On the Rise
The number of tornadoes in this country is on the rise. Whether this increase is due to global warming, better radar or more awareness by the public can all be debated, but are beyond the scope of this article. Unfortunately, the number of deaths due to tornadoes continues to increase also. In 2011, more than 550 people lost their lives in places like Joplin MO and Tuscaloosa AL due to major tornadic events. Effective shelters could have saved many if not all of these people.

FEMA Guidelines
What has been done to shelter design to reduce the death toll from these events? Over the past 40 years, construction guidance for tornado shelters has undergone an amazing transformation in complexity and effectiveness. In the early 1970s, the former Office of Civil Defense published a simple guide that highlighted some of the issues related to tornado shelter design. Then in 1998, FEMA published a document for small shelters, mainly for use in residential and small
2015 IBC is reflecting a big change relative to storm shelters, specifically tornado shelters. It states the following:

**423.3 Critical emergency operations.** In areas where the shelter design wind speed for tornadoes per Figure 304.2(1) of ICC 500 is 250 MPH, 911 call stations, emergency operation centers and fire, rescue, ambulance and police stations shall have a storm shelter constructed in accordance with ICC 500.

**Exception:** Buildings meeting requirements for shelter design in ICC 500.

**423.4 Group E occupancies.** In areas where the shelter design wind speed for tornadoes is 250 MPH per Figure 304.2(1) of ICC 500, all Group E (Pre-Kindergarten-12) Occupancies with aggregate occupant load of 50 or more shall have a storm shelter constructed in accordance with ICC 500. The shelter shall be capable of housing the total occupant load of the Group E occupancy.

**Exceptions:**
- Group E day care facilities.
- Group E occupancies accessory to places of religious worship.
- Buildings meeting the requirements for shelter design in ICC 500.

Please note the operative word shall. The model building code now requires tornado shelters for the occupancy types noted above located in the 250 mph wind zone. (Figure 1) For these occupancy types, choices have been removed from owners and designers on this matter where the 2015 code has been adopted. These code requirements do not just affect what is commonly known as Tornado Alley which some define as this narrow strip of area from Kansas to Texas. The 250 mph wind zone effects 23 states! Understand that FEMA has defined risk assessments for tornadoes. FEMA indicates that the risk to people's safety is just as great in the 200 mph wind zone as the 250 mph. Code is the minimum, however when one is designing a structure in the 200 mph wind zone, one may want to consider FEMA's risk assessment.

Shelters Withstand 250 mph Wind Event

So what can be done to comply with these new code requirements? The obvious answer is to design and engineer space that can withstand the wind loads produced by a 250 mph wind event and also resist the debris impact associated with these events. There are many strategies to accomplish this; concrete masonry is high on the list of optional materials.

Many impact tests have been conducted and well documented utilizing different thicknesses of concrete masonry with different reinforcement and even include cavity wall type construction. The impact loads can be large, but in most cases, it is actually the wind load that will govern the design of the protective envelope of the shelter. Designers must understand those differences between debris testing and wind loads. Do not get caught up in these debris tests thinking that this is all one has to address in one’s design. They are merely a jumping off point. In fact, passing the debris impact test is usually the easier
requirement when compared to the need to survive the extreme positive and negative pressures exerted on walls during a tornadic event. For that reason, in most cases, the wind load will govern the design of the wall.

When designing a tornado shelter for a building owner, a designer looks for opportunities to provide multi-use shelters, the perfect solution for the situation. A building owner has the possibility of using that shelter, designed correctly, more often for other uses than as a shelter itself. No one particular structure is facing violent storms every day of the year. If it does, then it is probably time to move!

In school occupancies, small gyms, multi-purpose rooms, classrooms, cafeterias and music/band rooms are all possible multi-use shelter spaces. In a fire station, it could be the dorm/sleeping quarters, training room, conference room or cafeteria that could serve as shelter space. And in a 911 dispatch center, the dispatch area itself would be a good choice. All of these fall under the category of community safe room/storm shelter.

**Community Shelters**

By definition, a community shelter is one that is not associated with a dwelling unit or has an occupant load of less than 16. Community shelters do not have to be open to the public. They may be designed for the host building occupants only. However, community shelters may be opened for public use. Responsible parties must give a great deal of care to creating the vitally important shelter management plan for public use shelters. Issues that must be addressed include:

- Who is going to open the shelter?
- When is the shelter going to be opened?
- Who determines when the shelter is full?
- Who is going to lock the shelter down?
- How is security with the shelter addressed?

This is just the tip of the iceberg with the issues that must be addressed for a public shelter and **everything must have a backup plan with a backup plan. Redundancy is crucial.** For more management plan information, reference the FEMA 361 document.

**Reinforced CMU**

In many types of structures noted above, concrete masonry, with perhaps some type of masonry veneer, is commonplace and fits well into the protective envelope of the shelter.

Fully reinforced concrete masonry is a good choice for shelter walls for the following reasons:

- **Common product, widely and immediately available**
- **Ease of construction**
- **Durability for day-to-day use**
- **Compressive strength to resist tornadic wind and debris loads**
- **Flexibility of use for shelter protection and non-shelter applications**
- **Flexibility in unit size**

- **Small modular size adds flexibility in the shelter designs**
- **Sound attenuation minimizes exposure of sound produced by tornadoes to shelter occupants reducing possibility of post traumatic issues**
- **Can easily blend with existing host structures**
- **Provides a finished surface or surface ready for finish**
- **General public’s perception and trust in CMU being a strong material that will keep them safe**

**Without proper design for continuous load path, there may be a failure which could cost shelter occupants their lives.**
Continuous Load Path
When one is designing any tornado shelter, one must follow the Golden Rule which is accounting for continuous load path from wall to wall, from roof to foundation and all parts in between. So what is continuous load path? Simply stated, it is the old thigh bone connected to the knee bone, the knee bone connected to the shin bone, etc. As shown in the diagram, continuous load path provides a load that is exerted on the roof, walls, and/or opening protective devices such as doors, window shutters, etc. It is a path that carries the load(s) to the foundations and eventually into the ground below and around the shelter. The schematic diagram denotes the use of concrete masonry units and load path considerations. Without proper design for continuous load path, there may be a failure which could cost shelter occupants their lives.

The Peer Review
It cannot be stated strongly enough how important peer reviews are in tornado shelter design. If a designer makes a mistake with the design of the shelter, that mistake may not expose itself until the shelter occupants need the protection of the shelter the most – during the tornado strike. At that point, it is too late to make adjustments. One mistake could cost one or hundreds of shelter occupants their lives. Occupants have trusted the design team’s experience and capabilities to keep them safe, to live another day in the wake of one of the strongest natural forces on this planet. That should not and cannot be taken lightly by any designer. A designer needs to bear in mind that it could be your parent, your spouse, your child, and/or your friend whose life is dependent upon what you have designed. If you are not an experienced tornado shelter-safe room designer, find someone to put on your team that knows what these are about. If you are an experienced shelter designer, find someone that is also experienced to do the peer review for you, just in case.

Reasoning for the change
Let’s think about this. In a tornadic event, who helps keep law and order, assists those that are in need due to injury or being trapped and directs those services to the proper locations? It is the first responders of course! The 2015 IBC now attempts to assure that those first responders that could be effected by the same storm as the general public they are protecting have some sort of protection themselves. The intent of this requirement is not to protect equipment; the shelters are required to protect the individuals and their training and experience for which the public / taxpayers have paid. Then post-event, they are alive and well able to put that training and experience to the use for which it was intended.

Where do the E (Pre-Kindergarten-12) occupancies come into the picture? As parents, when we put our children on the bus every morning, there are two things that we expect and many times take for granted:

1] We expect our children to learn something which is why we send them to school.
2] We expect at the end of the day that our children will be returned to us safely.

Unfortunately, the reality is that this is not always the case, for different reasons. For example, the shootings at Columbine High School or Sandy Hook Elementary were both tragedies where 12 and 20 students respectively were killed. Truly, truly tragic. But let’s not forget the eight Enterprise High School students in Enterprise AL, and seven Plaza Towers Elementary School students in Moore OK, that perished in tornadic events while at school. Equally as tragic as the shootings. The number of children who lost their lives in the tornadic events may be lower than the shooting events, but one must consider what type of events can wipe out an entire school population in a matter of a minute? A tornado is definitely high on that list and therefore the code has reacted to that possibility.

Code changes for shelters are long overdue, but better late than never. We now know how to properly design/engineer shelters. The use of masonry is a good and viable choice for the protective envelope of any tornado shelter/safe room. As with any material though, it is only as good as the design, detailing, engineering and construction. Follow the Golden Rule and get assistance from experienced designers and engineers when you need it. At the end of the day, you will have the satisfaction of knowing that any shelter you design and/or construct will actually protect someone’s life.

Sound attenuation minimizes exposure of sound produced by tornadoes to shelter occupants reducing possibility of post traumatic issues.

References
1 The FEMA P-320 and P-361 and many other tornado shelter resources are available free of charge from FEMA’s website at www.fema.gov/safe-room-resources
2 The ICC-500 is available for purchase at www.iccsafe.org

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