

SHELTER FROM THE STORM



Tornados, hurricanes, and other windstorm events can be deadly, and strike without warning. According to the Insurance Information Institute, in the United States tornados kill 70 people and cause \$400 million dollars in damage each year; annual losses caused by hurricane winds total \$54 billion. That's why, in communities susceptible to tornados and hurricanes, storm shelters are an essential part of building design.

Storm shelters are specialized structures designed to protect people during a severe windstorm event. There are two primary types, community storm shelters and residential storm shelters. Community storm shelters are commonly for places with more than 50 occupants and serve the general public.

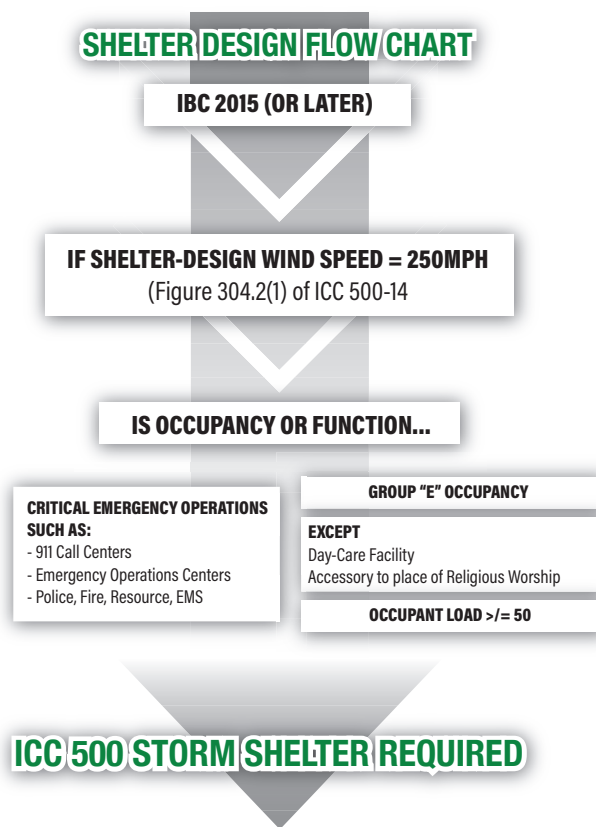
Residential storm shelters serve residential buildings with 16 or fewer residents.

Since the release of the 2015 International Building Code (IBC), storm shelters built in accordance with the ICC-500 code are required when located in a 250-mph wind-speed zone for tornados. In the United States, the impacted area includes much of the Midwest and central southern states, from Texas in the south to Minnesota and North Dakota in the north, and Kansas and Nebraska in the west to Ohio, Kentucky, and Tennessee in the east. Building occupancy types requiring shelters include education groups — from grade schools through universities — as well as critical public service facilities like police stations, fire stations, and other emergency



services centers. It is important to note that the code excludes this requirement for day-care facilities and places of worship. The code also includes expansions to existing facilities that fit these criteria.

As a result of those 2015 changes to the IBC, construction requirements are more stringent. They include higher levels of coordination in the building design, and more effort by the general contractors to ensure the shelters are built as designed and detailed. Contractors now must provide letters of responsibility to the municipalities that oversee the permits for these structures, stating they are aware of the additional effort involved.



ENHANCED FUJITA SCALE FOR TORNADOS The Enhanced Fujita Scale (EF), introduced in 2007, provides estimates of tornado strength based on damage surveys. The original scale was developed by Dr. Theodore Fujita and implemented in 1971.		
EF SCALE	WIND SPEED	TYPICAL DAMAGE
0	65-85 MPH	Peels surface off some roofs, some damage to gutters or siding
1	86-110 MPH	Roof severely stripped, mobile homes overturned or badly damaged, loss of exterior doors, windows, and other glass broken
2	111-135 MPH	Roofs torn off well-constructed homes; foundations of frame homes shifted; mobile homes completely destroyed
3	136-165 MPH	Entire stories of well-constructed homes destroyed; severe damage to large buildings such as shopping malls
4	166-200 MPH	Well-constructed houses and whole-frame homes completely leveled
5	200+ MPH	Strong frame houses level off foundations and swept away; high-rise buildings have significant structural deformation



Photo credit: Smiley N. Pool / dallasnews.com

DEVELOPING STORM SHELTERS

Storm shelters come in all forms. Some are stand-alone structures while others are designated rooms within a building or complex. For example, school music halls are often used as storm shelters because they tend to have sufficient room and reinforced walls for soundproofing purposes. Conversely, utilizing cafeterias as shelters requires more effort because they tend to have more windows that can be damaged or destroyed during storm events. For this reason, it is important to plan the location of your shelter very early on in your design efforts.

When considering where to place the shelter, it is important to consider both its location in the building's program and its vertical location. Ground-floor shelters are typically the safest, most cost-effective choice — but sometimes the ground floor isn't an option. Locating a storm shelter on the second floor increases the development cost by 15-20% because the shelter must be developed as a separate box that's suspended in the air. In this situation you have many more factors to consider including uplift, overturning, secondary force effects from building drift, and overall higher reactions at your foundation. If your only

choice is to put a shelter on stilts you are strongly encouraged to consider and design the space below as a shelter as well.

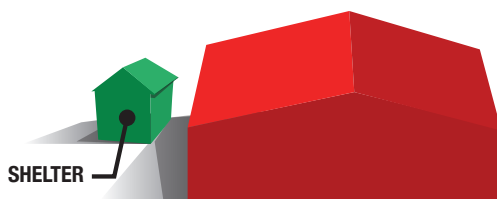
Ventilation is an essential element of storm-shelter design. A key consideration is whether to mechanically or naturally ventilate the space. This is one of the most important decisions that goes into storm-shelter development. It's important to provide a comfortable environment for occupants, but it's equally vital to keep debris out of the building. There are many variables that go into this decision, including the available development budget, the size of the space,

and whether it's intended to serve adults or children. Natural ventilation is less expensive, but much louder. Noise is an important factor for spaces intended to protect children because loud storms are extremely frightening. Also, it is important to consider the amount of forces and air movement in natural ventilation designs. Shelters meant primarily for children may not be a good fit for natural ventilation as the vents will allow infiltration of a large volume of air. Baffles or marked zones on the floors can be used to keep people away from low cross ventilation but this will be detracted from your useable space.

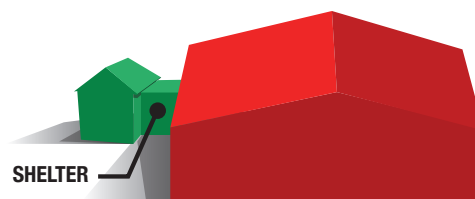
Conversely, in shelters designed to protect police or fire professionals, noise is a lesser issue. For these facilities, more focus is on maximizing usable square footage as there is generally not much available. The noise and pressure may have little impact on police and fire fighters, therefore making natural ventilation a viable option.

There are also choices in which materials to use. For smaller rooms, Concrete Masonry Units (CMU) work best with composite steel roofs. For larger spaces like theaters or cafeterias, a better choice is precast concrete wall panels and precast double Ts. Both have their advantages and disadvantages on the design and construction side. For larger rooms, cast-in-place concrete will also work, but this approach is more expensive and requires more skilled labor to properly develop. You must also consider your schedule to allow time for forming and concrete curing. The primary reason to pursue the cast-in-place approach is if the contractor is more comfortable working that way, rather than using a precast concrete system.

Hardware is another element that must be considered, especially doors and windows. Improperly located and installed doors can weaken a storm shelter. Doors and windows should be located away from shelter corners.



FREE STANDING



**FREE STANDING
W/CONNECTION**



SURROUNDED



**ABUTTED
(EXTERIOR)**



**ABUTTED
(INTERIOR)**



CONJOINED

The walls with windows and doors should be as solid as possible. It is vitally important that only hardware meeting the code's minimum-testing requirements is used in tornado shelters. Additionally, fire extinguishers shouldn't be recessed into walls because this removes CMU and weakens the protective barrier the wall provides.

When installed, the walls, doors, and roofs need to be tested to extremely specific specs, such as tornado-missile testing. This test launches a 2x4 projectile into walls and doors at speeds of up to 100 mph to determine whether the shelter component will withstand typical storm conditions. It's essential to rigorously test all hardware and external wall assemblies

for the impact force of debris, including mechanical screens such as louvers. All openings, including joints, gaps, or voids in shelter envelopes that are greater than 3/8-inches must be protected. The ICC 500 code provides all the necessary testing criteria these components must meet.

A final consideration — one WGI receives many questions on as both a designer and peer reviewer for shelters — is whether to connect the shelter to the host building. Typically, this is not a recommended practice, primarily because the ICC 500 code requires you design that connection to the full force up to failure. That means the shelter must resist the storm loading, plus whatever ultimate failure

load that connection can resist. If the host building is connected, there must be break-away connections between the building and shelter to assure that a host building's structural failure will not impact the shelter. This is difficult to achieve, considering the limited resources and research currently available. Generally, it will come down to a matter of engineering judgment. WGI encourages designers in this situation to consult early with their peer reviewer to establish a dialogue about requirements and interpretation of the code.

WGI's team of structural engineers are experts at working with building owners to determine exactly what type of storm shelter is best for each individual situation.



Tornado missile testing performed at Texas Tech University's National Wind Institute.



INDEPENDENT PEER REVIEW

Even after these choices are made and a storm shelter's design is complete, the process is far from over. It's essential to engage an independent registered reviewer to assess all of the plans, calculations, and quality assurance documents for general compliance with the current code. During the design process, additional reviews should be completed at 50% and 90% of design. WGI recommends a third follow-up review just prior to building

permit submittal. If the reviews raise any concerns or questions, additional reviews should be completed as required to meet general conformance with the code.

The independent review process protects the owner and the occupants of the shelter and, in some ways, can help the shelter's design team, too. A second pair of eyes helps diminish the probability of human error. It is important to remember responsibility for the shelter design falls

on the architect and engineers of record — their judgement, their expertise, and their seal are affixed to the plans and details. A peer reviewer is a recommended necessity, but no replacement for the designer's responsibilities.

WGI's storm-shelter experts can also provide independent peer reviews, and designs for

new shelters. The development of a storm shelter represents a significant investment, and it's important that essential aspects receive proper consideration and critical elements meet the stringent code requirements. WGI's independent reviewers can provide peace of mind, assuring that your storm shelter is properly designed and reviewed.

LET'S TALK.

For more information about this study or to have a conversation with one of our experts, please contact us:



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