

Masonry Storm Shelters & Safe Rooms

Tornadoes and hurricanes expose buildings to extreme meteorological forces, with highly unpredictable impacts. Designing structures that provide safety during such events requires adherence to specific standards beyond typical building codes. Masonry is an ideal material for storm shelters due to its inherent strength, durability, and fire resistance, as well as its availability throughout the U.S. This paper explores the design criteria and considerations for constructing storm shelters and safe rooms using masonry.



DESIGN STANDARDS and DEFINITIONS

Storm Shelter: The construction of storm shelters and safe rooms is governed by guidelines from the International Code Council (ICC) and the Federal Emergency Management Agency (FEMA). Defined per ICC 500 as a building or structure (or a part of it) designed to offer protection during a tornado or hurricane. Design requirements are codified in ICC 500, which has undergone a consensus standard vetting process.

Safe Room: As outlined by FEMA 361 or 320, a safe room provides near-absolute life-safety protection against tornadoes and hurricanes. "Near-absolute protection" implies a very high probability of protecting occupants from serious injury or death under the most extreme storm conditions.

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

Residential vs. Community Safe Rooms: Residential safe rooms cater to dwelling units with a maximum occupancy of 16 people. Community safe rooms serve larger groups and must accommodate higher occupancy and more stringent requirements.

The primary difference between ICC and FEMA standards lies in FEMA's prescriptive guidance for best practices, particularly in FEMA P-361 for community and residential structures and FEMA P-320 for smaller applications like homes and businesses.

STRUCTURAL DESIGN CONSIDERATIONS

When designing storm shelters, several critical load cases must be taken into account:

1. High Wind Load Requirements: Shelters must be engineered to withstand wind speeds up to 250 mph for tornadoes (Figure 1) and 220 mph for hurricanes (Figure 2), following ASCE 7-10 guidelines. The design wind load for tornado-prone regions can be nearly five times higher than the standard design load for typical buildings (e.g., 115 mph wind speed zone). Determining whether a shelter is classified as "enclosed" or "partially enclosed" affects the design, as enclosed shelters face stricter requirements regarding penetrations and ventilation.



2. Impact from Wind-borne Debris: All structural components, including walls, roofs, and coverings for openings, must be tested to resist the impact of debris such as a 2x4 timber propelled at high velocities, depending on regional requirements. Masonry's strength makes it a suitable choice for these applications, and the minimum specification generally requires solid-grouted nominal 6-inch CMU reinforced with #4 rebar spaced at 32 inches on center. In practice, reinforcement is often governed by direct wind loads, particularly in corner regions where wind pressures exceed standard design values. Minimizing or avoiding openings at corners is recommended to maintain structural integrity.



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

3. Additional Load Cases: In extreme storms, considerations extend beyond direct wind pressures and debris impacts:

Live Loads: Roofs must be designed to support minimum live loads of 100 psf for tornadoes and 50 psf for hurricanes to account for debris accumulation.

Below-Grade Shelters: Underground shelters must address hydrostatic pressures, potential flooding, and buoyancy forces.

Proximity Risks: Tall buildings, overhead power lines, radio towers, and adjacent parking areas can pose additional risks during storms, as objects can become airborne projectiles.



4. Ensuring a Continuous Load Path: Establishing a robust load path through the shelter is vital to its performance (Figure 3). Missing or inadequate connections could lead to catastrophic failure. Special inspections should verify the integrity of post-installed anchors, especially given the significant uplift forces

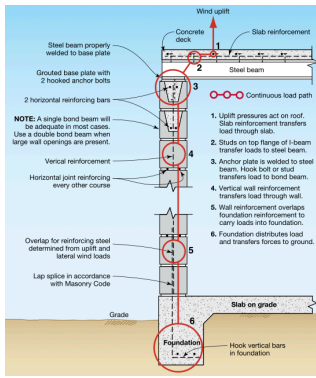


Figure 3: FEMA P-361

generated by storm winds. The self-weight of solid masonry walls contributes to stability against sliding and overturning; however, hold-down details and foundation connections must be scrutinized for adequacy.

5. Peer Review: To ensure that all design requirements are met, an independent review by a licensed engineer with experience in storm shelter design should be conducted.

ARCHITECTURAL DESIGN CONSIDERATIONS

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

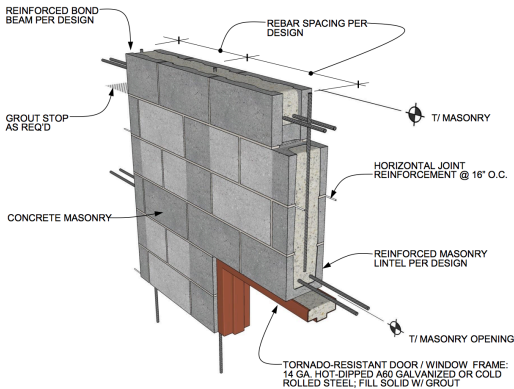


Figure 4: Storm Shelter Head Detail

IMI Masonry Detail Series,

<http://imiweb.org/masonry-detailing-series/>



The design of masonry storm shelters and safe rooms necessitates a comprehensive approach that integrates stringent structural requirements with practical architectural considerations. By accounting for all potential load cases and ensuring a continuous load path, engineers can design shelters that effectively protect occupants during the most severe meteorological events. Masonry's inherent properties make it a robust material choice for these critical structures, ensuring safety, durability, and fire resistance.