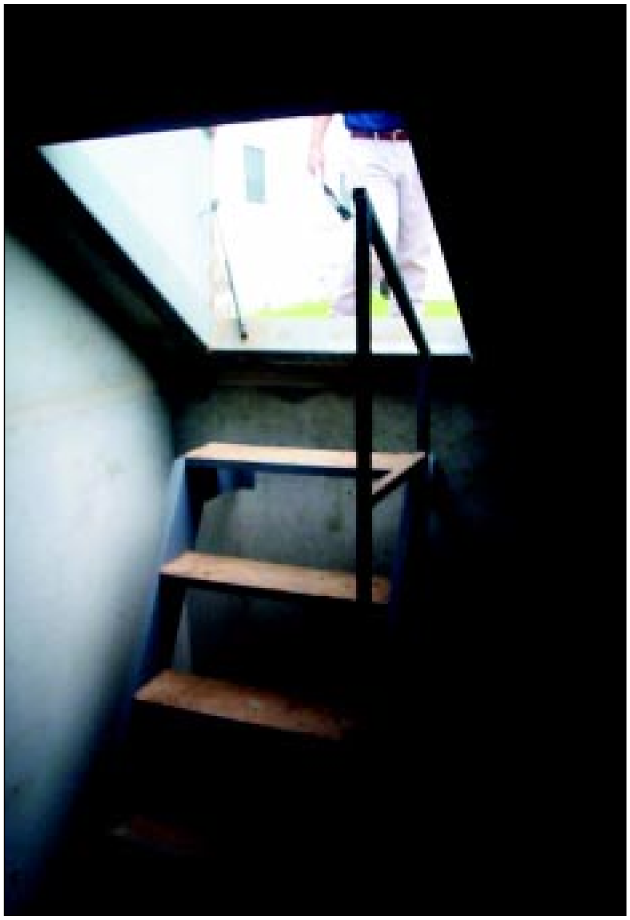

FIGURE 6-16: Stairway access to group shelter at manufactured home rental development, Wichita, Kansas, shown in Figure 6-9. This development was not affected by any of the tornadoes that struck on May 3, 1999.

FIGURE 6-17: Heavy gauge ventilation pipe for a belowground shelter in Oklahoma withstood considerable debris impact.

6.1.6 Shelter Location

Most aboveground in-resident shelters observed were easily accessible by the occupants. Their location within the house allowed access with minimal threat to wind and windborne debris. Below-grade shelters offered the same advantages, but posed an access problem to occupants with disabilities.

Storm cellars (belowground shelters) were located either in the front, side, or rear yards of the homes. Front yard locations were vulnerable to vehicular traffic and water runoff. The side and rear yard cellars were also vulnerable to water runoff (Figure 6-18). In many cases, the cellar entrance was insufficiently raised above grade and would have allowed for easy entrance of surface water.

FIGURE 6-18: This belowground shelter is susceptible to water runoff.

6.2 Other Places of Refuge

If a specially designed tornado shelter is not available for refuge, people are forced to seek shelter in areas not designed or constructed to be places of refuge. Some areas within buildings typically offer a greater level of protection than other areas. However, when people take refuge in a portion of a building not specifically designed and built as a tornado shelter, they are at significant risk of being injured or killed if a tornado of any intensity directly strikes the building or passes nearby. The following sections discuss occupant protection areas within residential and non-residential buildings that do not have specifically designed tornado shelters.

6.2.1 Refuge in Residences

For conventionally-constructed residences without basements or specially designed tornado shelters, observations following the Oklahoma and Kansas tornadoes, as well as previous post-tornado damage investigations, consistently revealed that interior bathrooms and closets offer the greatest occupant protection. Interior bathrooms and closets are small rooms that do not have an exterior wall (Figure 6-19). These areas are referred to as core remnants and are further discussed in Section 6.2.1.2.

FIGURE 6-19: Remains of an interior room (or core) of a home in a Moore, Oklahoma, subdivision that was hit by a violent tornado.

6.2.1.1 General Observations

In many instances, only the interior core of the residence was left standing while the exterior walls and other interior walls and the roof structure and ceiling were blown away. The surviving core typically was composed of a bathroom, a closet or two, and perhaps a kitchen wall that was stiffened by cabinets (Figure 6-20). Although interior bathrooms and closets typically offer the greatest protection, people taking refuge in them are still at great risk during a tornado, as illustrated by Figures 6-21, 6-22, 6-23, and 6-24. Some minimal protection from smaller missiles is provided by the core walls and cabinets, but, in many cases, the rooms were left open to the sky when the building's roof was blown away and occupants were then totally unprotected from free-falling missiles (see Figure 3-16).

If the residence was more than one floor above grade, the first floor consistently was found to suffer less structural damage than the second floor (Figure 6-25). Therefore, greater protection was afforded when refuge was taken in interior bathrooms or closets on the first floor rather than the second.

Basements were uncommon in the areas investigated in Oklahoma; however, many of the houses investigated in Kansas did have basements. Basements typically provided greater occupant protection than first floor bathrooms or closets; however, as with first floor bathrooms and closets, basements were not immune to tornado damage. In one instance, a vehicle was blown into a house, penetrated the first floor, and hit or nearly hit the basement slab and then was blown back out of the house. In other instances, missiles traveled

FIGURE 6-20: Interior core of house remains, consisting of a bathroom, closets, and a wall with kitchen cabinets after being struck by a strong tornado.

FIGURE 6-21: This apartment complex in Kansas was affected by inflow winds associated with a strong tornado. The roof and ceiling were blown off of the interior bathroom of this house, the door was blown into the bathroom, and the tub was full of debris. This bathroom would not have provided a safe place of refuge.

FIGURE 6-22: A 10-ft long 2-in by 6-in missile penetrated the exterior wall of an apartment in this multi-family house, which was sheathed with hardboard panels. The missile, which was generated from the vortex of a strong tornado, then penetrated the gypsum board and plastic tile tub enclosure, the tempered glass shower door, and the interior partition near the door frame. At the interior partition, it pierced through a stud and projected a few inches into the hallway (Figure 6-23).

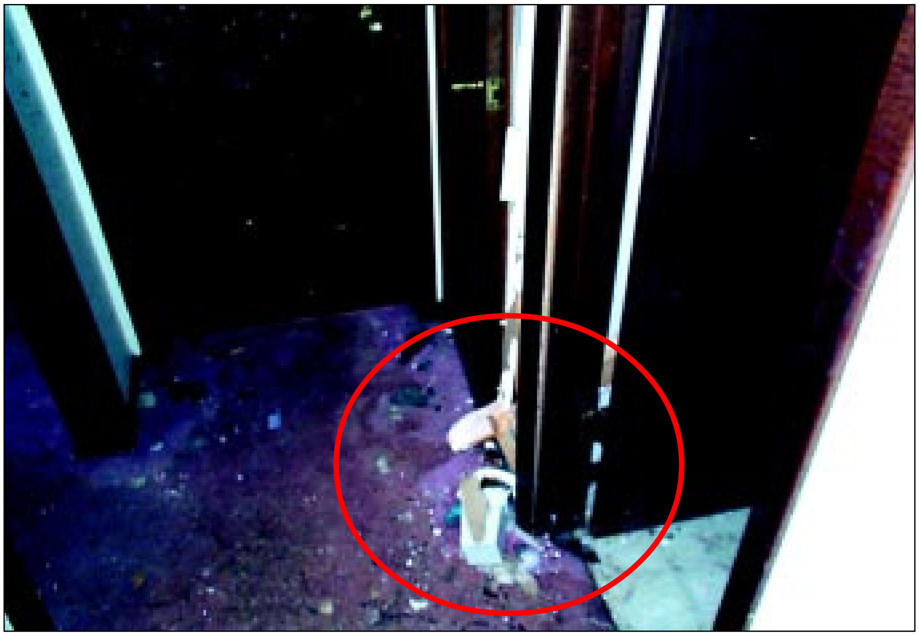

FIGURE 6-23: The missile in Figure 6-22 impacted and broke a 2-in by 4-in stud after traveling through the bathroom.

FIGURE 6-24: This bathroom was on an exterior wall and had a window. It did not provide a safe place of refuge.

FIGURE 6-25: The second story of single-and multi-family houses typically experienced far greater damage than the first story. This multi-family home in Wichita, Kansas, was affected by inflow winds of a strong tornado.

down the stairway to the basement and flew into rooms at the bottom of the stairway. Basements, that were partially above grade and had windows, were observed to be susceptible to missile penetration (Figure 6-26).

FIGURE 6-26: Basement windows of a single-family residence, showing vulnerability to debris.

Below-grade crawl spaces were also observed in Kansas. These spaces provided protection from windborne missiles traveling horizontally, but, as with basements, minimal protection was provided from free-falling missiles. In one case, a person in a below-grade crawl space was seriously injured even though the floor sheathing remained in place. There was reportedly sufficient high-speed wind flow within the crawl space to blow the person around, causing numerous injuries that required hospitalization.

Based on the BPAT observations, persons taking refuge in bathrooms or closets in manufactured houses on non-permanent foundations appear to be at significantly greater risk of injury or death than persons taking similar refuge in conventionally constructed housing (Figure 6-27). The bathrooms and closets of single-width manufactured houses typically provide very little protection because all ot the rooms have at least one exterior wall. The BPAT observed a possible exception in some of the newer manufactured homes placed on permanent foundations, and designed and constructed to resist wind forces specified in U.S. Department of Housing and Urban Development's (HUD's) latest Manufactured Home Construction and Safety Standards (MHCSS). Specifically, improved sheltering is achieved in double-wide manufactured homes placed on permanent foundations since they offered the refuge of interior rooms.

FIGURE 6-27: Damaged and destroyed manufactured homes on non-permanent foundations in Wichita, Kansas, that were in the direct path of a strong tornado.

6.2.1.2 Case Study of Residential Core Remnants

As part of the BPAT effort, data were collected to further ascertain which locations within residential buildings are most likely to resist the wind loads of a weak or strong tornado and provide some personal protection in the absence of a designed shelter. To this end, members of the BPAT members surveyed 89 residential core remnants along the center of the Oklahoma City tornado track (see Figure 2-3). Sampling was carried out by systematically inspecting all accessible core remnants. The size and location of the survey along the tornado track were ultimately limited due to safety considerations and time constraints. In collecting the core remnant data, no effort was made to assess the likelihood that a core remnant would in fact survive a weak or strong tornadic event. Consequently, the data collected only suggest the most likely locations within a residential structure that may survive as a core remnant.

A core remnant is defined as a group of interior walls that may remain following the failure of the roof and some or all of the exterior wall framing. Core remnants are partially enclosed areas and have at least four surviving walls. Overhead floor or ceiling joists may or may not be present. A sampling of core remnants studied are shown in Figures 6-28, 6-29, and 6-30. Each core remnant was photographed and inspected. Given the broad definition of a core remnant, there was no requirement that the remnant provide protection from free-falling debris, because it was assumed that roof framing is completely destroyed. Consequently, individuals seeking refuge in core remnant locations maybe susceptible to serious injury or death from free-falling debris. In the absence of a designed shelter, cellar, or basement refuge area, core remnant locations will provide an individual with the best chance of survival within their home.

Only three categories of interior rooms were observed as core remnants with any significant frequency of occurrence: first floor interior bathrooms, interior closets, and kitchens. Interior bathrooms were the most likely room to be part or all of a core remnant 81% of the time; interior closets were next at 75%. These values add up to more then 100% because core remnants are often composed of multiple interior rooms. Kitchens were also observed and made

FIGURE 6-28: The core remnant of this house consisted of a central room and closets.

FIGURE 6-29: The core remnant of this house consisted of a central room and adjacent closets.

FIGURE 6-30: The core remnant of this house was a central room on the back of the kitchen.

up roughly 16% of all survivable core remnants surveyed. Although kitchens were often attached to core remnants, most of their walls had failed, except where they were attached to the core remnant. Thus, kitchens alone cannot always be considered to be a viable place to seek shelter. It is interesting to note that roughly 63% of all core remnants surveyed consisted of both an interior bathroom and an adjacent interior closet. The combined framing from adjoining interior closets and bathrooms may contribute to the stiffness of the core remnant. Other observed core remnants had kitchen cabinets and counter tops mechanically attached to a least one surviving wall of the core remnant. In other cases, it is the added framing from staircases that may have provided the added stiffness to resist wind loads (Figure 6-31).

The BPAT's observations of residential core remnants supports theories held prior to the BPAT investigation that indicated small interior locations, principally first floor interior closets and bathrooms, are locations that may provide some personal protection during weak or strong tornadoes and outside a violent tornado's vortex in the absence of a designed tornado shelter.

FIGURE 6-31: The core remnant of this house was beneath the staircase to the second floor.

6.2.2 Refuge in Non-Residential Buildings

The BPAT also investigated a selected number of public use buildings to determine the existence of formalized emergency plans for tornado refuge. These buildings included public schools, nursing homes, and a day-care center. In all cases, each had a formal tornado refuge plan.

The nursing home tornado refuge plan, which was successfully exercised during the storm, consisted of evacuating staff and residents to the central core of the building and evacuating the long, exposed corridors of the building. The day-care center's plan similarly utilized a central corridor; however, the building was not occupied during the storm. Neither building was directly hit by a tornado or suffered major damage.

The emergency plans of five public schools were reviewed by the BPAT. Westmoore High School, located in the City of Moore, was within 100 yards of the vortex of a violent tornado and received building envelope and roof structure damage. Just prior to the storm, several hundred students and parents occupied the auditorium. In accordance with the emergency plan, most of the students and parents were moved to a predetermined area in a central core of the building where they successfully took refuge (Figure 6-32). Other individuals reportedly took refuge in a reinforced concrete stairwell adjacent to the auditorium.

FIGURE 6-32: Westmoore High School, Moore, Oklahoma, central locker core – a designated place of refuge.

Eastlake Elementary in Moore, Oklahoma, was on the outer periphery of a violent tornado and received minor building envelope damage. The building construction consists of CMU walls with brick veneer and built-up roof over steel decking and steel joists. Interior classroom walls were also built of CMU. The tornado plan for the school indicated that the places of refuge consisted of each classroom within the building, even though each classroom entrance door (from the interior hallway) was flanked by a large glass sidelight (Figure 6-33). There were no exterior windows in the exterior wall of most of the classrooms. Centrally located offices were also identified as places of refuge with the building. None of the identified areas appeared sufficiently constructed to withstand a direct hit by a violent tornado.

FIGURE 6-33: Eastlake Elementary, Moore, Oklahoma, glazed sidelight at classroom entrance.

Tornado refuge plans for Northmoor Elementary and Kelly Elementary in Moore and Sooner Rose Elementary in Midwest City were reviewed by the BPAT. None of the schools were occupied during the storm. Northmoor and Kelly were of a similar design and construction and had similar emergency plans of taking refuge in the central corridors.

Figure 6-34 shows a central corridor of Northmoor that illustrates the corridor masonry walls topped with windows, called "clerestory". These types of walls have limited capacity to resist lateral forces because of the windows located along the tops of the wall systems. Figure 6-35 shows a corridor in Kelly Elementary of nearly identical construction to the hallway in Figure 6-34. The inability of the corridor walls to withstand extreme loads due to lateral and uplift wind forces resulted in the collapse of this corridor. Many schools identify their central corridors as places of refuge in their tornado plans. Obviously, had these corridors been used for shelter during the tornado, numerous injuries or deaths would have occurred. Sooner Rose Elementary was a different construction type from the above, but contained similar windowed corridors (see Figure 6-36).

FIGURE 6-34: Northmoor Elementary place of refuge, Moore, Oklahoma – corridor with clerestory windows. This corridor offers little protection from tornadoes as shown in a school of similar design in Figure 6-35.

FIGURE 6-35: Kelly Elementary School, Moore, Oklahoma, place of refuge – corridor with clerestory windows. These interior corridor walls had brick masonry up to a height of approximately 7 ft. Glass extended from the top of the brick masonry to the top of the wall.

If a tornado is approaching an occupied non-residential building that does not have a specifically designed tornado shelter, or a tornado plan indicating places of refuge (based on an evaluation by a qualified architect or engineer), it is difficult for building occupants to quickly determine where persons should be directed to take refuge. Some walls appear to offer substantial resistance to wind and windborne missile loads, but, in fact, have very little resistance. For example, an exterior insulation finish system (EIFS) can be mistaken for a concrete wall. However, most EIFS wall assemblies consist only of a thin layer of synthetic stucco over expanded polystyrene (EPS) insulation and

FIGURE 6-36: Sooner Rose Elementary School, Midwest City, Oklahoma. According to the tornado plan for this school, this hallway is designated as a place of refuge.

gypsum board that is supported by studs, and a layer of gypsum board on the interior side of the studs (Figure 6-37). Brick and CMU walls can also be deceiving. If they are adequately reinforced and braced, they can offer a significant level of protection. But if they are inadequately reinforced or braced, they can collapse, thereby trapping and crushing people (Figure 6-38).

FIGURE 6-37: This EIFS wall system was penetrated by numerous windborne missiles.

FIGURE 6-38: The non-reinforced interior CMU walls in this area of Kelly Elementary collapsed after the roof system was removed by vortex winds of a violent tornado.

Basement areas without windows and concrete stair towers in multi-story buildings, while not specifically designated as shelters, generally provide a reasonable level of protection from weak and strong tornadoes for occupants. Interior corridors and smaller rooms that do not have glass openings in doors or walls, and are inward as far as possible from exterior walls, may provide protection or a false sense of security, depending on the severity of the tornado and the proximity to the tornado vortex (Figure 6-39). Rooms with large ceiling spans (rooms with more than 40 ft between walls or columns) such as auditoriums and gymnasiums should be avoided unless specifically designed as shelters. Large-span rooms often provide a lower level of occupant protection than rooms with smaller spans. Again, these areas of refuge have been shown to provide little protection from the effects of a direct hit by a tornado vortex unless specifically designated as shelters.

FIGURE 6-39: The roof and ceiling over this interior bathroom blew off. CMU from a firewall a few feet away blew into the bathroom, which was located on a motel's second floor in Midwest City, Oklahoma. This bathroom would not have provided a safe refuge.