Building 43: Recreation Center

Culminating Experience in Fire Protection Engineering
Daniel Gonzalez
Presentation Overview

• Prescriptive Based Analysis
  • Building Overview
  • Occupant Loads and Exit Capacities
  • Structural Fire Protection
  • Fire Alarm and Detection System
  • Sprinkler System

• Performance Based Analysis
  • Three different fire scenarios
  • One scenario simulated with Pathfinder and Pyrosim
Reference Materials

• International Building Code (2015)
• NFPA 13 (2015) – Installation of Sprinkler Systems
Prescriptive Based Analysis
Building Overview
– Location
Building Overview
– Location
Building Overview – Layout
Building Overview – Layout
Building Overview - Specifications

• Total Square Footage: ~165,000 ft²
• Number of Stories: 2
• Construction Type: IB
• Fire Alarm System
• Fully Sprinklered
Building Overview - Uses

• Typical day use
  • Place for students to work out and take fitness classes.
  • Thousands of students enter and exit the Recreation Center at various times throughout the day.

• Special events
  • Concerts
  • Graduation Ceremonies
  • Career Fairs
Occupant Loads – First Floor

- Assembly
- Restrooms, locker rooms, etc
- Storage
- Service Spaces (electrical, mechanical, etc)
- Office
- Exit Access Corridors
- Athletic Facilities
Occupant Loads – Second Floor

<table>
<thead>
<tr>
<th>Assembly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restrooms, locker rooms, etc</td>
</tr>
<tr>
<td>Storage</td>
</tr>
<tr>
<td>Service Spaces (electrical, mechanical, etc)</td>
</tr>
<tr>
<td>Office</td>
</tr>
<tr>
<td>Exit Access Corridors</td>
</tr>
<tr>
<td>Athletic Facilities</td>
</tr>
</tbody>
</table>
## Occupant Loads – Load Factors

<table>
<thead>
<tr>
<th>Space</th>
<th>Color on Floorplan</th>
<th>Occupant Load Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly (Fitness Rooms)</td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>Assembly (Gymnasiums)</td>
<td></td>
<td>15</td>
</tr>
<tr>
<td>Locker Rooms</td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>Service Spaces (Control Room, First Aid, Laundry)</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Service Spaces (Maintenance, Mechanical)</td>
<td></td>
<td>300</td>
</tr>
<tr>
<td>Office</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Athletic Facilities (Weight Areas, Wrestling Rooms)</td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>Athletic Facilities (Jogging Track)</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Storage</td>
<td></td>
<td>300</td>
</tr>
</tbody>
</table>
Occupant Loads – Summary

• Occupant Loads calculated for each space based on square footage, and occupant load factor.

• Two different occupancy cases were considered.
  • Case 1: Bleachers in Gym are extended
  • Case 2: Bleachers in Gym are folded up

<table>
<thead>
<tr>
<th>Case</th>
<th>Floor</th>
<th>Occupant Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>5739</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>369</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>6108</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>2932</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1224</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>4156</td>
</tr>
</tbody>
</table>
Exit Capacities
– First Floor
Exit Capacities – Second Floor
Exit Capacities – Summary

- 19 exits were identified.
- An exit capacity was determined for each, based on physical dimensions and limiting factor.

<table>
<thead>
<tr>
<th>Case</th>
<th>Floor</th>
<th>Occupant Load</th>
<th>Exit Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>5739</td>
<td>8460</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>369</td>
<td>2237</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>6108</td>
<td>10697</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>2932</td>
<td>8460</td>
</tr>
<tr>
<td></td>
<td>2</td>
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<tr>
<td></td>
<td>Total</td>
<td>4156</td>
<td>10697</td>
</tr>
</tbody>
</table>
Structural Fire Protection

• Type IB Construction

• Steel Columns
  • Coated in fire resistive material
  • Encased in concrete

• Steel Beams
  • Coated in fire resistive material
  • Surrounded by metal cover

• Floor and Roof assemblies
  • Constructed of steel, gypsum wallboard, and plaster over metal lath

• Walls
  • Metal framing
  • Gypsum wallboard cover
Structural Fire Protection – Fire Resistance Ratings

- The International Building Code was used to determine the required fire resistance ratings of various building elements.

<table>
<thead>
<tr>
<th>Building Element</th>
<th>Rating (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Structural Frame</td>
<td>2</td>
</tr>
<tr>
<td>Exterior Bearing Walls</td>
<td>2</td>
</tr>
<tr>
<td>Interior Bearing Walls</td>
<td>2</td>
</tr>
<tr>
<td>Exterior Nonbearing Walls and Partitions</td>
<td>0</td>
</tr>
<tr>
<td>Interior Nonbearing Walls and Partitions</td>
<td>0</td>
</tr>
<tr>
<td>Floor Construction</td>
<td>2</td>
</tr>
<tr>
<td>Roof Construction</td>
<td>1</td>
</tr>
</tbody>
</table>
Structural Fire Protection
– Interior Finish and Furniture Requirements

• Interior Finish Requirements were found in Table 803.11 from the International Building Code

<table>
<thead>
<tr>
<th>Group</th>
<th>Interior Egress Paths</th>
<th>Corridor and Enclosure for Egress Paths</th>
<th>Rooms and Enclosed Spaces</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-3 (assembly)</td>
<td>B</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>B (business)</td>
<td>B</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>S (storage)</td>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
</tbody>
</table>

• All furniture is required to meet the standard set by Technical Bulletin 133
  • No furniture can have a maximum heat release rate greater than 80 kW
Structural Fire Protection – Smoke Control

• Closure of Combination Fire Smoke Dampers:
  • Area smoke or heat detector
    • Alarm Signal
  • In-duct smoke detector
    • Supervisory Signal
  • Sprinkler water flow switch
    • Alarm Signal
  • Elevator Lobby / Machine Room smoke or heat detector
    • Alarm Signal
  • FACP Power Failure
    • Trouble Signal
Fire Alarm and Detection System

• Initiating devices:
  • Smoke Detectors (area and in-duct)
  • Heat Detectors
  • Manual Pull Stations

• Notification Devices:
  • Speaker/Strobes
  • Speakers
  • Strobes (wall and ceiling)
  • Voice Message

“May I have your attention, please. May I have your attention, please. There has been a fire alarm reported in the building, there has been a fire alarm reported in the building. Please proceed to the nearest exit and leave the building.”
# Initiating Devices – First Floor

<table>
<thead>
<tr>
<th>Type of Initiating Device</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual Pull Station</td>
<td>🍊</td>
</tr>
<tr>
<td>Area Smoke Detector</td>
<td>🟩</td>
</tr>
<tr>
<td>In-duct Smoke Detector</td>
<td>⭐️</td>
</tr>
<tr>
<td>Heat Detector</td>
<td>▶️</td>
</tr>
</tbody>
</table>
Initiating Devices – Second Floor

<table>
<thead>
<tr>
<th>Type of Initiating Device</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual Pull Station</td>
<td>●</td>
</tr>
<tr>
<td>Area Smoke Detector</td>
<td>■</td>
</tr>
<tr>
<td>In-duct Smoke Detector</td>
<td>◆</td>
</tr>
<tr>
<td>Heat Detector</td>
<td>▲</td>
</tr>
</tbody>
</table>
Notification Appliances – First Floor

<table>
<thead>
<tr>
<th>Type of Alarm Notification Device</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire Alarm Speaker/Strobe</td>
<td>▪</td>
</tr>
<tr>
<td>Weatherproof Speaker</td>
<td>■</td>
</tr>
<tr>
<td>Fire Alarm Ceiling Strobe</td>
<td>◆</td>
</tr>
<tr>
<td>Fire Alarm Wall Strobe</td>
<td>▲</td>
</tr>
<tr>
<td>Fire Alarm Speaker</td>
<td>●</td>
</tr>
</tbody>
</table>
Notification Appliances – Second Floor

<table>
<thead>
<tr>
<th>Type of Alarm Notification Device</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire Alarm Speaker/Strobe</td>
<td>🔴</td>
</tr>
<tr>
<td>Weatherproof Speaker</td>
<td>🔴</td>
</tr>
<tr>
<td>Fire Alarm Ceiling Strobe</td>
<td>🔵</td>
</tr>
<tr>
<td>Fire Alarm Wall Strobe</td>
<td>⬤</td>
</tr>
<tr>
<td>Fire Alarm Speaker</td>
<td>🔴</td>
</tr>
</tbody>
</table>
Sprinkler System

- Wet-pipe system, with quick-response sprinklers.
- Ordinary hazard and light hazard occupancies.
- System is supplied by two separate risers.

*Diagram not to scale*
Sprinkler System – Riser Locations

- Larger Riser
- Smaller Riser
Sprinkler System – Riser Locations

- Larger Riser
- Smaller Riser
Sprinkler System – Larger Riser

- 4-inch Riser
- System #1 serves areas A and C
- System #2 serves areas B and D

*Diagram not to scale*
Sprinkler System – Smaller Riser

• 3-inch Riser
• Smaller riser serves area E
  • Area E is only the main gymnasium, and the spaces below the upper basketball courts.
Sprinkler System – Water Supply

City Water Supply:
- Static Pressure = 140 psi
- Residual Pressure = 132 psi
- Flow = 1186 gpm

Demand (Large Gymnasium):
- Pressure = 60 psi
- Flow = 279 gpm
- Hose Steam Allowance = 100 gpm
Performance Based Analysis
Performance Based Analysis

• Available Safe Egress Time (ASET)
• Required Safe Egress Time (RSET)
• ASET vs. RSET
Fire Scenario 1

• Occurs in main gymnasium during Career Fair.

• Assumptions:
  • Gymnasium is filled to max capacity with many rows of tables and chairs across basketball courts.
  • 1728 occupants
  • Pre-movement Time = 20 seconds
Fire Scenario 1 – Fuel Load

- Wooden table
- Cloth table cover
- Foamboard poster
- Then two adjacent tables ignite
- Estimated Fire Size: 4500 kW
- Assumptions:
  - Fast Growing Fire
  - Ramp-up time of 310 seconds
Fire Scenario 1 – Pathfinder Model (0 sec)
Fire Scenario 1 – Pathfinder Model (0 sec)
Fire Scenario 1 – Pathfinder Model (23 sec)
Fire Scenario 1 – Pathfinder Model (55 sec)
Fire Scenario 1 – Pathfinder Model (153 sec)

- Total Evacuation Time = RSET = 155 seconds
Fire Scenario 1 – Pyrosim Model (160 sec)
Fire Scenario 1 – Pyrosim Model
(160 sec)
Fire Scenario 1 – Pyrosim Model (160 sec)
Fire Scenario 1 – Pyrosim Model (160 sec)

Temperature ~20°C

Visibility ~30 meters
Fire Scenario 1 – Pyrosim Model (440 sec)
Fire Scenario 1 – Pyrosim Model (1000 sec)
Fire Scenario 1 – Summary

- RSET = 155 seconds
- ASET = 450 seconds
- ASET > RSET

<table>
<thead>
<tr>
<th>Tenability Criteria</th>
<th>Tenability Limit</th>
<th>Time to Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>60°C</td>
<td>&gt; 1000 seconds</td>
</tr>
<tr>
<td>Visibility</td>
<td>10 meters</td>
<td>440 seconds</td>
</tr>
</tbody>
</table>

Visibility at Second Floor Exits

Temperature 60°C > 1000 seconds
Visibility 10 meters 440 seconds
Fire Scenario 1 – Summary

- RSET = 155 seconds
- ASET = 440 seconds
- ASET > RSET

<table>
<thead>
<tr>
<th>Tenability Criteria</th>
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</thead>
<tbody>
<tr>
<td>Temperature</td>
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</tr>
<tr>
<td>Visibility</td>
<td>10 meters</td>
<td>440 seconds</td>
</tr>
</tbody>
</table>

Visibility at Second Floor Exits
Fire Scenario 2

- Occurs in main gymnasium during a concert.
- Fuel Load: extended bleachers
- Estimated Fire Size: 4000 kW or more
Fire Scenario 3

• Occurs near main entrance/exit.
• Many students might accidentally head towards fire in first attempt to escape.
• Fuel Load: couch
• Estimated Fire Size: 80 kW
  • Technical Bulletin 133
Conclusion

• Prescriptive Analysis:
  • The Recreation Center has sufficient exit capacity considering the calculated occupant load.
  • Construction, Fire Alarm System, and Sprinkler System all satisfy requirements from respective codes.

• Performance Analysis:
  • $ASET = 440$ seconds
  • $RSET = 155$ seconds
  • $ASET > RSET$ in simulated fire scenario.

• Recommendations:
  • The University must be careful with occupant load of main gymnasium
  • Must have a Fire Safety Management Plan for events in main gymnasium
Questions?