MASONRY INSIGHTS

written in conjunction with International Masonry Institute

Masonry Storm Shelters & Safe Rooms

Tornadoes and hurricanes produce extreme meteorological conditions and forces on buildings with unpredictable outcomes. Providing safe structures for people to be during the storm events requires many specific design requirements not typically needed for a standard building that must be coordinated with the entire design team. Masonry is a great option due to the inherent strength, durability, and fire resistance of the material as well as being highly available throughout the US.

Design Standards and Definitions

- ICC 500 (2014 - Second Edition)
- FEMA P-361 (2015 - Third Edition)
- FEMA P-320 (2014 - Fourth Edition)

Storm Shelter: A building or structure (full or portion) designed and constructed per ICC 500 designated for use during a tornado or hurricane

Safe Room: an interior room or an entire building designed and constructed per FEMA 361 or 320 to provide *near absolute* life-safety *protection* for its occupants from tornadoes or hurricanes

Near Absolute Protection: safe room occupants will have a very high probability of being protected from injury or death based on current knowledge of tornadoes and hurricanes

Residential Safe Room/Storm Shelter: a safe room or storm shelter serving occupants of dwelling units and having an occupant load not exceeding 16 people.

Community Safe Room/Storm Shelter: Any safe room or storm shelter not defined as a residential safe room or storm shelter

The main difference between the ICC and FEMA documents is that FEMA provides best practices and recommended criteria as guidance for design and construction of safe rooms while ICC presents a codified document which has undergone the consensus standard vetting process. FEMA P-361 provides design criteria and commentary for community and residential structures (which are more stringent than ICC) while FEMA P-320 covers prescriptive solutions for homes and small businesses.

Structural Design Considerations

During a tornado or hurricane, there are many special load cases that must be considered during the design phase for a storm shelter or safe room. The first of the two main load cases is the high direct wind loads based on maximum ultimate winds speeds of 250mph for tornadoes and 220mph for hurricanes using ASCE 7-10 load cases. Since wind loads are based on the square of the wind speed, the tornado loads for example will be 4.7 times higher than the standard design wind load in the 115mph area for most of the U.S. Discussions with the design team are critical when determining whether a shelter is enclosed or partially enclosed. Enclosed shelters have specific requirements that must be met involving penetrations and venting whereas partially enclosed shelters do not.

Figure 1: ICC 500-14 Figure 304.2(1)
Shelter Design Wind Speeds for Tornadoes

The second major loading is from flying debris. All walls, roofs, and materials covering openings must be strength tested by withstanding the force of a 2x4 shot through the air at various high speeds depending on the requirements for the specific region in which the shelter or safe room is located. Masonry is a good material choice for these loadings due to inherent strength and durability. At a minimum the masonry must be solid grouted nominal 6" CMU with #4 rebar at 32 inches on center, however, the direct wind loading usually controls the reinforcement requirements. The design team must be aware that corner wind loads often exceed the tested capacity of the fabricated design elements; thus openings at the corners should be minimized or avoided.

Figure 2: ICC 500-14 Figure 304.2(2)
Shelter Design Winds for Hurricanes

For these strong storms, many other load cases need to be considered as well. Heavy dense debris can land on the shelter roof, thus minimum live loads are required (100 psf for tornadoes and 50 psf for hurricanes). Shelters below ground could experience hydrostatic, flood, and buoyancy loads. It is important to consider proximity to taller buildings, above-ground power lines, radio antennas, and even parking lots. The wind forces are strong enough to turn vehicles into projectiles that can go through walls or land on the roof.

After considering all of the possible load cases, the most critical part of the design

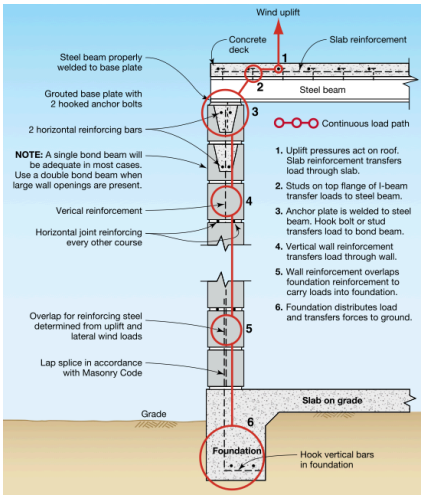

Figure 3: FEMA P-361 Figure B3-6 Continuous Load Path

is ensuring a continuous load path through the structure (see figure 3). Missing connections would be disastrous for the performance of the structure during an event, thus the contract documents must clearly detail all aspects of the load path. Following the load path, sliding and overturning of the structure must be reviewed. Due to the magnitude of the uplift forces, special inspection must be performed on all post-installed anchors. Fortunately, the weight of the solid masonry aids greatly with overturning and sliding resistance, but a close look at holdown connections to the foundation is still critical.

The final step of the design process is to have a peer review of the design completed by an independent licensed engineer experienced in the design of storm shelters or safe rooms to ensure all critical design requirements have been properly addressed.

Architectural Design Considerations

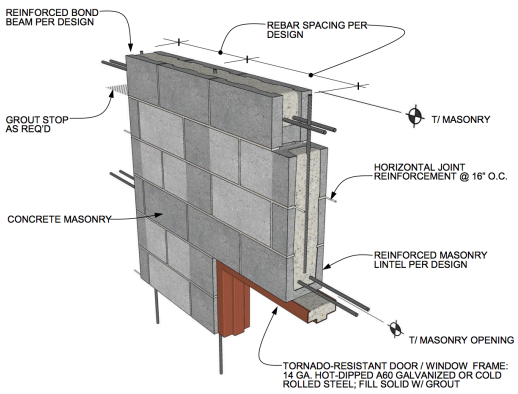

Figure 4: Storm Shelter Head Detail
IMI Masonry Detail Series,
http://imiweb.org/masonry-detailing-series/

The architectural design of storm shelters and safe rooms has many requirements beyond the impact testing material requirements of the exterior door and window openings of the structural envelope. There are many human factors to consider which include but are not limited to:

- Three design phases
  - Pre-event: opening shelter, getting occupants inside, locking
  - Event: structural envelope, deter people from opening protective devices
  - Post-event: evacuation, treatment of injuries, return shelter to original condition for daily use
- Entrances/Exiting/ADA
- Free-standing vs. connected to non-shelter structures
- Proximity to taller structures, adjacent structures with roof-top equipment, overhead power lines, radio towers, parking lots, etc.
- Flooding and flood zones
- Storm design duration
  - tornadoes = 2 hours
  - hurricanes = 24 hours
- Occupancy Density
  - Emergency power
  - Storage for water, food, and other supplies