6 Observations on Personal Protection and Sheltering

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

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 survival. This section presents observations on the types of shelters observed by the BPAT.

6.1.1 Types of Shelters

Both above ground in-resident shelters and below ground shelters were successfully utilized in the May 3 storms in Oklahoma and Kansas, and were responsible for saving many lives. The above ground in-residence shelters observed were constructed of cast-in-place concrete. Figure 6-1 shows an above ground in-residence shelter located in Del City, Oklahoma, that consists of a reinforced concrete room (including a roof slab) located behind the brick veneer which was hit by inflow winds and was about 50 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. Homes adjacent to the home in Figure 6-1 were hit by inflow winds and are in the background. The other type of personal above ground shelter observed is an insulated concrete formed (ICF) shelter shown in Figure 6-3 which was hit by inflow winds of violent tornado in Bridge Creek, Oklahoma.

FIGURE 6-1 Above ground 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 exterior brick masonry veneer.

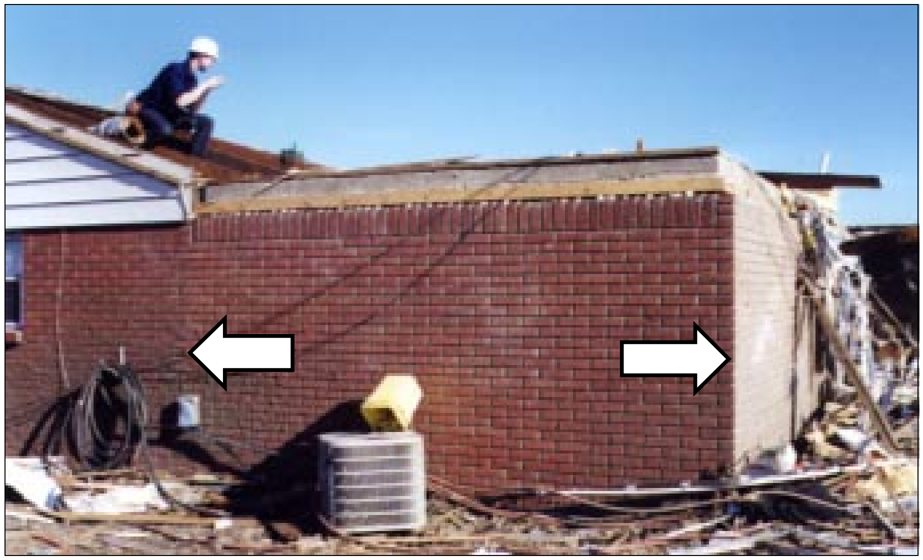

FIGURE 6-2: Damage to houses near the home in Figure 6-1.

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

Below ground 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 cover (Figure 6-5). Figure 6-6 shows a community shelter observed by the BPAT. The BPAT did not observe fiberglass or steel tank storm cellars, though 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 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 steel sheets with a concrete cover. This area was directly struck by the vortex of a violent tornado.

FIGURE 6-6: Community Shelter at a Wichita, Kansas, manufactured home park. While the park was directly hit by a severe tornado, the shelter was not within the damaged area.

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 above ground in-residence shelters that had been added to their existing homes or incorporated into the construction of their new homes. In Kansas, no above ground in-residence shelters damaged by the tornadoes were inspected by the BPAT. However, the BPAT did inspect new reinforced concrete above ground in-residence shelters that were being constructed in Wichita, Kansas (Figure 6-7).

FIGURE 6-7: Above ground in-residence shelters under construction in Wichita, Kansas.

Group-sized shelters were the second type of shelter observed. A group-sized shelter was located within a plastics manufacturing plant in Haysville, Kansas, and is intended to accommodate factory workers (Figure 6-8). The plant's shelter functioned daily as a conference and lunch room 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 6-9). None of the group-size shelters observed by the BPAT were directly impacted by a tornado on May 3, 1999.

FIGURE 6-8: Entrance to the plastics manufacturing plant group shelter in Haysville, Kansas.

FIGURE 6-9: Group shelters at a manufactured home development in Wichita, Kansas.

Community-sized or mass shelters were also inspected by the BPAT. A manufactured home community shelter in Wichita, Kansas, was constructed partially underground, located at one end of the large development, and was intended to house all residents of the development (Figure 6-10). Approximately 200 people reportedly sought shelter in this building during the May 3, 1999, tornadoes. Another community-sized shelter was located underground and under the concrete bleachers in the Mid West High School gymnasium in Mid West City, Oklahoma (Figure 6-11). Approximately 500 people sought shelter here during the May 3, 1999 tornado (the shelter has a capacity of 3,500). A similar shelter is located at Del City, Oklahoma, High School. 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, ample parking is available near the gymnasiums for those seeking shelter.

FIGURE 6-10: Manufactured home development community shelter in Wichita, Kansas.

FIGURE 6-11: Community shelter, Mid West High School gymnasium in Mid West City, Oklahoma.

6.1.3 Maintenance 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 poor selection of building materials and maintenance of painted items such as hinges and latches led to failures or poor performance (Figure 6-12). Storm cellar doors observed by the BPAT were often covered with thin gauge sheet-metal and exhibited deterioration of the zinc galvanization resulting from 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.

FIGURE 6-12: Door to underground shelter with rotting wood and corroded hinges.

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 missiles and one observed failure resulted in the door destruction and the partial filling of the storm cellar with debris (Figure 6-13). Widespread door failures were observed on the below-ground shelters; this included both metal and wooden doors. The above ground in-resident shelters observed had hollow metal doors and three hinges on one side and an insufficient single deadbolt locking device (Figure 6-14). The door metal skin thickness and the single lock would have probably been insufficient to secure the door had they experienced a direct missile strike from a violent tornado vortex or near vortex inflow area.

FIGURE 6-13: Failed wooden door at a below ground shelter in Oklahoma.

FIGURE 6-14: Shelter door of home in Del City, Oklahoma, showing an insufficient deadbolt locking device. The circled area on the door frame is the catch for the only latching mechanism on the door.

Other shortcomings of shelters were observed by the BPAT. The community shelter in Figure 6-15 produced a potential safety hazard to nearby buildings resulting from missile generation from a fence and a ballasted roof covering. Figure 6-15 shows the aggregate ballast roof covering on the community shelter in Wichita, Kansas. 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.

FIGURE 6-15: 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.

6.1.4 Shelter Accessibility

The observed above ground 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. Figure 6-16 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 Figures 6-10 and 6-16 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 6-17 shows the stairs required to access the group shelter and the manufactured home rental development.

FIGURE 6-16: Stairway leading to entrance of manufactured home community shelter, Wichita, Kansas. The only means of accessing this structure were this stairway and an identical on at the other side of the shelter.

FIGURE 6-17: Stairway access to group shelter at manufactured home rental development, Wichita, Kansas. This development was not affected by any of the tornadoes that struck on May 3, 1999.

The gymnasium community shelters required suitable storm warnings because of travel time, distance, and time required to open the facility. In unincorporated Sedgwick County, Kansas, a wheelchair bound individual, who resided in a manufactured home was unable 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.

6.1.5 Shelter Ventilation

The observed above ground in-residence shelters did have 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 6-18) or turbine ventilators (Figure 6-9). The vent pipe in Figure 6-18 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 6-9 was 8-inches in diameter and made of light gauge metal. It would have been easily destroyed by flying debris if impacted by even a moderate 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 risk.

FIGURE 6-18: Heavy gauge ventilation pipe for a below ground shelter in Oklahoma withstood considerable debris impact.

6.1.6 Shelter Location

Most above ground 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. Basements and basement shelters offered the same advantages, but posed an access problem to occupants with disabilities. Basement windows and wells, however, were poorly protected and vulnerable to windborne debris (Figure 6-19). In addition, basement shelters only offered minimal protection when the house was blown off the foundation, leaving those seeking shelter in the basement subject to windborne missiles.

FIGURE 6-19: Basement windows of residential home, showing vulnerability to debris.

Storm cellars (underground cellars) 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 6-20). In many cases, the cellar entrance was insufficiently raised above grade and would have allowed for easy entrance of water.

FIGURE 6-20: This below ground 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 intended to be places of refuge. Although some areas typically offer a relatively greater level of protection than others, when people take refuge in a portion of a building that was 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 areas where occupants often seek shelter 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 6-21).

FIGURE 6-21: Remains of an interior room or core of a home in a Moore, Oklahoma, subdivision that was hit by a violent tornado.

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 4-22). While interior bathrooms and closets typically offer the greatest protection, people taking refuge in them are at great risk during a tornado, as illustrated by Figures 6-23, 6-24, 6-25, and 6-26. While some minimal protection from missiles is provided by the core walls and cabinets, in many cases the rooms were left open to the sky when the building's roof was blown away and occupants were therefore totally unprotected from free falling missiles (see Section 3.3).

FIGURE 6-22: Interior core of house remains, consisting of a bathroom, closets and a wall with kitchen cabinets after being struck by a severe tornado.

FIGURE 6-23: This house outside of Moore, Oklahoma, was affected by inflow winds associated with a severe 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 was not a safe refuge.

FIGURE 6-24: A 10-ft long 2-in by 6-in missile penetrated the exterior wall of this house in Wichita, Kansas, which was sheathed with hardboard panels. The missile, which was generated from the vortex of a severe tornado, then penetrated the gypsum board and tile tub enclosure, the tempered glass shower door, and the interior partition near the door frame. At the interior partition, it pierced through a wall stud and projected a few inches into the hallway (Figure 6-25).

FIGURE 6-25: The missile in Figure 6-24 impacted and broke a 2-in by 4-in wall stud after traveling through the bathroom.

FIGURE 6-26: This bathroom was on an exterior wall and had a window. It was not a safe refuge.

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 6-27). Therefore, greater protection was afforded when refuge was taken in interior bathrooms or closets on the first floor rather than the second.

FIGURE 6-27: 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 severe tornado.

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 sucked back out of the house. In other instances, missiles traveled 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 6-19).

Below-grade crawl spaces were also observed in Kansas. These spaces provided protection from missiles traveling horizontally, but as with basements, minimal protection was provided from free falling missiles when the house above was blown off its foundation. 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 not attached to properly constructed permanent foundations appear to be at significantly greater risk of injury or death than persons taking similar refuge in conventionally constructed housing (Figure 6-28). The bathrooms and closets of manufactured houses typically provide very little protection. The BPAT observed a possible exception in some of the newer manufactured homes placed on proper foundations, built to the Department of Urban Development's (HUD's) newer wind requirements, and designed to resist increased wind loads.

FIGURE 6-28: Damaged and destroyed manufactured homes in Wichita, Kansas, that were in the direct path of a severe tornado.

6.2.2 Refuge in Non-residential Buildings

The BPAT also investigated a selected number of public use buildings in order 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 6-29). Other individuals reportedly took refuge in a reinforced concrete stairwell adjacent to the auditorium.

FIGURE 6-29: 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 and cladding damage. The building construction consists of CMU walls with brick veneer and built-up roof over steel decking and steel bar 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 6-30). There were no exterior windows in the exterior wall 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 6-30: 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 double loaded corridors. Figure 6-31 shows a double loaded corridor of Northmoor that illustrates the corridor masonry walls topped with windows. Sooner Rose Elementary was a different construction type from the above, but contained similar windowed corridors (see Figure 6-33). Figure 6-32 shows a similar corridor in Kelly Elementary, which was destroyed by the storm. Obviously, had these corridors been used for shelter during the impact of a violent tornado, numerous injuries or deaths would have occurred.

FIGURE 6-31: Northmoor Elementary place of refuge, Moore, Oklahoma - double loaded corridor with clerestory windows. This corridor offers little protection from a violent tornado as shown in a school of similar design in Figure 6-32.

FIGURE 6-32: Kelly Elementary School, Moore, Oklahoma, place of refuge - double loaded corridor with clerestory windows. These interior corridor walls had brick masonry up to a height of approximately 7 feet. Glass extended from the top of the masonry to the top of the wall.

FIGURE 6-33: Sooner Rose Elementary School, Mid West City, Oklahoma. According to the tornado plan for this school, this hallway is designated as a place of refuge – double loaded corridor.

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, 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 gypsum board that is supported by studs, and a layer of gypsum board on the interior side of the studs (Figure 6-34). 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 6-35).

FIGURE 6-34: EIFS wall system torn from metal wall studs.

FIGURE 6-35: 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 multistory buildings generally provide a reasonable level of protection 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 6-36). Rooms with large ceiling spans such as auditoriums and gymnasiums should be avoided at all costs, unless specifically designed as shelters (e.g., more than 40 ft between walls or columns) 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 violent tornado vortex.

FIGURE 6-36: 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 Mid West City, Oklahoma. This bathroom was not a safe refuge when impacted by the vortex of a severe tornado.