National Concrete Masonry Association

Concrete Masonry Storm Shelter Case Study Design Commentary

2015

Commentary accompanying case study construction drawings explaining architectural and structural design decisions for a hypothetical concrete masonry tornado storm shelter addition to a Kansas elementary school.

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Preface

The purpose of this document is to provide architects and engineers an opportunity to step into the shoes of an experienced shelter design team to understand the shelter decision making process.

The information and documents in this case study and commentary have been provided for information purposes only to assist architects/engineers in understanding tornado shelter design. They are not intended as an end-product. Any use or reuse of the information or documents will be at the end user's sole risk and without any liability or legal exposure to the authors or the National Concrete Masonry Association. This case study should provide an architect and/or engineer a design comparison to their own designs only.

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Introduction

Tornadoes Shelter Case Study

This hypothetical above ground community storm shelter is located in Kansas, is a multi-use (classroom) addition to an existing 3 section elementary school to support approximately 775 occupants. The shelter is designed for use by the school occupants and is not intended as a public shelter. An addition has been selected to assist in understanding the issues of a shelter as an addition to an existing host building and because in the near future based on the storm shelter requirements of the 2015 International Building Code (IBC) there is a likelihood to be more storm shelter additions to existing facilities than there will be new structures with storm shelters incorporated into them.

This case study utilizes concrete masonry construction for the main wind force resistant system relative to the walls.

Architectural Issues

Layout

The shelter layout consists of four, 1,000 sf kindergarten rooms. In elementary schools, kindergarten rooms work well for the following reasons;

- Larger rooms - Kindergarten rooms are typically larger thus allowing for more occupants
- Furnishings – Kindergarten rooms typically utilize tables and chairs in lieu of typical classroom desks allowing tables to be easily stacked on top of one another allowing for better utilization of space. This would allow for a 65% utilization factor in lieu of 50%.
- Toilets – Kindergarten rooms typically have restrooms programmed with them making the cost of the shelter more cost effective.
- Small children move the slowest – In a school setting, ideally, one wants to place the shelter closest to the people that move the slowest i.e. Pre-kindergarten, Kindergarten, First Grade, and Special Needs.

The layout selected by the designer is a free-standing structure with physical connection. This allows shelter occupants to access the shelter without the need to go outside where there maybe torrential rain, large hail, and/or small debris that could create access problems.

This configuration allows the corridor to be effectively utilized as shelter space due to the fact that it is located within the shelter envelope in lieu of being the shelter envelope.

Occupant Load Calculations

Areas planned to be used for shelter occupants are the classrooms, corridor, and hallways. Areas not included in the occupant count are the restrooms, storage room, vestibule, and janitor's closet/electrical room.

This case study, the following reduction factors were utilized

- Classrooms – 35% reduction based on the type of furniture to be utilized which in this case are tables and stackable chairs in lieu of student desks, typical 8" CMU wall thicknesses, and minimal cabinetry. Note: If typical students desk would be located in the classroom, a 50% reduction factor would have been applied due to the large amount of space a typical student desk occupies.

- Corridor and Hallways – 15% reduction based on typical 8” CMU wall thicknesses, and allowances for door swings, space for drinking fountains, etc.

Many designers want to utilize all restrooms for shelter space. This can be problematic especially when a restroom is required by the ICC-500. If the restrooms are calculated full of shelter occupants and one person needs to use the restroom, you are swapping 7-10 occupants for one. Therefore, the main part of the shelter would be undersized. If absolutely necessary, restrooms required by the code standard and/or funding agency should have an occupant load of one, period. If restrooms are provided over and above what is required by the code standard and/or funding agency, and the additional restrooms are not providing floor area for additional shelter occupants, then the additional restroom facilities may not be eligible for funding therefore those additional restrooms may need to house shelter occupants.

In this case study, three restrooms are required by the code standard, so to ease potential shelter management confusion, all four are utilized as restrooms.

The storage rooms were not calculated as occupied because one never knows how much stored materials over time may end up in each one of these rooms. Therefore, one cannot plan on *any* open floor space in a storage room. So why include the storage rooms within the shelter envelope? For a few reasons

- Day-to-day use of the room requires it to be directly adjacent to the room it supports.
- The storage rooms in this case provides a home to the first aid kit, NOAA radio, emergency communications, tools, etc.
- It would be impractical and cost prohibitive to separate the storage room from the rest of the shelter. It would require a separate roof structure, the walls of the storage rooms would need to be reinforced as a shelter wall and tested door assemblies would be required. By the time one does this, it is more practical just to include the square footage within the envelope.

Siting

There are many factors to consider when siting the shelter relative to an existing host building as well as if it was a part of a new structure.

Central Location

- It is always preferable to site a storm shelter centered within the structure to allow easy and quick access for the shelter occupants. With that said, it is not always possible/practical to accomplish this. It may be due to the layout of the existing building, the programmed space of the shelter relative to the existing building, or site restrictions.
- This addition is located at the end of a centrally located classroom wing.
- This project is an above ground in lieu of below ground. In below ground shelters, one does not have to address the wind loads on the walls, however issue that have to be addressed include but are not limited to; soil pressures, handicap accessibility issues, waterproofing issues, ventilation issues are more difficult, and post event evacuation issues.

Access

- For ease of access, this storm shelter corridor aligns with the existing corridor.
- The finish floor elevation matches the host building minimizing handicap accessibility issues.

Connection

- The storm shelter addition has been located away from the host building (free standing with a physical connection) for the following reasons:
  1. Construction

     1.1 This construction time frame of this structure will exceed the normal school summer recess. Many jurisdictions will not allow the host building exterior doors to be blocked during construction. The classroom addition minus the connection can be constructed while school is in session, maintaining the existing exit. The connection design as a framed structure with minimal walls can be constructed during the summer recess.

     1.2 Shelter foundations can be sizeable and may not be conducive to an eccentrically loaded configuration. Freestanding the storm shelter minimizes conflict between existing and new foundations.

     1.3 Since the shelter is for the most part free standing, it is much easier to address separate roof structure for the shelter. The framing for the connection is separate from the shelter. An expansion joint between the shelter and the connection is planned thus the shelter is structurally separated from the host building and the connection.

  2. Minimize the 2-hour separation requirements

2.1 The free standing configuration allows the design team to separate the shelter as a separate building and providing an assumed property line between the buildings minimizing the possibility of renovation of the existing building wall. The connection becomes a part of the host building (unoccupied).

2.2 The fully reinforced CMU shelter walls easily meet the fire separation requirements without any additional concessions.

3. Eliminate dead end corridor

3.1 Any shelter doors with panic devices MUST open to the shelter exterior therefore the connection allows for the north set of corridor doors to open to the exterior along with the existing exterior door opening in the direction of travel.

Located away from taller structures

- There were several locations this addition could have been located. Two of the locations were adjacent to taller structures, Media Center and Gymnasium. In an effort to minimize the possibility of those structures collapsing onto the shelter, the designer chose to locate the shelter away from any higher structures.

Post event shelter evacuation

- The free standing with a physical connection strategy aids in post event shelter evacuation because a majority of the exterior walls of the shelter are open. With doors swinging to the exterior of the shelter, it takes very little debris to block the doors to the shelter. In this case, there are two doors from the shelter located on opposite walls. If wind born debris is pushed into the windward wall of the shelter, then the likelihood of debris blocking the other door is minimized. If both doors happened to be blocked, the window shutters swinging to the shelter interior should allow for shelter evacuation.

Envelope materials

Walls

- The bearing elevation of the deck is 114’-0” thus making it suitable and easily achievable design with 12” fully reinforced CMU. In this design, the wall bending and uplift require two vertical rebar properly spaced thus the need for the 12” CMU. The wall thickness also provides additional dead weight helping to resist uplift loads.

- The corridor walls are bearing and are therefore CMU. The CMU provides a durable finish that is common in school construction.
- The designer selected the balance of the partitions to be CMU for consistency and durability.
- The exterior parapet wall sitting on top of the roof slab is designed to break away without being detrimental to the shelter wall or roof system since the parapet is subject to debris impact and wind load from both sides of the wall. Although the parapet is intended to be sacrificed during a wind event, it was also included in the main wind force resistant system to account for additional over strength concerns of the connection.

Roof

- With the roof spans at a maximum of 32'-8" and for ease of connections, the designer chose to utilize wide flange steel members, with 1 ½" galvanized composite roof deck with fully reinforced concrete slab over the deck.
- The steel roof members allow for easy attachment of items such as opening protective devices and ductwork work.
- The steel deck also serves as a membrane to keep any concrete that due to debris impact spalls off on the shelter side of the slab. This membrane keeps the concrete from becoming internal debris.
- The thickness of the roof slab is slightly thicker than what is required but the 8" dimension between the deck bearing and top of slab courses with the CMU and brick which in turn saves labor costs.

Doors

A designer should attempt to minimize the number of shelter doors for the following reasons:

1. The weight of the door can be problematic for the younger (shorter) students to get enough leverage on the hardware to activate it and push/pull the door open.
2. If improper door hinges, weight, size, and number, are installed, the weight of the door alone can cause it to sag and may keep the hardware from operating properly.
3. The doors, frames, anchorage, and hardware can make the doors rather expensive. It is not uncommon to budget $5,000/door leaf for shelter doors with panic devices, installed.
4. It is preferable to put tornado doors and/or shutters on hold-opens, either mechanical or magnetic as the code requires. A designer wants to minimize the number of cycles that a door has to go through on any given day. The less the number of doors and the

less the cycles, the less possibility that the door will malfunction when it is needed the most.

5. Additional openings in the shelter envelope reduces the redundancy of the shelters structural system.

In this case study, the north doors (1 ½ hour rating) are on magnetic hold open connected to the fire alarm, the south doors and all of the window shutter are on mechanical hold opens.

It is important for the designer to understand what is available by door manufacturers at the time of design. This is an ever changing industry and what was not available last month may be available now and what is available from one manufacturer may not be available from another.

Windows

Daylighting may be extremely important for the multi-use function of the shelter, in this case a classroom. There are several ways to address window openings from shutters used in this case, to tornado resistant storefront, to glass brick systems.

Window Shutter System

- The decision for the case study was to use a typical aluminum window unit with an awning vent, laminated glass in the insulated glass unit, and a four sided hollow metal frame and shutter unit as the opening protective device. The window units are sacrificial. The laminated glass is there to buy a little insurance to make sure that the glass, even if hit with small debris will stay in place long enough to get the shutter closed. You do not want a shelter occupant to have to close a shutter against a 60, 70, 100 mph wind coming through a broken window. If the shutter doesn't get closed, then all the shelter occupants could be at risk.
- Elementary school teachers typically like to have windows to be operable. To date, this is the only way to achieve a cost effective operable window in a tornado shelter.
- Windows with shutters can be a secondary means of evacuation of occupants. Other window protective devices typically will not.
- A word of caution using operable windows and shutters; hopper window configurations may interfere with the shutters and/or frames minimizing how much the hopper window can open.
- Another word of caution with window shutters; if utilizing a four sided frame, make sure that you specify a 1/4" undercut on the shutter itself. Otherwise, the normal undercut on a door will be provided which is typically 5/8"–3/4" and therefore the

bottom of the shutter will be above the stop of the frame. That look is not very appealing and the fix may be just as bad!

Other Window Protective Systems

- If you chose to utilize one of the other window systems, it is recommended that blinds be installed on the interior and as a part of the management plan, they are closed during an event. Some shelter occupants do not need to see what is going on outside the shelter during the event.

Ventilation

Shelter Ventilation

- The shelter ventilation system for this case study utilizes natural ventilation. Natural ventilation utilizes convection for its primary source of operation however, there may be some air movement i.e. wind that is moving air through the shelter. This system was selected because typically, it is much cheaper in initial cost and in long term maintenance costs than mechanical ventilation schemes. Mechanical ventilation needs some sort of emergency backup power source that in itself needs to be protected the same as a shelter occupant would plus must be maintained.
- The low (intake) ventilation openings have utilized a similar layout to the alcove entry layouts in Chapter 8 of the ICC-500 2014. One is just moving air through the system instead of people. This allows for minimizing small debris that may enter the shelter through the louver. The configuration shown in the case study does not require an exterior louver that has been tested for debris. However, if a tested louver is provided, consideration should still be given on keeping the small debris out of the shelter.
- The upper opening (exhaust) has been installed in the roof. A typical gravity vent on a curb is provide at the roof while a tube frame is provided at the level of the concrete deck and a steel plate anchored to the bottom of the steel roof beams with tube supports has been provided to stop large and small debris from entering the shelter.
- Consideration needs to be given on how the air travels through the shelter whether it be interior doors remaining open, ceiling plenum grilles, and/or transfer grilles.
- In areas where the winter temperatures are a factor, some type of louver should be provided that will remain closed in the winter and may be utilized only when an event has taken out the electrical power for the mechanical system. These louvers may be on a small battery backup system that can still be controlled after power goes out via a ventilation switch within the shelter or one can use a fail open

configuration but this could cause problems during winter days, such as power failures due to ice storms, etc.

Main Ventilation System

- The main mechanical system is roof mounted equipment (RTU's) on curbs. Structural should provide some sort of anchorage to keep these unit in place for as long as possible. The duct penetrations are a steel plate duct assembly that is supported by the roof beams and tube supports to protect for missile debris should the RTU be removed during the event.
- It should be noted that the opening protective devices need to be sized according to the size of the opening through the protective envelopes. A missile line of travel (line of sight) should be established to determine the size of the protective device.
- Care must be given in the coordination of duct penetrations though bearing walls relative to the roof structure. The roof structure requires the walls to resist uplift and duct penetrations CANNOT interrupt this load path.

Plumbing

Water Supply

- The water supply for this shelter comes in from underground and rises within the shelter envelope. Bringing the line into the shelter overhead from the host building through the connection and into the shelter is not acceptable because one must assume that the host building has been completely destroyed therefore the water would also be lost. Running it underground give some protection to the shelter water line even though one will experience a reduction in water pressure within the shelter assuming other lines on the same system have been damaged and are free flowing.

Gas Supply

- Gas fire roof top units have been provided in an effort to keep the gas lines on the exterior of the shelter. Water heaters in this case are electric.
- If one must run a gas line into the shelter, provide a remote solenoid gas shut off valve, fail closed. Power off, gas off. Another option would be a remotes excess flow valve. Gas line breaks, free flow of gas is shut off with excess flow valve.
- If the gas line running into the shelter is damaged at the point of entry, without the solenoid valve or excess flow valve, gas could be dumped into the shelter making a hazard for shelter occupants. If possible, avoid gas lines running into the shelter.

- If the gas line is running on the roof, consideration should be given to installing some type of automatic valve. If a roof top unit is move off the curb, the gas line could break at the roof top dumping gas into the opening left by the roof top. This very scenario occurred at an elementary school storm shelter in Wichita, Kansas in April, 2015. The event occurred during the night but when school resumed the next day, the gas had been entering the storm shelter for approximately eight hours rendering it useless until the storm shelter was fully ventilated.

Roof penetrations

- Per the ICC-500 2014, any opening greater than 3 1/2 square inches or 2 1/16" diameter shall be protected as an opening. That means if you have a vent pipe from the toilets/lavatories or a flue from a gas water heater that is larger than 2 1/16" diameter, then it needs to be protected with an opening protective device. To date there are no "off the shelf" protective devices for these openings. The case study provides a 90 degree, schedule 40 steel pipe penetration device that is poured with the concrete. The 90 degree pipe does not allow any debris to come directly into the shelter and should a large debris item hit the device, secondary framing should keep it from becoming internal debris.
- Vent pipe systems can be divided into smaller openings i.e. less than 2 1/16" and may not require any protective device.

Electrical

Lighting

- Lighting is one of the most important human factors in a storm shelter. In the case study, for the sake of redundancy, multiple battery operated egress lights have been provided in each occupant area. They are specified to have a minimum of 120 minutes of power supply. It is recommended that additional rechargeable flashlights or chemical glow sticks be provided in case power is out and occupants must spend more than 2 hours in the shelter.

Power Distribution

- As stated above in the roof penetration section, opening greater than 3 1/2 square inches or 2 1/16" in diameter must be protected. Electrical contractors may have a tendency to cut one opening and bundle many conduit through that one opening. This can be a big problem.
- The conduit running into the case study storm shelter are run under slab.

Structural Issues

Main Wind Force Resistant System Design Considerations

- The Main Wind-Force Resisting System (MWFRS) of the case study consisted of a reinforced concrete masonry unit bearing wall system, with the walls acting as shear walls. The reinforced masonry walls transferred the lateral wind load vertically between the slab on grade and composite concrete slab on metal deck. The composite concrete slab on metal deck, in combination with the wall dowels, steel beams, and shear connectors, transfer the wind loadings to the perpendicular reinforced masonry shear walls. These masonry shear walls then transfer the wind forces to the footings, which dissipate the load into the surrounding soils.
- Although two allowable methods are indicated in the ASCE7-10 design guide (Direction Procedure and Envelope Procedure), the designer chose to determine the MWFRS loads using the Directional Method as a personal preference and consistent with previous versions of FEMA 361 guidelines.

Foundations

- The foundation system of formed foundation walls with spread footings was selected based both on economics and typical soil conditions encountered in Kansas. By utilizing foundation walls and spread footings, the weight of the soil above the footing projection could be utilized to resist uplift and overturning loads, in addition to allow footing projections needed to comply with bearing pressure requirements.
- Although a shallower depth may be acceptable to meet local jurisdiction requirements, the foundation walls depth and footing thickness was reviewed to ensure the connection capacity of the adjoining elements.
- Another type of foundation that was considered for the case study was a trench footing system where the foundation walls and footings are poured as a solid mass. However, after footing projections had been determined, the footings would be exposed above finish grade.

Walls

- The primary reason for the selection of the masonry walls is indicated in the Architectural portion of the commentary. However, the use of masonry walls also provide a solid structural system that meets the loading requirements and gives some flexibility to achieve load paths.

- To simplify the construction of the walls, the designer has attempted to provide similar details at multiple locations and reduced the bar stress to allow for shorter laps in the masonry reinforcement as allowed by the International Building Code.
- Reinforced horizontal bond beams were utilized to assist in vertical and horizontal load distribution throughout the wall and around openings. However, steel lintels were utilized over the openings for additional vertical and lateral load capacity.

Roof Structure

- The roof structure selected for the case study was a composite concrete slab on metal deck, supported by steel beams. Shear connectors were utilized to provide both composite action in the steel beam framing and a positive attachment between the concrete slab and steel beams to transfer uplift loads.
- The concrete slab is reinforced to transfer uplift loads between the steel beams, transfer diaphragm shear to supporting walls, create chord and drag struts, and assists in restraining the steel beam connections. Although the composite metal deck was used for gravity loads, it also created redundant structural support and was used as a containment element for spalling concrete in the event of larger missile impact.

Custom Opening Protective Devices

- In order to protect miscellaneous openings from missile penetrations in the roof, steel framing was used to create baffle assemblies, similar in concept to the baffled entry systems in Chapter 8 of the ICC 500-2014. For the smaller openings, steel box structures were created and supported to meet the missile impact criteria and designed for the wind load pressures. Larger openings were protected similar to the smaller openings using the entire beam spacing as the “box” structure. Although not specifically required by the ICC 500-2015, the larger openings are also protected with steel framing in the plane of the concrete roof slab to assist with the potential impact of larger debris.

Miscellaneous Issues

- Consideration for interior pressure distribution was also considered in the case study, and should be considered in larger shelters where solid wall framing compartmentalizes a shelter space. For the case study, the interior load bearing walls were designed for the internal pressure of the wind forces to ensure structural performance during the tornadic event.

Structural Calculations

Wind Load Calculations per the ASCE 7-10

General Data

H = 14.67 ft.	Building Height	
L = 86.67 ft.	Building Length	
B = 79.33 ft.	Building Width	
P = 16.67 ft.	Parapet Height	
V = 250 mph	Safe Room Design Wind Speed	(Figure 304.2(1), ICC 500-2014)
Exposure C	Site Exposure	(Section 304.4, ICC 500-2014)
$K_d = 1.0$	Directionality Factor	(Section 304.3, ICC 500-2014)
$K_{zt} = 1.0$	Topographic Factor	(Section 304.5, ICC 500-2014)
$GC_{pi} = \pm 0.55$	Internal Pressure Coefficient	(Section 304.7 Exception ICC 500-2014)
G = 0.85	Gust Effect Factor	(Section 26.9 of ASCE 7-10)

MWFRS (Directional Procedure) per Chapter 27 of ASCE 7-10

Velocity Pressure (Eq. 27.3-1 of ASCE 7-10)

$q_z = q_h = 0.00256 K_z K_{zt} K_d V^2$ (lb/ft^2)

$K_z = K_h = 0.849$ $K_p = 0.849$ (Table 27.3-1 of ASCE 7-10)

$q_z = q_n = 135.8$ psf $g_p = 135.8$ psf

Wall Pressures (Eq. 27.4-1 of ASCE 7-10)

$p = qGC_p – q_i (GC_{pi})$

C_p Varies (Table 27.4-1 of ASCE 7-10)

L/B = 1.09

Windward Wall	$C_p = 0.8$
Leeward Wall	$C_p = -0.5$
Side Wall	$C_p = -0.7$

Roof Pressure (Eq. 27.4-1 of ASCE 7-10)

$p = qGC_p – q_i (GC_{pi})$

C_p Varies (Table 27.4-1 of ASCE 7-10)

H/L = 0.15

0 to H/2 C_p = -0.9, -0.18

H/2 to H Cp = -0.9, -0.18

H to 2H Cp = -0.5, -0.18

>2H Cp = -0.3, -0.18

Parapet Pressures (Eq. 27.4-4 of ASCE 7-10)

$p_p = q_p (GC_{pn})$

GCpn = +1.5 (Section 27.4.5 of ASCE 7-10)

GC_{pn} = -1.0

MWFRS Load Summary

Surface	**q_hGC_p**	**q_hGC_{pi}**	**Pressure w/ $+GC_{pi}$ (psf)**	**Pressure w/ $-GC_{pi}$ (psf)**
Windward Wall	92.4	+/- 75.0	17.7	167.1
Leeward Wall	-57.7	+/- 75.0	-132.4	19.1
Side Wall	-80.8	+/- 75.0	-155.5	-6.1
Leeward Roof	Included in Windward Roof			
Windward Roof				
0 to H/2	-103.9	+/- 75.0	-178.6	-29.2
H/2 to H	-103.9	+/- 75.0	-178.6	-29.2
H to 2H	-57.72	+/- 75.0	-132.4	17
> 2H	-34.63	+/- 75.0	-109.4	40.1

Windward Parapet = 208.3 psf
Leeward Parapet = -138.9 psf

Components and Cladding (Part 1) per Chapter 30 of ASCE 7-10

Velocity Pressure (Eq. 30.3-1 of ASCE 7-10)

qz = qh = 0.00256KzKztKdV2 (lb/ft2)

Kz = Kh = 0.849 (Table 30.3-1 of ASCE 7-10)

qh = 135.8 psf

Wall Pressures (Eq. 30.4-1 of ASCE 7-10)

p = qn [(GCp) – (GCpi)]

GCp Varies (Figure 30.4-1 of ASCE 7-10)

Note: Values of GC_p may be reduced 10% for roofs w/ slope < 10° but were not used here.

Effective Area = 10 sf

Negative Zone 4	GC_p = -1.1
Negative Zone 5	GCp = -1.4
Positive Zone 4 & 5	GCp = 1.0

Effective Area = 100 sf

Negative Zone 4	GCp = -0.92
Negative Zone 5	GCp = -1.04
Positive Zone 4 & 5	GCp = 0.82

Effective Area = 500 sf

Negative Zone 4	GCp = -0.8
Negative Zone 5	GCp = -0.8
Positive Zone 4 & 5	GCp = +0.7

Corner Zone Width (Figure 30.4-1 of ASCE 7-10)

a = > 0.10 (B) = 7.93 ft.

0.4 (H) = 5.87 ft. **< = Governs**

0.04 (B) = 3.17 ft.

Minimum Width = 3.0 ft.

Roof Pressures (Eq. 30.4-1 of ASCE 7-10)

p = qh [(GCp) – (GCpi)]

GCp Varies (Figure 30.4-2A of ASCE 7-10)

Effective Area = 10 sf

Negative Zone 1	GCp = -1.0
Negative Zone 2	GCp = -1.8
Negative Zone 3	GCp = -2.8
Positive Zones 1, 2, & 3	GCp = 0.3

Effective Area = 100 sf

Negative Zone 1	GCp = -0.9
Negative Zone 2	GCp = -1.1
Negative Zone 3	GCp = -1.1
Positive Zones 1, 2, & 3	GCp = 0.2

Effective Area = 500 sf

Negative Zone 1	GCp = -0.9
Negative Zone 2	GCp = -1.1
Negative Zone 3	GCp = -1.1
Positive Zones 1, 2, & 3	GCp = 0.2

Corner Zone Width (Figure 30.4-2A of ASCE 7-10)

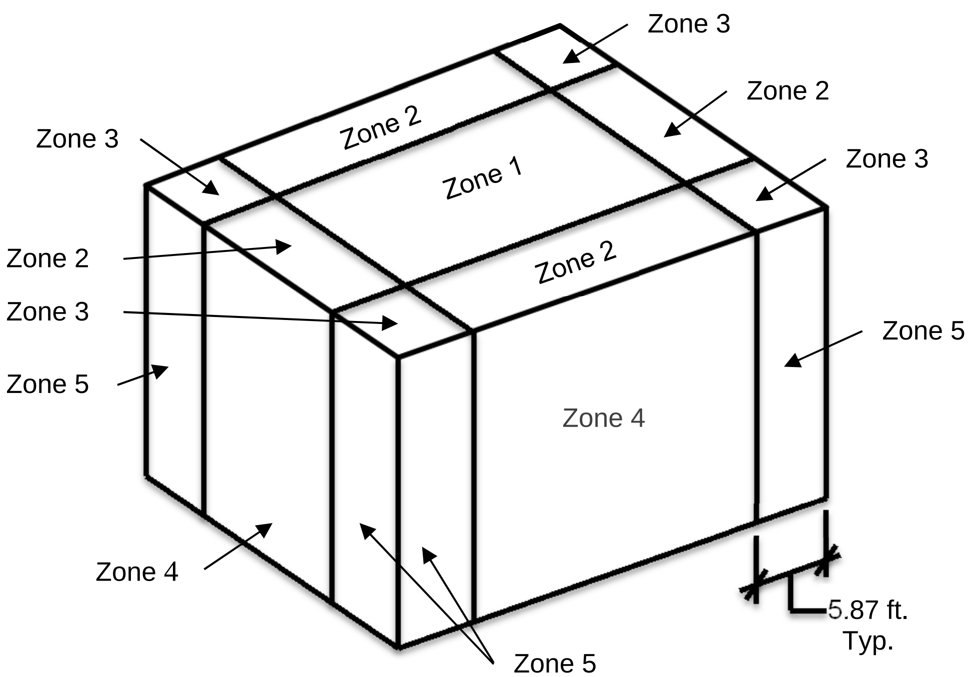
a = > 0.10 (B) = 7.93 ft.

0.4 (H) = 5.87 ft. **< = Governs**

0.04 (B) = 3.17 ft.

Minimum Width = 3.0 ft.

Components and Cladding Load Summary



Surface	Zone	10 SF Trib. Pressure (psf)	100 sf Trib. Pressure (psf)	500 sf Trib. Pressure (psf)
Roof	Negative Zone 1	-210.5	-196.9	-196.9
	Negative Zone 2	-319.2	-224.1	-224.1
	Negative Zone 3	-455.0	-224.1	-224.1
	Positive All Zones	115.4	101.9	101.9
Wall*	Negative Zone 4	-224.1	-199.6	-183.3
	Negative Zone 5	-264.8	-215.9	-183.3
	Positive All Zones	210.5	186.1	169.8

*Note GC_p values for the walls was not reduced due to the roof slope

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