Cal Poly Recreation Center

Connor McGill
About Myself

Connor McGill E.I.T

• Undergraduate: Mechanical Engineering Cal Poly SLO

• Cal Poly Society of Fire Protection Engineers President

• Cal Poly Men’s Water Polo Club Coach

• Aon Fire Protection Engineering Intern 2012

• Rolf Jensen and Associates Intern 2013-2014

• Aon Fire Protection Engineering Consultant
Presentation Outline

1. General Building Overview
2. Prescriptive based analysis
   1. Codes and Standards
   2. Use and Occupancy
   3. Building Area and Height limitations
   4. Types of Construction
   5. Fire-resistance Rated Construction
   6. Interior Finishes
   7. Fire Protection Systems
   8. Means of Egress
3. Performance Based Design
South Section of Gym
1st Floor
MAC and Racquetball courts

Multipurpose Activity Center (MAC)

Racquetball court
General Building Information

• Old Rec Center Opened 1993
• Funding for new expansion started 2008
• Total for new Rec Center was close to $72 Million Dollars
  • $65 per quarter per student to cover costs
• Remodeled 26,300ft²
• New construction of 100,275 ft²
• Total building size: ~165,575 ft²
• Two stories tall, fully sprinklered
• Gym includes: two-court gym, administrative offices, six racquetball courts, cardio fitness areas, exercise rooms, and an indoor jogging track.
• Opened in January 2012
Prescriptive Based Design
Applicable Codes, Standards, and References

2007 California Building Code (CBC) Part 2, Title 24 C.C.R
2007 California Fire Code (CFC) Part 9, Title 24 C.C.R
SFPE Handbook 3rd, and 4th edition
NFPA Codes:
13 Sprinkler Systems 2010
72 Fire Alarm Code 2007
Use and Occupancy

**TABLE 1004.1.1 MAXIMUM FLOOR AREA ALLOWANCES PER OCCUPANT**

<table>
<thead>
<tr>
<th>Function of Space</th>
<th>Occupancy</th>
<th>Occupancy Load Factor (SF/person)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business, office space</td>
<td>B</td>
<td>100</td>
</tr>
<tr>
<td>weight lifting space, exercise rooms with equipment</td>
<td>A-3</td>
<td>50</td>
</tr>
<tr>
<td>Racquetball Courts</td>
<td>A-3</td>
<td>8 per court</td>
</tr>
<tr>
<td>Assembly fixed seating</td>
<td>A-4</td>
<td>1 per 18 inches</td>
</tr>
<tr>
<td>Basketball Courts, multi-use assembly space, concentrated not fixed seating for events</td>
<td>A-3</td>
<td>7</td>
</tr>
<tr>
<td>Pre-function Space, standing non concentrated</td>
<td>A-3</td>
<td>15</td>
</tr>
<tr>
<td>Locker Room</td>
<td>A-3</td>
<td>50</td>
</tr>
<tr>
<td>Accessory Storage areas, mechanical equip room</td>
<td>S-2</td>
<td>300</td>
</tr>
</tbody>
</table>
South Section of Gym
1st Floor
South section of Gym 2nd Floor
North East section of Gym 2nd Floor
Building Area and Height limitations

Nonseparated occupancy approach, section 508.3.2
• Allowable height and area calculated by most restrictive occupancy

Based on the Area Modification section 506
Largest possible amount of area increase: \( A_a = 5A_t \)

\[
A_a = \left\{ A_t + \left[ A_t \times I_f \right] + \left[ A_t \times I_s \right] \right\}
\]
Building Area and Height limitations

First Floor Area: 105,884 ft$^2$

$A_t = 15,500 \times 5 = 77,500$ ft$^2$

<table>
<thead>
<tr>
<th>GROUP</th>
<th>HGT(feet)</th>
<th>TYPE OF CONSTRUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HGT(S)</td>
<td>TYPE I</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>A-1</td>
<td>S</td>
<td>UL</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>UL</td>
</tr>
<tr>
<td>A-2</td>
<td>S</td>
<td>UL</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>UL</td>
</tr>
<tr>
<td>A-3</td>
<td>S</td>
<td>UL</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>UL</td>
</tr>
<tr>
<td>A-4</td>
<td>S</td>
<td>UL</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>UL</td>
</tr>
</tbody>
</table>
## Fire Resistance Rated Construction

Fire Resistance Rating of Type 1B Building Elements from Table 601

<table>
<thead>
<tr>
<th>Building Element</th>
<th>Fire Resistance Ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural Frame</td>
<td>2</td>
</tr>
<tr>
<td>Exterior bearing wall</td>
<td>2</td>
</tr>
<tr>
<td>Interior bearing wall</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>
Interior Finishes

<table>
<thead>
<tr>
<th>GROUP</th>
<th>SPRINKLERED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exit enclosures and exit passageways</td>
</tr>
<tr>
<td>A-1 &amp; A-2</td>
<td>B</td>
</tr>
<tr>
<td>A-3, A-4, A-5</td>
<td>B</td>
</tr>
<tr>
<td>B, E, M, R-1, R-4</td>
<td>B</td>
</tr>
</tbody>
</table>

Class A: Flame spread 0-25; smoke-developed 0-450.

Class B: Flame spread 26-75; smoke-developed 0-450.

Class C: Flame spread 76-200; smoke-developed 0-450.

Interior wall and ceiling finishes shall be classified in accordance with ASTM E 84.
Fire Protection Systems

Fire Suppression System:
Automatic Sprinkler System Section 903 CBC
Assembly occupancies require sprinklering if above 300 occupants

New Risers
Sprinkler System Design
Designed and installed according to NFPA 13

- Mostly light hazard occupancy
- Some storage at ordinary hazard
- Calculated using Density Area Method

<table>
<thead>
<tr>
<th>Design Criteria for Light Hazard</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharge Density (gpm/ft2)</td>
<td>0.1</td>
</tr>
<tr>
<td>Area of Operation (ft²)</td>
<td>1,500</td>
</tr>
<tr>
<td>Total Hose Stream (gpm)</td>
<td>100</td>
</tr>
<tr>
<td>System Duration (min)</td>
<td>30</td>
</tr>
<tr>
<td>Area per sprinkler</td>
<td>163</td>
</tr>
<tr>
<td>C-Factor</td>
<td>120</td>
</tr>
</tbody>
</table>

- Several remote areas were calculated to find most demanding area.
- Full design details can be found in Final Report.

- NFPA 102 states sprinklers are not even needed for activity are if ceiling is 55ft above floor, and is not needed for spectator seating area either, section 9.5.1
- NFPA 102 is Standard for Grandstands, Folding and Telescopic Seating, Tents, and Membrane Structures
- NFPA 13 section A.8.1.1 states that, “based upon experience and testing, sprinklers have been found to be effective and necessary at heights in excess of 50ft.
- **8.5.5.3.1** Sprinklers shall be installed under fixed obstructions over 4 ft (1.2 m) wide.
City Water Supply:
C1 - Static Pressure: 140
C2 - Residual Pressure: 132
C2 - Residual Flow: 1186

Demand:
D1 - Elevation: 3.465
D2 - System Flow: 212.397
D2 - System Pressure: 102.577
Hose (Adj City): 100
Hose (Demand): 100
D3 - System Demand: 312.397
Safety Margin: 36.745

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Water Pressure at Riser
Water Supply pressure even above the rated 175 psi marking.
Fire Alarm System

Uses Notifier Fire Alarm Control Panel Model NFS2-640

- Digital voice command built in for voiced evacuation (EVACS)
- Total evacuation not staged
- Automatic and manual detection system
Means of Egress

Chapter 10 CBC

Egress Width Capacity using a 0.2 in per occupant factor per section 1025.2 for occupancies over 300

<table>
<thead>
<tr>
<th>Location</th>
<th>Occupant Load.</th>
<th>Required Egress Width</th>
<th>Provided Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>Far West Exit</td>
<td>804</td>
<td>120.6</td>
<td>136</td>
</tr>
<tr>
<td>Middle of Building</td>
<td>452</td>
<td>67.8</td>
<td>68</td>
</tr>
<tr>
<td>Main East Entrance and Exit</td>
<td>260</td>
<td>52</td>
<td>204</td>
</tr>
<tr>
<td>MAC</td>
<td>1230</td>
<td>246</td>
<td>340</td>
</tr>
<tr>
<td>North West Weight Area</td>
<td>452</td>
<td>67.8</td>
<td>68</td>
</tr>
<tr>
<td>Basket Ball Gym</td>
<td>300</td>
<td>45</td>
<td>204</td>
</tr>
<tr>
<td>Old Existing Gym</td>
<td>1869</td>
<td>373.8</td>
<td>816</td>
</tr>
<tr>
<td>Pre-function Space</td>
<td>1221</td>
<td>183.15</td>
<td>408</td>
</tr>
</tbody>
</table>
Occupant Capacity Conflict

What they designed the Space for: What the space should technically be designed for:

[Diagram showing the comparison of the planned use vs. the technical design requirements for the space.]
Another Egress Issue

Another issue the turnstiles at the front 1008.3 Only 50 people per turnstile is permitted Exit serves 1379 not the 250 allowed

All other Egress components meet requirements:

- Unenclosed stairways meet 1020.1 exception 8 or 9
  - Are not required to be enclosed due two only serving one floor
- Travel distance met according to section 1016
- Meets minimum number of exits, 4, per Table 1019.1
- Exit remoteness met according to section 1015.2

Details given in full report
Objective: Get everyone out before area becomes untenable

Required Safe Egress Time < Available Safe Egress Time

RSET   ASET

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## Performance Based Criteria

### Tenability

<table>
<thead>
<tr>
<th>Design Criteria</th>
<th>Tenability Limit</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Monoxide</td>
<td>6000 ppm</td>
<td>Incapacitation level Table 2-6.B1 SFPE Handbook</td>
</tr>
<tr>
<td>Temperature</td>
<td>140°F (60°C)</td>
<td>Assessment of Hazards to Occupants from Smoke, Toxic Gases, and Heat.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>By Purser in the SFPE Handbook 4th edition</td>
</tr>
<tr>
<td>Heat Flux</td>
<td>1.7kW/m²</td>
<td>SFPE Engineering Guide, <em>Predicting 1st and 2nd degree skin burns from</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>thermal radiation</em></td>
</tr>
<tr>
<td>Visibility</td>
<td>42 ft (13m)</td>
<td>SFPE Handbook, Table 2-42 Assuming building occupants are unfamiliar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>with surroundings</td>
</tr>
</tbody>
</table>
Design Fire Scenarios

1. Wrestling room trash can fire with sprinklers that do not work.
2. Old Gym folded bleacher fire where sprinklers do not work.
3. Old Gym bleacher fire that blocks off an exit.
Design Fire Scenario 1

Wrestling room trash can fire with sprinklers that do not work. Mats are never stored vertically.
Design Fire Scenario 1
Wrestling room mat fire with sprinklers that do not work.

Mat made from PVC Rubber Nitrile foam that has been treated with fire retardant.

- Lower ceiling height 18ft = easier sprinkler activation
- Egress directly outside
Design Fire Scenario 1
Fire Analysis
Heat Release Rate Tests of Plastic Trash Containers
Tests done by NIST, FR 4018

Trash can actually tested
Design Fire Scenario 1
Egress Analysis

Pathfinder Results
276 occupants exit in 83 seconds, 1min 23secs

Such a fast exit time the fire would only be around 50 kw at 83 seconds.
Design Fire Scenario 2

Old Gym folded bleachers

424 occupant load
6360 ft²
15 person/ft²

Bleachers are folded up 95% of the time
72ft to top of ceiling
Design Fire Scenario 2
Old Gym folded bleacher fire where sprinklers do not work.

Bleach Break Down

Materials:

- Polyethylene $\text{C}_2\text{H}_4$
  - $\Delta h_{\text{ch}} = 43.4 \text{MJ/kg}$ Table C.3 SFPE
  - Smoke yield 0.102 Table 3-4.22

- Plywood $\frac{1}{2}''$
  - $\Delta h_{\text{ch}} = 19.6 \text{ MJ/kg}$ Table C.3 SFPE
Design Fire Scenario 2

Old Gym folded bleacher fire where sprinklers do not work.

FDS Model

Steel
Plywood
Polyethylene

Ignition source 300kW fire from backpack.
Design Fire Scenario 3
Old Gym bleachers fully extended with a fire blocking exit
Design Fire Scenario 3
Fuel Load

Side view of bleachers extended

Backpack Ignition Source ~300kW
Design Fire Scenario 3

Old Gym folded bleacher fire where sprinklers do not work.

Ignition Source: Back pack with laptop and sweatshirt \(\sim 300\text{kW}\)

- Add 80 seconds for assumed Fast growth fire.

![Figure 3-1.29. Single, packaged, and boxed computers and monitors.](image1)

![Figure 3-1.19. Two men’s jackets.](image2)
Fire Dynamic Simulator

- Fire: Starts at 300kW
- Model uses pyrolysis to model flame spread
- Resolution: 0.1m mesh size by fire 0.5 for open space area

For detail on all inputs please see full report.

HRR vs Time

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Fire Dynamic Simulator: Tenability Results

At 1.83m above the highest occupants in the highest level

276sec+80sec=356sec into the fire
At 1.83m above the highest occupants in the highest level

285sec + 80sec = 365sec into the fire

At 1.83m above the highest occupants in the highest level
At 1.83m above the highest occupants in the highest level

Fire Dynamic Simulator
Tenability Results

447.5sec + 80sec = 527.5sec
Into the fire
Fire Dynamic Simulator
Tenability Results

Temperature Slice at 447 sec
Design Fire Scenario 3

RSET

- Detection time: 45 seconds
  - by person intimate with fire.

- Alarm time: 25 seconds
  - See report for timed analysis

- Premovement time: 30 seconds
  - SFPE Handbook with train personnel

- Total time before people move to egress: 100 sec

- Movement time determined by Pathfinder
Design Fire Scenario 3
Pathfinder
Design Fire Scenario 3
Pathfinder

Time to untenable conditions for red area, 356 sec
Minus the time before people start moving -100sec
Movement time when untenable conditions happen = 256sec
Design Fire Scenario 3
Pathfinder

460.8 seconds into Movement time
560.8 seconds into Fire time
Design Fire Scenario 3
Pathfinder Results

- Total movement time: 485 seconds
- Time to exit from top of bleachers: 461s
- Total RSET = 45s + 25s + 30s + 461s = 561s
  - 9 min and 21 seconds
Conclusion
RSET > ASET

561 sec > 365 sec
9min 21sec > 6min 5sec

This does not pass the performance criteria of allowing everyone to safely egress before the space becomes untenable.

Recommend providing mechanical exhaust smoke control method for the gym.
Design it to increase the ASET time to allow for safe egress.
Questions?