Life Safety Report – Adams County High School – District 14

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Fire Protection Engineering
Cal Poly San Luis Obispo
Culminating Experience Project
June 13th, 2013
Outline

• Overview of Building & Location
• Prescriptive Requirements
  • Egress & Occupants
  • Structural (Passive) Systems & FRR
  • Fire Protection Systems
  • Fire Alarm Systems
• Performance Based Design Scenarios
  • Scenario 1 – Theatre
  • Scenario 2 – Gym
• Results
• Thanks
Building Overview

• Completed in 2009
• Sits within defunct Rocky Mountain Arsenal
• Serves 9th – 12th grades
• Largest ‘Original’ School Structure in Colorado
  • 293,000 total square feet!
  • 2 Story

• Applicable Codes:
  • 2006 International Codes
  • State of Colorado Division of Fire Prevention & Control (2006 I-Codes)
  • NFPA Standards (10, 13, 72)
  • No local jurisdictional requirements
Site Plan

Adams 14 High School
7200 Quebec Parkway
1300 Broadway
Denver, Colorado 80203
Site Plan – Rocky Mountain Arsenal
Building Picture – Theatre View
Building Picture – Front Entrance
Building Picture – Gym View
Floorplans – Overall Basement

Arrows show exit stairs
Floorplans – Overall 1st Floor

Arrows show exits

Areas:
- Area ‘A’
- Area ‘B’
- Area ‘C’
- Area ‘D’
- Area ‘E’
- Area ‘F’ & ‘G’
- Area ‘H’
1st Level – Enlarged Area A
Design Scenario #1 - Theatre
1st Level – Enlarged Area G
Design Scenario #2 - Gym
Floorplans – 2nd Floor Overall

Arrows show exit stairs
## IBC Occupancy Classifications

2006 IBC – Section 302

<table>
<thead>
<tr>
<th>USE OF THE SPACE/AREA</th>
<th>OCCUPANCY CLASSIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Educational</td>
<td>E</td>
</tr>
<tr>
<td>Offices / Admin</td>
<td>B</td>
</tr>
<tr>
<td>Theatre / stage</td>
<td>A-1</td>
</tr>
<tr>
<td>Cafeteria</td>
<td>A-2</td>
</tr>
<tr>
<td>Fitness / gym / pool areas</td>
<td>A-4</td>
</tr>
<tr>
<td>Storage Areas</td>
<td>S-2</td>
</tr>
<tr>
<td>Mechanical / Electrical Equipment</td>
<td>Incidental Use Areas, See Table 508.2</td>
</tr>
<tr>
<td>Equipment Rooms</td>
<td></td>
</tr>
<tr>
<td>Small Storage Rooms/Closets</td>
<td>Incidental Use Areas, See Table 508.2</td>
</tr>
</tbody>
</table>
## Occupant Loads

2006 IBC – Table 1004.1.1

<table>
<thead>
<tr>
<th>FUNCTION OF SPACE</th>
<th>FLOOR AREA (SF) PER OCCUPANT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly with fixed seats</td>
<td>Use actual seat count or 18” of seating length per person for benches without dividing arms.</td>
</tr>
<tr>
<td>Assembly – Concentrated (chairs only, not fixed)</td>
<td>7 net</td>
</tr>
<tr>
<td>Assembly – Un-concentrated (tables and chairs)</td>
<td>15 net</td>
</tr>
<tr>
<td>Assembly – Standing Space</td>
<td>5 net</td>
</tr>
<tr>
<td>Business Areas</td>
<td>100 gross</td>
</tr>
<tr>
<td>Educational – Classroom Area</td>
<td>20 net</td>
</tr>
<tr>
<td>Educational – Shops and Vocational Areas</td>
<td>50 net</td>
</tr>
<tr>
<td>Exercise Rooms / Locker rooms</td>
<td>50 gross</td>
</tr>
<tr>
<td>Kitchen</td>
<td>200 gross</td>
</tr>
<tr>
<td>Accessory storage, mechanical and electrical</td>
<td>300 gross</td>
</tr>
</tbody>
</table>
## Basement Occupant Loads

<table>
<thead>
<tr>
<th>Occupancy</th>
<th>Area (sq. ft.)</th>
<th>OLF</th>
<th>Occ. Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>2,519</td>
<td>50</td>
<td>51</td>
</tr>
<tr>
<td>E</td>
<td>5,359</td>
<td>20</td>
<td>268</td>
</tr>
<tr>
<td>S-2</td>
<td>846</td>
<td>300</td>
<td>3</td>
</tr>
<tr>
<td>ACC</td>
<td>5,242</td>
<td>300</td>
<td>19</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>13,966</strong></td>
<td></td>
<td><strong>341</strong></td>
</tr>
</tbody>
</table>
# 1st Floor Occupant Loads

<table>
<thead>
<tr>
<th>Occupancy</th>
<th>Area (sq. ft.)</th>
<th>OLF</th>
<th>Occ. Load</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>57,750</td>
<td>20</td>
<td>2,888</td>
<td>Classroom</td>
</tr>
<tr>
<td>E</td>
<td>60,368</td>
<td>50</td>
<td>1,208</td>
<td>Shop/Vocational</td>
</tr>
<tr>
<td>E</td>
<td>3,859</td>
<td>200</td>
<td>20</td>
<td>Kitchen</td>
</tr>
<tr>
<td>S-2</td>
<td>3,396</td>
<td>300</td>
<td>12</td>
<td>Storage</td>
</tr>
<tr>
<td>A-1</td>
<td>1,772</td>
<td>5N</td>
<td>355</td>
<td>Lobby</td>
</tr>
<tr>
<td>A-1</td>
<td>5,155</td>
<td>50</td>
<td>104</td>
<td>Theatre</td>
</tr>
<tr>
<td>A-1</td>
<td>225’-10”</td>
<td>18”</td>
<td>151</td>
<td>Theatre Seats</td>
</tr>
<tr>
<td>A-1</td>
<td>2,263</td>
<td>15</td>
<td>151</td>
<td>Stage</td>
</tr>
<tr>
<td>B</td>
<td>23,627</td>
<td>100</td>
<td>237</td>
<td>Offices / Admin</td>
</tr>
<tr>
<td>A-2</td>
<td>7,126</td>
<td>15N</td>
<td>476</td>
<td>Cafeteria</td>
</tr>
<tr>
<td>A-4</td>
<td>33,707</td>
<td>50</td>
<td>675</td>
<td>Sports</td>
</tr>
<tr>
<td>A-4</td>
<td>5118 LF</td>
<td>18”</td>
<td>3,412</td>
<td>Gym Seats</td>
</tr>
<tr>
<td>A-4</td>
<td>3,594</td>
<td>5N</td>
<td>719</td>
<td>Lobby</td>
</tr>
<tr>
<td>ACC</td>
<td>1,147</td>
<td>300</td>
<td>4</td>
<td>Mech room</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>203,764</strong></td>
<td></td>
<td><strong>10,412</strong></td>
<td></td>
</tr>
</tbody>
</table>
## 2nd Floor Occupant Loads

<table>
<thead>
<tr>
<th>Occupancy</th>
<th>Area (sq. ft.)</th>
<th>OLF</th>
<th>Occ. Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>46,001</td>
<td>20</td>
<td>2,300</td>
</tr>
<tr>
<td>B</td>
<td>9,398</td>
<td>100</td>
<td>94</td>
</tr>
<tr>
<td>S-2</td>
<td>350</td>
<td>300</td>
<td>2</td>
</tr>
<tr>
<td>ACC</td>
<td>249</td>
<td>300</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>55,998</strong></td>
<td></td>
<td><strong>2,397</strong></td>
</tr>
</tbody>
</table>


Fire Resistive Rated Construction

- Type II-B (Non-rated) Construction
- Building employs features from Chapter 7 of the IBC:
  - Fire Barriers (Separating Construction Trades, Gym, Pool/Gym, Kitchen area) – 2 hour separation
  - Shaft Enclosures (Elevator Shaft) – 1 hour rated (connects less than 4 stories)
  - Smoke Barriers (Incidental storage, Science / Prep rooms, MEP Equip room, Armory in basement) – 1 hour rated
- Fire Separation Distance is greater than 30’.
  - Exterior Walls / Glazing not rated
- Interior Finish Requirements per IBC
# FRR Construction

2006 IBC – Table 601 (Type IIB)

<table>
<thead>
<tr>
<th>BUILDING ELEMENT</th>
<th>RATING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary structural frame</td>
<td>0-hours</td>
</tr>
<tr>
<td>Columns supporting floors</td>
<td>0-hours</td>
</tr>
<tr>
<td>All other</td>
<td>0-hours</td>
</tr>
<tr>
<td>Bearing walls</td>
<td>0-hours</td>
</tr>
<tr>
<td>Exterior</td>
<td>0-hours</td>
</tr>
<tr>
<td>Interior</td>
<td>0-hours</td>
</tr>
<tr>
<td>Nonbearing walls and partitions</td>
<td>0-hour</td>
</tr>
<tr>
<td>Floor construction and secondary members</td>
<td>0-hours</td>
</tr>
<tr>
<td>Roof construction and secondary members</td>
<td>0-hour</td>
</tr>
</tbody>
</table>
# Interior Finish Requirements
2006 IBC – Table 803.5

<table>
<thead>
<tr>
<th>GROUP</th>
<th>Exit enclosures and exit passageways</th>
<th>Corridors</th>
<th>Rooms and enclosed spaces</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1 &amp; A-2</td>
<td>B</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>A-4</td>
<td>B</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>B &amp; E</td>
<td>B</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>S</td>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
</tbody>
</table>
Fire Protection Systems

- Compliant to NPFA 13 – 2007 Edition
- Combination of Light Hazard, Ordinary Hazard Group I & Group II on all floor levels
- Municipal Water Supply
  - Static = 85psi
  - Residual = 20psi @ 4,000 GPM (Designed to Code Minimum)
- Risers for sprinkler system located in Room H112 [Fire Service Entry]
<table>
<thead>
<tr>
<th></th>
<th>Basement</th>
<th>1st Floor</th>
<th>2nd Floor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light Hazard</td>
<td>ROTC Center, corridor &amp; bathroom group</td>
<td>Bistro, Music, Classrooms, Admin</td>
<td>Classrooms</td>
</tr>
<tr>
<td>Ordinary Hazard</td>
<td>Armory, Rifle Range, Mechanical Room, Pool Equip</td>
<td>Fire Entry, Storage, Mechanical / Electrical, Gym, Sports, Main Kitchen(s), Wrestling, Auditorium</td>
<td>Prep Rooms (Flammable Liquid Storage), Storage</td>
</tr>
<tr>
<td>Group I</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ordinary Hazard</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group II</td>
<td></td>
<td></td>
<td>Stage, Construction Trades, Library</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Fire Protection Systems

City Water Supply:
- $P_{\text{static}} = 85$ psi
- $P_{\text{residual}} = 20$ psi @ 4,000 GPM

Most Demanding Remote Area
Construction Trades Area
(Ord. Hazard Group II)
- 333.73 GPM @ 57.682 psi
- 583.73 GPM @ 57.682 psi w/ Hose

Flow - GPM (Circle scale used.)
© 1996 National Fire Sprinkler Association, P.O. 1000, Patterson, NY 12563
Special Suppression Systems

- Kitchen hoods – Ansul Wet Chemical
  - In both student kitchen and main cafeteria
- IT Room(s) – FM200 System
Fire Alarm Systems

• Compliant to NFPA 72 – 2007 Edition
• Fully addressable Simplex 4100U – Located in same room as fire sprinkler risers
• Typical Initiation Devices (manual pulls at exits, heats in mech room, smoke detectors for electrical rooms, duct detectors, corridor smoke detectors) – Doesn’t conform to all exceptions listed in IFC.
• Notification Devices consist of speaker / strobe, interconnected with Paging System to allow for voice evacuation and pre-recorded or live messaging
• Connected to central monitoring (To Adams County School District then to South Adams County FPD)
Fire Command Center

- Technically not a true ‘FCC’; however is main staging point for first responders
- Located in Room H112
- Has FACP, sprinkler system risers, elevator status
- FD can communicate to entire school from this one room
Summary of Prescriptive Requirements

- NFPA 13 & 72 Compliant Systems
- Meets State requirements for Schools (Division of Fire Prevention and Control)
Performance Based Analysis

• Building was built to prescriptive codes!
  • Therefore, during initial design no performance based criteria was established. However, after 5 years of operations:

• Owner would like to manage risk within certain areas of the building
• High occupancy during student plays in the Theatre
• High occupancy during student ‘dance’ in the Main Gym

• For these, NFPA 101 – 2009 Life Safety Code was used for design fire scenarios
ASET vs. RSET

Signature Time Development Period for Occupants during a Fire Event
ASET vs. RSET

- **ASET** – Available Safe Egress Time
  - Time from ignition until tenability limit is reached.
  - Used to determine when criteria objectives are met.
- **RSET** – Required Safe Egress Time
  - Time from ignition until evacuation is complete.
  - Used to determine actual time for occupants to egress the space.

These will be used to compare and validate the results for the performance approaches.
Scenario 1 - Theatre

- Student Play
- Fully occupied (255 persons)
- Fire originates in storage room near vomitory, renders exit unuseable
- CO, Temp and Visibility criteria
- 101 – 5.5.3.2
- Scenario 2 & 3
- Primary Means of egress, reduction of means of egress, potentially endangering/migrating into space with high number of occupants.
Scenario 1 - Theatre
Scenario 1 - Theatre

Storage Room
Scenario 1 – Theatre – ASET

• Performance Criteria
  • Visibility – Shall remain above 10m (30’) for duration of egress
  • CO Levels – Must stay under 1,400 PPM for duration of egress
  • Temperature – Shall remain below 60 deg C for duration of egress.
  • Temperature in storage room shall stay below 500 deg C to prevent flashover

• Are these greater than the Required Safe Egress Time?

Assumed that exit is no longer in service
Scenario 1 – Theatre [RSET]

- Detection Time = 183 seconds (FDS output)
- Notification Time = 5 seconds (Detector to FACP to Notification Devices)
- Pre-movement Time = 45 seconds (NFPA HB 20th Ed. Table 4.2.1)
- Travel Time (vertical) = 13 seconds (SFPE/NFPA Method)
- Travel Time (horizontal) = 149 seconds (SFPE/NFPA Method)
- Door Exit Time = 106 seconds (SFPE/NFPA Method)
- **Total Required Safe Evacuation Time = 501 seconds**
Scenario 1 – Theatre – Fuel Package

- Fuel package – Stacks of chairs within the storage room
- Per SFPE curve – 6 chairs / stack
- Assumed 4 stacks of chairs
- SFPE 4th Ed. Table 3-4.14 Yields used for FDS modeling [well ventilated]
- FDS Model includes incipient stage of fire growth, growth then is defined as ‘medium’ growth
Scenario 1 – Theatre

- FDS Modeling

- Length = 38m (124ft)
- Width = 27m (88ft)
- Height = 10m (32ft)
Scenario 1 – Theatre
Scenario 1 – Theatre

- No radiant ignition of other stacks of chairs occurred
- Curve was modeled (capped) after sprinkler activation, then resumed after HRR was met on the decay side to simulate mass loss

- Smoke Detector Activation = 183 seconds (delayed due to incipient growth)
- Sprinkler Activation = 522 seconds (delayed due to incipient growth)
Scenario 1 – Theatre - Visibility

- 501 seconds (RSET) - Pass
- 1000 seconds (~2x RSET) - Fail
Scenario 1 – Theatre – CO

- 501 seconds (RSET) - Pass
- 1200 seconds (~2.4x RSET) - Pass
Scenario 1 – Theatre - Temperature

- 501 seconds (RSET) - Pass
- Upper Layer Temp – Height of room allows for smoke storage
- 501 seconds (RSET) - Pass
Scenario 1 – Theatre – Storage Room

- Pre Sprinkler Activation
  - Spread of hot gas layer

- Post Sprinkler Activation
  - Sprinkler ‘Controls’ fire
Scenario 1 - Theatre

- RSET
- ASET

• Required objects for this design scenario were met.
• No recommendations or additional work
Scenario 2 – Gym

- Student ‘dance’
- Partially occupied (1,300+ persons)
- Gym mats under bleachers is fuel package
- Visibility, CO, Temperature
- 101 – 5.5.3.5 Scenario 5
Scenario 2 - Gym
Scenario 2 - Gym
Scenario 2 – Gym – ASET

• Performance Criteria
  • Visibility – Shall remain above 10m (30’) for duration of egress
  • CO Levels – Must stay under 1,400 PPM for duration of egress
  • Temperature – Shall remain below 60 deg C for duration of egress.

• Are these greater than the Required Safe Egress Time?
Scenario 2 – Gym – Fuel Package

- Fuel package is four flexible polyurethane gym mats under bleachers
- Shielded fire (no sprinkler control)
- NIST curves were averaged for FDS model
- SFPE 4th Ed. Table 3-4.14 Yields used for FDS modeling [well ventilated]

- 10cm x 1.2m x 1.2m – Results from NIST Large Scale Testing of Polyurethane Foam Slabs

<table>
<thead>
<tr>
<th>Material</th>
<th>$\Delta H_f$ (kJ/g)</th>
<th>$y_{CO_2}$ (g/g)</th>
<th>$y_{CO}$ (g/g)</th>
<th>$y_{CH}$ (g/g)</th>
<th>$y_s$ (g/g)</th>
<th>$\Delta H_{ch}$ (kJ/g)</th>
<th>$\Delta H_{con}$ (kJ/g)</th>
<th>$\Delta H_{rad}$ (kJ/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyurethane (flexible) foams</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GM21</td>
<td>26.2</td>
<td>1.5</td>
<td>0.010</td>
<td>0.002</td>
<td>0.131</td>
<td>17.8</td>
<td>8.6</td>
<td>9.2</td>
</tr>
<tr>
<td>GM23</td>
<td>27.2</td>
<td>1.51</td>
<td>0.031</td>
<td>0.005</td>
<td>0.227</td>
<td>19.0</td>
<td>10.3</td>
<td>8.7</td>
</tr>
<tr>
<td>GM25</td>
<td>24.6</td>
<td>1.50</td>
<td>0.028</td>
<td>0.005</td>
<td>0.194</td>
<td>17.0</td>
<td>7.2</td>
<td>9.8</td>
</tr>
<tr>
<td>GM27</td>
<td>23.2</td>
<td>1.57</td>
<td>0.042</td>
<td>0.004</td>
<td>0.198</td>
<td>16.4</td>
<td>7.6</td>
<td>8.8</td>
</tr>
</tbody>
</table>
Scenario 2 – Gym – Fuel Package

- Fuel package is four flexible polyurethane gym mats under bleachers
- Peak HRR for all 4 mats = 2,800kW
- Bleachers are steel and fire-retardant high density plastic
- Temperatures were not enough to ignite bleachers (secondary fuel source) [AIT > 350deg C]
Scenario 2 – Gym - RSET

- Detection Time = 100 seconds (Human Detection)
- Notification Time = 20 seconds (Walk to Pull, to FACP, to Notification)
- Pre-movement Time = 15 seconds (NFPA HB 20th Ed. Table 4.2.1)
- Travel Time (horizontal) = 30 seconds (SFPE/NFPA Method)
- Door Exit Time = 135 seconds (SFPE/NFPA Method)
- **Total Evacuation Time = 300 seconds**
Scenario 2 - Gym

- FDS Modeling

- Length = 40m (132ft)
- Width = 35m (115ft)
- Height = 10m (32ft)
Scenario 2 - Gym

• FDS Results

• 1\textsuperscript{st} sprinkler activated at 180 seconds.
• By 300 seconds [RSET] two sprinklers have activated
Scenario 2 – Gym – Visibility

- 200 seconds – first exit blocked
- 300 seconds - (RSET) – Fail – Multiple exits blocked
Scenario 2 – Gym – Visibility

- 445 seconds – complete failure of visibility criteria
- Visibility in middle of room fails right at RSET
Scenario 2 – Gym – CO

- 300 seconds – RSET - Pass
- 800 seconds (~2.6x RSET) – Pass
Scenario 2 – Gym - Temperature

- 300 seconds – RSET - Pass
- 800 seconds (≈2.6x RSET) – Pass
Scenario 2 – Gym - Temperature

- 300 seconds – Distinct upper gas layer, above occupants
Scenario 2 - Gym

**Recommendations**

- Enforce International Fire Code [304.1.3] criteria for not allowing for storage of mats under bleachers
- Provide NFPA 92 compliant smoke control system to keep smoke layer greater than 2m above walking surface (costly)
- Limit number of occupants in area [not realistic]
Summary of PBD

• Design Scenario #1 – Theatre & Chairs
  • Will it work with existing conditions? – YES

• Design Scenario #2 – Gym & Mats
  • Will it work with existing conditions? – NO, if prescriptive codes are not enforced!

• However.....
  • Meets prescriptive requirements for a code compliant building!
Thanks

• Dr. Mowrer
• Dr. Pascual
• Dr. Rich
• Dr. Lautenberger

• And the rest of the great staff in the FPE program at CalPoly!