CALPOLY Recreation Center Fire Protection Review

CAL POLY

Presented by Alain Mamada

PRESENTATION OUTLINE

- ▶ Overview of the building
- ▶ Prescriptive Design Approach
 - Structural Analysis
 - Fire Protection Systems:
 - Fire Alarm and Detection System
 - Water-based Fire Suppression System
 - Egress Analysis
- ▶ Performance-Based Design Approach
 - Design Fire Scenarios
 - FDS
- ▶ Conclusion and Recommendations

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CAL POLY
Fire Protection Engineering

OVERVIEW

- ▶ Opened first time: 1993
- ▶ Expansion construction: 2009 to 2011
- ▶ Renovated building opened: January 2012
 - ✓ 165 715 square feet
 - ✓ State of the art weight and cardio equipment
 - ✓ Fitness studios
 - ✓ Indoor track

OVERVIEW continued...

- ▶ Applicable Codes and Standards
 - ❖ California Building Code (2007)
 - International Building Code (2006)
 - ❖ California Fire Code (2007)
 - International Fire Code (2006)
 - ❖ NFPA 13: Automatic Sprinkler Systems (2003)
 - ❖ NFPA 72: National Fire Alarm Code (2007)
 - ❖ [NFPA101: Life Safety Code]

STRUCTURAL ANALYSIS

- ▶ Classification: IBC: Based on intended use and occupancy:
 - Group A [IBC, Section 303]
- ▶ IBC: Mixed and non-separated occupancy: [IBC, Section 508.3.1]

Use of room / Space	Occupancy Classification
Gymnasium	A-3
Fitness	A-3
Offices / Administration	B
Yoga / Meditation	A-3
Storage rooms	S
Mechanical/Electrical Equipment rooms/spaces	Accessory (Incidental use)

- ▶ LSC: Mixed and non-separated occupancy [LSC 6.1.14.3]

STRUCTURAL ANALYSIS

- ▶ As a multiple occupancy building, the Recreation Center shall comply with all requirements that are applicable to each of the purposes for which the room or space will be occupied.
- ▶ The means of egress facilities, construction type, protection, and other safeguards in the building shall comply with the most restrictive fire and life safety requirements of the occupancies involved

STRUCTURAL ANALYSIS

- ▶ Building Construction Type: I-B
 - Physical Dimensions:
 - Stories: 2
 - Height: 65 ft (average height)
 - Total area: 165 715 square ft (15 396 m²)

STRUCTURAL ANALYSIS

GENERAL BUILDING HEIGHTS AND AREAS

TABLE 503
ALLOWABLE BUILDING HEIGHTS AND AREAS^a
 Building height limitations shown in feet above grade plane. Story limitations shown as stories above grade plane.
 Building area limitations shown in square feet, as determined by the definition of "Area, building," per story

GROUP	HEIGHT(feet)	TYPE OF CONSTRUCTION								
		TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
		UL	160	65	55	65	55	65	50	40
		STORIES(S) AREA (A)								
A-1	S	UL	5	3	2	3	2	3	2	1
	A	UL	UL	15,500	8,500	14,000	8,500	15,000	11,500	5,500
A-2	S	UL	11	3	2	3	2	3	2	1
	A	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
A-3	S	UL	11	3	2	3	2	3	2	1
	A	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
A-4	S	UL	11	3	2	3	2	3	2	1
	A	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
A-5	S	UL	UL	UL	UL	UL	UL	UL	UL	UL
	A	UL	UL	UL	UL	UL	UL	UL	UL	UL
B	S	UL	11	5	3	5	3	5	3	2
	A	UL	UL	37,500	23,000	28,500	19,000	36,000	18,000	9,000
E	S	UL	5	3	2	3	2	3	1	1
	A	UL	UL	26,500	14,500	23,500	14,500	25,500	18,500	9,500
F-1	S	UL	11	4	2	3	2	4	2	1
	A	UL	UL	25,000	15,500	19,000	12,000	33,500	14,000	8,500
F-2	S	UL	11	5	3	4	3	5	3	2
	A	UL	UL	37,500	23,000	28,500	18,000	50,500	21,000	13,000
...	S	1	1	1	1	1	1	1	1	NP

STRUCTURAL ANALYSIS

- ▶ IBC, Section 506.1 allows Table 503 building areas to be increased due to frontage and automatic Sprinkler System protection.
- ▶ Summary of increased tabular values

Occupancy Groups	Type II		Type III		Type IV	Type V	
	A	B	A	B		A	B
Group A-3							
Tabular A	15500	9500	14000	9500	15000	11500	6000
Increased A	49083	30083	44333	30083	47500	36416	19000
Group B							
Tabular A	37500	23000	28500	19000	36000	18000	9000
Increased A	118750	72833	90250	60166	114000	57000	28500

STRUCTURAL ANALYSIS

- ▶ Analysis of increased values for areas, story heights due to frontage and automatic sprinkler system installation revealed that no other building construction types would have been allowed in accordance with IBC provisions
- ▶ Limiting factor is the building floor area

STRUCTURAL ANALYSIS

- ▶ Fire resistance ratings of construction elements [IBC section 602]
 - Interior and exterior building elements

Building Element	Fire Resistance Ratings
Primary structural frame	2
Exterior bearing walls	2
Interior bearing walls	2
Exterior nonbearing walls & partitions	See Table 602
Interior nonbearing walls & partitions	0
Floor construction & secondary members	2
Roof construction & secondary members	1

STRUCTURAL ANALYSIS

- Exterior Walls

TABLE 602
FIRE-RESISTANCE RATING REQUIREMENTS FOR EXTERIOR WALLS BASED ON FIRE SEPARATION DISTANCE^{a, b}

FIRE SEPARATION DISTANCE =X (feet)	TYPE OF CONSTRUCTION	OCCUPANCY GROUP ^c	OCCUPANCY GROUP F-1, M, S-1 ^d	OCCUPANCY GROUP A, B, E, F-2, I, R, S-2 ^d , U ^e
$X < 5^c$	All	3	2	1
$5 < X < 10$	IA Others	3 2	2 1	1 1
$10 \leq X < 30$	IA, IB IIB, VB Others	2 1 1	1 0 1	1 ^d 0 1 ^d
$X \geq 30$	All	0	0	0

STRUCTURAL ANALYSIS

Examples of building elements

Typical GFRC Exterior Column-FR 2h

Typical Interior Gypsum Wallboard Column-FR 2h

Floor and roof assemblies covered with 5/8" gypsum wallboard or with 7/8" plaster over metal – required fire ratings

FIRE PROTECTION SYSTEM

FIRE ALARM & DETECTION SYSTEM

- ▶ Fire Alarm System in the REC Center:
 - Building Fire Alarm System connected to a proprietary supervising Station [Cal Poly University Police building]
 - Addressable initiating devices
 - Addressable notification appliances
 - Interfaces with auxiliary systems
 - Elevator recall
 - Fire dampers

- ▶ Fire control panel displays/transmits three signal types:
 - Alarm signals
 - Supervisory signals
 - Trouble signals

FIRE PROTECTION SYSTEM

FIRE ALARM & DETECTION SYSTEM continued

- ▶ Initiating devices
 - Smoke detectors

FSP-851 with B710LP base

- Heat detectors

FST-851 Series in B710LP base

- Manual pull station
- Wet-pipe sprinkler system flow switch
- Duct-smoke detector

The NBG-12LX

Ceiling & wall mounted. UL & FM approved

- ▶ Notification Appliances
 - Speaker / Strobes

- Horn / Strobes

Wall or ceiling mounted. UL & FM approved

FSD-751PL

FIRE PROTECTION SYSTEM

FIRE ALARM & DETECTION SYSTEM

- ▶ Supervisory signal initiating devices

- Flow switch:

- Tamper switch: Gate valve OSY monitoring switch

Devices are UL listed & FM approved for applications

FIRE PROTECTION SYSTEM

FIRE ALARM & DETECTION SYSTEM

- Activate local audible and visible alarm notification appliances to notify the occupants to evacuate the building
- Send a fire alarm signal to the supervising station; where operators, in constant attendance, monitoring all signals will respond accordingly
- “Female vs male” voice recorded message for EVAC system

FIRE PROTECTION SYSTEM

WATER-BASED SUPPRESSION SYSTEM

- ▶ Occupancy hazard classification:
 - Light Hazard [NFPA13,§5.2]
 - Ordinary Hazard (Group 1) [NFPA13,§5.3.1]
- ▶ Automatic sprinkler system required [NFPA13,§12.3.5.2]
- ▶ Wet-pipe automatic sprinkler system installed throughout the building
 - QRSC: Quick Response Standard Coverage
 - QREC: Quick Response Extended Coverage

FIRE PROTECTION SYSTEM

WATER-BASED SUPPRESSION SYSTEM

- ▶ Using CMDA [Control Mode Density/Area]:
 - Hose stream allowance: 100 gpm for 30 minutes

Rooms	Hazard Classifications	Density and Design Area of Operation
<ul style="list-style-type: none"> Gymnasiums/MAC Fitness/Weight rooms Racquet ball courts Prefunction areas Offices/Corridors/Lobbies Restrooms/Locker rooms 	Light Hazard	<ul style="list-style-type: none"> 0.10 gpm/ft² 900 ft² <p>Reduced area as per NFPA13, Figure 11.2.3.2.3.1 for quick response sprinklers</p>
<ul style="list-style-type: none"> Storage rooms Mechanical/Electrical rooms Custodian rooms 	Ordinary Hazard (Group 1)	<ul style="list-style-type: none"> 0.15 gpm/ft² 1013 ft² <p>Reduced area as per NFPA13, Figure 11.2.3.2.3.1 for quick response sprinklers</p>

FIRE PROTECTION SYSTEM WATER-BASED SUPPRESSION SYSTEM

► Sprinkler riser locations

FIRE PROTECTION SYSTEM WATER-BASED SUPPRESSION SYSTEM

► Water Supply vs System demand [Gymnasium]

$$P_{\text{static}} = 140 \text{ PSI}$$

$$P_{\text{system}} = 78 \text{ PSI}$$

EGRESS ANALYSIS & DESIGN

► Life Safety Code: NFPA101

- Occupation load calculations based on the use of the each space. [Reference §7.3.1.2, Table 7.3.1.2]
- Summarized Occupant Load factors used:

USE	OLF (Square ft/person)
Assembly Use	
Concentrated use without fixed seating	7 net
Less concentrated use without fixed seating	15 net
Exercise room with equipment	50 net
Exercise room without equipment	15 net
Business Use	
Offices	100
Storage Use	
Store rooms	500

EGRESS ANALYSIS & DESIGN

- ▶ Life Safety code: NFPA101
 - Egress capacity based on capacity factors in accordance with §7.3.3.1
 - The minimum required width:
 - Stairways: 0.3 inches (width/person)
 - Other components (e.g. doors): 0.2 inches (width/person)

EGRESS ANALYSIS & DESIGN

- Summary of occupant load calculations (2nd floor):

Floor/Space	Occupancy	Area (ft ²)	OLF (ft ² / OCC)	Calculated Occupant Load	Number of Exits Required
Fitness Studio 1	B	1688	50	34	1
Fitness Studio 2	B	1962	50	40	1
Main Gym North	A-3	6396	-	1180	2
Main Gym South	A-3	6414	-	1180	2
Fitness Studio 3	B	2356	50	48	2
Cardio Fitness	A-3	3330	50	67	2
Jogging Track	A-3	2014	-	69	2

EGRESS ANALYSIS & DESIGN

EGRESS ANALYSIS & DESIGN

Space designations	Color codes
Assembly	Green
Business	Blue
Storage	Yellow
Mechanical rooms	Orange
Electrical rooms	Grey
Changing /Restrooms	Light Green

EGRESS ANALYSIS & DESIGN

Space designations	Color codes
Assembly	Green
Business	Blue
Storage	Yellow
Mechanical rooms	Orange
Electrical rooms	Grey
Changing /Restrooms	Light Green

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EGRESS ANALYSIS & DESIGN

EGRESS ANALYSIS & DESIGN

- ▶ Exit Stairway sizes larger than required
- ▶ Arrangement of exits:
 - Arranged to provide access for each occupant to not less than two exits by separate ways of travel
- ▶ Remoteness of means of egress
 - Remotely located from each other and
 - In accordance with NFPA101, §7.5.1.3.2, the minimum separation distance between two exits is not less than one-third the length of the maximum overall diagonal of the area served
- ▶ Travel distance, common path of travel
 - code compliant in accordance with NFPA101, §7.6.1

EGRESS ANALYSIS & DESIGN

► Building egress time

SFPE mode: 2 min 47 s

STEERING mode: 2 min 41 s

PRESCRIPTIVE DESIGN SUMMARY

- ▶ The following areas raised concerns about enforcement:
 - Maximum occupancy load of the “event” areas rely on administrative control:
 - Gymnasium: 2nd Floor
 - Seats: 1180 people (bleachers)
 - Egress capacity: 720 people
 - Maximum occupancy: 424 people
 - Who controls? But what if?

PERFORMANCE BASED ANALYSIS

- ▶ Goal:
 - To demonstrate that occupants in the REC Center are protected against fire hazards
- ▶ Objectives:
 - To confirm that REC Center occupants are able to evacuate safely and timely (before conditions become untenable) during a fire emergency
- ▶ Performance Criteria:[Reference SFPE Handbook, 4th ed., Section 2-6]
 - Visibility level: > 5 m [2 m above walking floor]
 - Exposure to temperature: < 60 °C
 - Exposure to toxic gases [CO concentration]: < 1200 ppm [30 min]

Figure 1 Exposure in Building Fire

PERFORMANCE BASED ANALYSIS

► Postulated Design Scenarios: 1st Floor

- ❑ A concert fire in the main Gym
- ❑ Floor mat fire in the martial arts studio
- ❑ Storage area fire
- ❑ Laundry room fire
- ❑ Administrative office fire

FLOOR 1

PERFORMANCE BASED ANALYSIS

► Postulated Design Fire Scenario: 2nd Floor

□ Fire under bleachers

FLOOR 2

PERFORMANCE BASED ANALYSIS

- ▶ ASET: Available Safe Egress Time: Time from ignition until building becomes untenable. Determined using FDS modeling
- ▶ RSET: Required Safe Egress Time: Time needed by occupants to evacuate from the building. Determined using Pathfinder egress simulator:

$$t_{RSET} = \Delta t_{detection} + \Delta t_{alarm} + \Delta t_{pre-movement} + \Delta t_{travel}$$

PERFORMANCE BASED ANALYSIS

□ Egress time assumptions:

- All building occupants start evacuation at same time
- Occupants use the exits in an optimum balance
- Occupant flow does not involve interruptions caused by evacuee decisions
- Occupants considered are free of physical and mobility impairments

PERFORMANCE BASED ANALYSIS

► Design fire scenario 1: GYM Concert Fire

The following assumptions were made:

- 3900 people attending a recreation event
- An electric fault ignites:
 - Sound system equipment
 - Computer boards
- Fire blocks South-West doors
- No automatic fire suppression available
- Ultrafast fire – t^2 fire
- Fuel properties
 - HRR = 3000 kW

[Estimated from SFPE HB, Chap 3-1]

- $Y_s = 0.2$ (Polyurethane)
- [SFPE HB, Tb 3-4.16]
-

PERFORMANCE BASED ANALYSIS

► RSET Time Analysis

■ Detection: Sprinkler activation time

❖ DETACT prediction:

- Inputs: QRS; RTI= 50 (m.s)^(0.5); Actuation Temperature=155°F
- Time of activation: 232 s (~4 min)
- Sprinkler activation time excessive due to high roof
- Manual pull device activation: 30 s

■ Alarm: Time of activation of Notification Appliances=10 s [NFPA72,§10.12.1]

■ Pre-movement: <3 min [SFPE-3rd edition, Table 3-13.1]

■ Travel: Determined using Pathfinder simulator

PERFORMANCE BASED ANALYSIS

- Using Pathfinder:

PERFORMANCE BASED ANALYSIS

► $t_{RSET} = \Delta t_{detection} + \Delta t_{alarm} + \Delta t_{pre-movement} + \Delta t_{travel}$

◦ $RSET = 30/60 + 10/60 + 30/60 + 5 \cong 7 \text{ min}$

→ $T < 3$ [SFPE, 3rd edition, Table 3-13.1]

► t_{ASET} to be established as t_{minimum} to reach either:

- Minimum visibility limit
- Maximum CO concentration (dose)
- Maximum temperature limit

PERFORMANCE BASED ANALYSIS

- FDS Output: Visibility @ 2 m above top seats (2nd floor)

Visibility = 5 m

Smokeyview 6.1.5 - Nov 22 2013

@ time = 5 min

PERFORMANCE BASED ANALYSIS

► FDS Output: Visibility in 2nd floor

PERFORMANCE BASED ANALYSIS

- FDS Output: Visibility above top seats (1st floor)

PERFORMANCE BASED ANALYSIS

- ▶ FDS summary: @ 5 min on second floor

Visibility		Carbon Monoxide		Temperature	
Limit	Minimum Value	Limit	Maximum Value	Limit	Maximum Value
5 m	5 m	1200 ppm	0.06 ppm	60 Deg C	40 Deg C

- ▶ $t_{ASET} = \Delta t_{FDS-visibility} = 5 \text{ min} < t_{RSET} [7 \text{ min}]$

$$t_{RSET} > t_{ASET}$$

- ▶ *Concert attendees on second floor are unable to evacuate safely before conditions become untenable*
 - *Recommend:*
- ▶ *Egress time on second floor needs to be improved*

PERFORMANCE BASED ANALYSIS

► Design fire scenario 2: Fire under bleachers

The following assumptions were made:

- Bleachers on ground floor retracted
- Bleachers on second floor 80 % full [926 people seated]
- Fire intentionally set: Gasoline spill under bleachers ignites:
 - HRR = 800 kW [NIST Spill Test]
 - Spill of 1000 mL
 - $Y_s = 0.1$
- Fire blocks one exit double-door
- No automatic fire suppression

Peak
HRR=800 kW

NIST Spill Fire Test
– NIJ report 604

PERFORMANCE BASED ANALYSIS

► RSET Time Analysis

■ Detection: Sprinkler activation time

❖ DETACT prediction:

- Inputs: QRS; RTI= 50 (m.s)^(0.5); Actuation Temperature=155°F
- Time of activation: 182 s (~3 min)
- Sprinkler activation time excessive due to high roof
- Manual pull device activation: 30 seconds

■ Alarm: Time of activation of Notification Appliances =10 s [NFPA72,§10.12.1]

■ Pre-movement: <3 min [SFPE-3rd edition, Table 3-13.1]

■ Travel: Determined using Pathfinder simulator

PERFORMANCE BASED ANALYSIS

► Pathfinder simulation: Scenario 2

SFPE mode: 8 min

PERFORMANCE BASED ANALYSIS

- Using Pathfinder:
 - Travel time: 8 min (SFPE mode)
 - ▶ $t_{RSET} = \Delta t_{detection} + \Delta t_{alarm} + \Delta t_{pre-movement} + \Delta t_{travel}$
 - $RSET = 30/60 + 10/60 + 30/60 + 8 \cong 10 \text{ min}$
 - ▶ t_{ASET} to be established as t_{minimum} to reach either:
 - Minimum visibility limit
 - Maximum CO concentration (dose)
 - Maximum temperature limit

PERFORMANCE BASED ANALYSIS

► FDS Output: Temperature

Temperature = 60° C

Time and location where
temperature limit is
reached

Smokeyview 6.1.5 - Nov 22 2013

@time = 10 min

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PERFORMANCE BASED ANALYSIS

- FDS Output: Visibility @ 6ft above to seats

PERFORMANCE BASED ANALYSIS

- ▶ FDS summary: @ 5 min on second floor

Visibility		Carbon Monoxide		Temperature	
Limit	Minimum Value	Limit	Maximum Value	Limit	Maximum Value
5 m	5 m	1200 ppm	0.07 ppm	60 Deg C	45 Deg C

- ▶ $t_{ASET} = \Delta t_{FDS-visibility} = 5 \text{ min} < t_{RSET} [10\text{min}]$

$$t_{RSET} > t_{ASET}$$

- ▶ *Event attendees are unable to evacuate safely before conditions become untenable*
 - *Recommend:*
- ▶ *Administrative controls to be strictly enforced for second floor gymnasium occupancy*

RECOMMENDATIONS

- ▶ Safety factor improvement: ASET vs RSET:
 - Reduction of egress time from second floor gymnasiums
 - Training of personnel in emergency crowd management [Life safety management]
 - Regular fire safety awareness campaigns
- ▶ Performance re-assessment of installed sprinkler system in the gymnasium
- ▶ Review enforcement of all administrative controls
- ▶ Update documentation to reflect as-built conditions
- ▶ Encourage further performance based analysis of the building

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