Appendix D Case Study II – School Community Safe Room (Kansas)

Introduction

This appendix presents an example of a tornado safe room that meets tornado hazards and design criteria set forth in this publication. This example was from the reconstruction of a damaged school after the May 1999 Midwest tornado outbreaks and background information on the project is included in the "Overview" section. Several additional items related to this project have been included in this appendix, including:

- Initial wind load calculations for the safe room.
- The initial budgetary cost estimate (which was originally prepared in 1999 and has been updated to 2008 dollars).
- A sample tornado Community Shelter Operations Plan (without attachments). The plan provided is a reference document for a tornado safe room plan. The plan is not from the Wichita Safe Room Project presented in this appendix because one was not required when the safe room was constructed. The plan attached, however, was a recent plan developed for a community tornado safe room in Missouri. Although it was developed prior to the update of the guidance provided in Chapter 3 of this publication, it is presented here for reference and use by the reader. The plan provides a good representation of an operations plan and, with the guidance provided in Chapter 3, can be adapted to any tornado safe room in the United States.
- A sample of the original conceptual design drawings for the Wichita safe room project.

Overview

On May 3, 1999, an outbreak of tornadoes tore through parts of Oklahoma and Kansas, leveling entire neighborhoods and killing 49 people in Oklahoma and 6 in Kansas. Chisholm Life Skills Center in Wichita, Kansas, sustained heavy damage from these storm systems. A double portable classroom was demolished and the roof system for the southwest classroom section of the school was destroyed. A mechanical room chimney collapsed onto an adjacent roof, causing roof and wall failure. The roof membrane was damaged at several locations over the entire building.

PBA, an A/E firm in Wichita, was commissioned by the Unified School District No. 259 to assess damages and provide retrofit options, including proposed locations for safe areas at Chisholm Center. Advantages and disadvantages for each proposal were listed, along with a recommendation and a cost estimate.

PBA recommended a centrally located classroom addition to replace the portable classrooms. The new addition would replace the lost facilities and also function as a community safe room to protect the population from extreme-wind events. It would provide 840 square feet of usable floor space and be constructed with pre-cast concrete wall panels, a pre-cast double tee concrete roof structure, and roof mounted mechanical equipment. The design would meet the requirements of the newest local building codes for normal building use and technical guidelines in FEMA documents for tornado community safe room use, including a design wind speed of 250 mph. Calculations of wind loads used in the original design (using ASCE 7-98) have been checked using the design criteria stated in Chapter 3 of this publication and ASCE 7-05, which yielded the same values for wind loads as the original calculations. Equations, figures, and tables have been referenced from both ASCE 7-98 and ASCE 7-05.

A major advantage of the design plan is that it could be implemented without disrupting school activities. Design plans for the new addition at the Chisholm Life Skills Center are provided in this appendix. The plans are preceded by the wind load analysis on which the design is based.

ASCE 7-98/7-05 Wind Load Analysis for Chisholm Life Skills Center Shop Addition

Using Exposure C

General Data

$K_z = 0.85$	Velocity Pressure Exposure Coefficient (Table 6-5 of ASCE 7-98; Table 6-3 of ASCE 7-05)
$I = 1.00$	Importance Factor (see Chapter 6 of this manual)
$V = 250$	Wind Speed (mph) from FEMA Wind Zone Map (Figure 3-1 of this publication)
$K_{zt} = 1$	Topographic Factor (Figure 6-2 of ASCE 7-98; Figure 6-4 of ASCE 7-05)
$K_d = 1.00$	Wind Directionality Factor (see Chapter 3 of this publication)

h = 14 Building Height (ft)

L = 56 Building Length (ft)

B = 35 Building Width (ft)

Velocity Pressure (Section 6.5.10 of ASCE 7-98 and ASCE 7-05)

$q_z = (0.00256)(K_z)(K_{zt})(K_d)(V^2 I)$ $q_z = 136.00$ psf

$q_h = q_z$

$q_h = 136.00$ psf

External Pressure Coefficients for Walls (Figure 6-3 of ASCE 7-98; Figure 6-6 of ASCE 7-05)

L/B = 1.60 $C_{p1} = 0.8$ windward wall B/L = 0.63 $C_{p1} = 0.8$ windward wall

$C_{p2a} = -0.38$ leeward wall $C_{p2b} = -0.5$ leeward wall

$C_{p3} = -0.7$ side wall $C_{p3} = -0.7$ side wall

Roof Pressure Coefficients (Figure 6-3 of ASCE 7-98; Figure 6-6 of ASCE 7-05)

h/L = 0.25 $C_{p4a} = -0.9$ from 0–7 ft from windward edge

$C_{p4b} = -0.9$ from 7–14 ft from windward edge

$C_{p5} = -0.5$ from 14–28 ft from windward edge

$C_{p6} = -0.3$ more than 28 ft from windward edge

(Note: Let $C_{p4} = C_{p4a} = C_{p4b}$ due to roof geometry)

Gust Factor

G = 0.85

Internal Pressure Coefficients for Buildings (Table 6-7 of ASCE 7-98; Figure 6-5 of ASCE 7-05)

GC_{pipos} = 0.55 for partially enclosed buildings

GC_{pineg} = -0.55 for partially enclosed buildings

ATMOSTPHERIC PRESSURE CHANGE (APC)

The internal pressure coefficient, GC_{pi}, may be taken as ±0.18 when venting area of 1 square foot per 1,000 cubic feet of interior safe room volume is provided to account for APC. As an alternative to calculating the effects of APC, and designing an appropriate venting system for the safe room, the design may be completed using an internal pressure coefficient GC_{pi} = ±0.55 as a conservative means to account for APC.

Design Wind Pressure for Rigid Buildings of All Heights (Section 6.5.12.2.1 of ASCE 7-98 and ASCE 7-05)

(for positive internal pressures)

$p_{wi} = (q_z)(G)(C_{p1}) - (q_h)(GC_{pipos})$ — p_{wi} = 17.68 windward wall

$p_{lee2a} = (q_z)(G)(C_{p2a}) - (q_h)(GC_{pipos})$ — p_{lee2a} = -118.73 leeward wall (wind parallel to ridge)

$p_{lee2b} = (q_z)(G)(C_{p2b}) - (q_h)(GC_{pipos})$ — p_{lee2b} = -132.60 leeward wall (perpendicular to ridge)

$p_{side} = (q_z)(G)(C_{p3}) - (q_h)(GC_{pipos})$ — p_{side} = -155.72 side wall

$p_{roof1} = (q_z)(G)(C_{p4}) - (qh)(GC_{pipos})$ — p_{roof1} = -178.84 roof pressures (0 –14 ft from windward edge)

$p_{roof2} = (q_z)(G)(C_{p5}) - (q_h)(GC_{pipos})$ — p_{roof2} = -132.60 roof pressures (14 – 28 ft from windward edge)

$p_{roof3} = (q_z)(G)(C_{p6}) - (q_h)(GC_{pipos})$ — p_{roof3} = -109.48 roof pressures (more than 28 ft from windward edge)

(for negative internal pressures)

$p_{wi} = (q_z)(G)(C_{p1}) - (q_h)(GC_{pineg})$ — p_{wi} = 167.28 windward wall

$p_{lee2a} = (q_z)(G)(C_{p2a}) - (q_h)(GC_{pineg})$ — p_{lee2a} = 30.87 leeward wall (wind parallel to ridge)

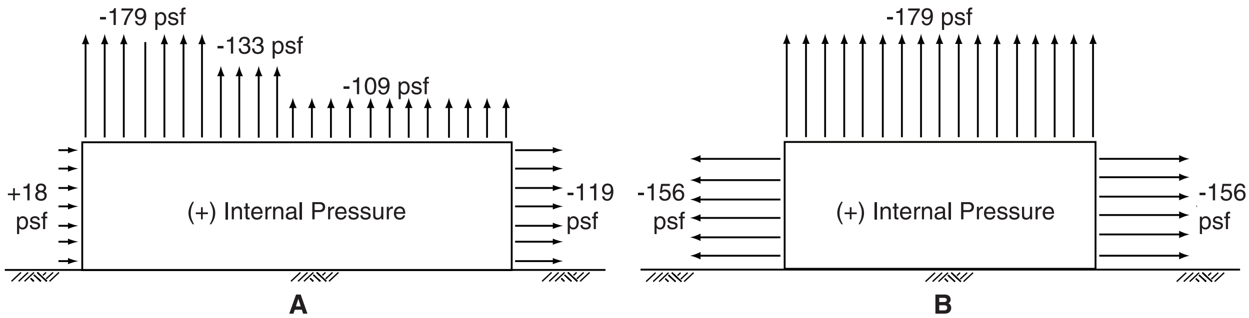
$p_{lee2b} = (q_z)(G)(C_{p2b}) - (q_h)(GC_{pineg})$ — p_{lee2b} = 17.00 leeward wall (perpendicular to ridge)

$p_{side} = (q_z)(G)(C_{p3}) - (q_h)(GC_{pineg})$ p_{side} = -6.12 side wall

$p_{roof1} = (q_z)(G)(C_{p4}) - (q_h)(GC_{pineg})$ p_{roof1} = -29.24 roof pressures (0 –14 ft from windward edge)

$p_{roof2} = (q_z)(G)(C_{p5}) - (q_h)(GC_{pineg})$ p_{roof2} = 17.00 roof pressures (14 – 28 ft from windward edge)

$p_{roof3} = (q_z)(G)(C_{p6}) - (q_h)(GC_{pineg})$ p_{roof3} = 40.12 roof pressures (more than 28 ft from windward edge)



Notes:
1. Positive pressure values act against the building surface.
2. Negative pressure values act away from the building surface.
3. Wind direction is from left to right in figure A, and going into the page in figure B.

Figure D-1. Design wind pressures when wind is parallel to ridge with positive internal pressures (Chisholm Life Skills Center Shop Addition)

Budgetary Cost Estimate For The Wichita, Kansas, Safe Room (In 2008 Dollars)

Estimated Construction Costs (+/- 20%)
(Safe Room Area = 2,133 Square Feet)

Construction Item	Cost
Site work and general requirements	$25,500
Utilities	$3,300
Cast-in-place concrete	$36,000
Pre-cast concrete structure	$90,500
Metals	$13,700
Woods and plastics	$33,000
Thermal and moisture protection	$25,100
Doors and hardware	$9,400
Finishes	$9,400
Specialties	$9,400
Special equipment/technology	$9,400
Electrical	$35,500
Mechanical	$69,200
Total Construction Costs	**$369,400**
Profit and Fees	$36,900
Total Estimated Construction Costs	**$406,300**
Unit Cost (Per Square Foot [sf])	**$190.00/sf**

NOTE: Currently, in this area of Kansas, school projects consisting of exterior load-bearing walls of CMU with brick veneer, interior non-load-bearing CMU walls, and open-web steel joist roof systems with metal decks are budgeted at $95.00–$100.00/ft^2.