Fire Protection Analysis of The Orfalea College of Business Building (#3)

William Fletcher
Fire Protection Engineering Department
Cal Poly San Luis Obispo
Culminating Experience Presentation
March 12, 2012

Outline

- Overview of the Building
- Fire Protection Systems
 - Egress
 - Fire Alarm and Detection
 - Water Based Suppression
 - Structural Fire Protection
- Potential Hazards and Non-Conforming Conditions
- Performance Analysis
- Results
- Recommendations

Overview of the Building

- Completed in 1992
- Increased useable space by 73,738 ft²
- Cost of \$13.5 million
- The building was designed and constructed without Automatic Fire Suppression
- Type II FR UBC 1985
- Type II A CBC 2010

Building Features

- Building was constructed adjacent to an existing building
- The design includes interconnection of the levels
- 3 of the 4 connect through open walkways
- Exit vestibule on the third floor
- Second floor has open stairway in the center
- Courtyard in the center between buildings

Building Description

- Occupancy Classification:
- Life Safety Code
 - Existing Business Building
 - Assembly
- California Building Code
 - Business
 - A-3

- The uses and room types include:
 - Lecture Halls
 - Classrooms (<50 persons)
 - Administrative Offices
 - Faculty Offices
 - Conference Rooms
 - Computer Labs

Business Silo

Occupant Load 240 Persons

Floor Plans: Fourth Floor

- **Occupant Load: 130 Persons**
- **Exit Capacity: 480 Persons**

Floor Plans: Third Floor

- **Occupant Load:**
447 Persons
- **Exit Capacity:**
510 Persons

Floor Plans: Second Floor

Business Silo

- Occupant Load: 240 Persons
- Exit Capacity: 360 Persons

Main Building

- Occupant Load: 504 Persons
- Exit Capacity: 680 Persons

- **Occupant Load:**
377 Persons
- **All Rooms Open to Outside with Access to Public Way**

Exit Arrangement

- Common Path Limits:
 - Two rooms exceed the allowable of 20 feet with distance of 35 feet
- Dead-End Limits:
 - Are met through limiting the distance to 50 feet with a fire door
- Travel Distance Limits:
 - All below allowable 200 feet

Fire Alarm and Detection

- The fire alarm activates notification appliances and reports to Cal Poly's Dispatcher
- Areas of concern:
 - The lower three levels have very few smoke detectors, only at the end of corridors
- Covered areas:
 - Top level has the highest density of smoke detectors
 - Heat detection in mechanical rooms

Locations	Type	Number
In Hallways	Photoelectric / Fixed Temperature 135F(57C)	16
In FACP, storage and mechanical rooms	Fixed Temperature Thermal Detector	4
In circular reception area on 3rd floor	Fixed Temperature Thermal Detector	1
Duct Detector	Photoelectric Sensor	5

Visual Requirements

- Current System
 - Gaps in coverage
 - Rooms without visual notification

	Audible and Visual Devices
Floor	
1	5
2	4
3	8
4	9
silo	2

Audible Requirements

- Currently system
 - Meets distance requirements
 - Closed doors level drops below recommended level

Water-based Suppression

- Dry-pipe risers in three stairwells 2 1/2" hook-ups
- Wet-pipe riser: fire hose cabinets with 1 1/2" hook-ups
- Replaced with fire extinguishers
- Fire Department Connection at south end of building

Structural Fire Protection

- UBC Type II Fire Resistive
- CBC Type IIA
 - Non-Sprinklered
 - Non-rated openings and operable windows
 - Exterior bearing walls only 1 hour

Element	CBC 2010 Requirements	Construction status
Primary Structural frame	1	2
Bearing walls Exterior	1	1
Bearing Walls Interior	1	-
Non-bearing walls and partitions interior	0	0
Non-bearing walls and partitions exterior with separation	0	0
Non-bearing walls and partitions exterior with no separation	1	2
Floor and secondary	1	2
Roof and construction	1	1
Shaft	2	2
Corridor	1	1

Fire Resistance Ratings

Fourth Floor

Fire Resistance Key
Non-Combustible
1- hr. Rated GWB Partition
2- hr Rated GWB Partition
2- hr Rated GWB Shaft wall
Acoustic Isolated Double Stud Wall

Potential Hazards and Non-Conforming Conditions

- Exit Sign Locations
- Exterior Exposure
- Passive Fire Protection
- Detector Location
- Combustibles and Obstructions in Exit Corridor

Exit Sign Locations

- Exit Sign Locations
 - Fourth Floor
 - View from Fire Scenario 1
 - LSC 7.10.2 Directional Signs

Exit Sign Locations

- Exit Sign Locations
 - Third Floor
 - Both Doors Propped Open
 - LSC 7.10.1.2.2 Horizontal components

Exterior Exposure

- Exterior Exposure
- No Ratings on Operable Windows
- 20 Feet of Separation

Passive Fire Protection

- Fire Doors Propped Open

Detector Location

- Obstructed smoke detector
- New door preventing continuous corridor to smoke detector on third floor

Combustibles and Obstructions in Exit Corridor

- Corridor Width with Obstruction 39"
- Required Width 44"

Performance-Based Analysis

- Performance Criteria
- Fire Dynamics Simulator
- Fire Scenarios
 - Scenario 1
 - Scenario 2
 - Scenario 3
- Egress Analysis
- Required Safe Egress Time(RSET)
- Results

Fire Protection Goals	Objectives	Performance Criteria
Minimize fire-related injuries and prevent undue loss of life	Maintain tenable conditions in paths of egress	CO < 1,400 ppm
		Temperature < 60 C
		Visibility greater than 20 feet or Optical density greater than 0.2 1/m
	Prevent flash over in room of origin	Smoke level 6 feet above floor
		Temperature inside of room and upper layer < 500 C
		q _r - floor level < 20 kW/m ²

Sources: The SFPE Handbook: Bryan, J.L., “Behavioral Response to Fire and Smoke,” Purser, D.A., “Toxicity Assessment of Combustion Products,” “Assessment of Hazards to Occupants from Smoke, Toxic Gases and Heat”, Performance Criterion from NFPA 101 Life Safety Code.

Drysdale, D. “An Introduction to Fire Dynamics.

NFPA Handbook Chapter “Combustion Products and Their Effects on Life Safety”

Fire Dynamic Simulator

- Used as a tool to help determine Available Safe Egress Time (ASET)
- Limitations
 - Based on conditions specified by user
 - Fire Size, Fire location, conditions, materials, etc.
 - Run times and mesh size
 - Rectilinear numerical grid
 - FDS will only consider CO formed directly through the combustion process
 - Experimental data
- Measuring Performance Criteria in room of origin and in the means of egress

Fire Scenario: 1

- There are open areas inside the corridor that are currently being utilized for waiting or display areas
- This places a large amount of combustibles in an exit corridor
- There are four alcoves on floor

Fire Scenario: 1

Fire Scenario 1

- Heat Release Rate
 - $Q = \alpha t^2$
 - Fast: $t_g = 150$ seconds
 - $\alpha = 0.047$

- A peak heat release rate of 2000 kW was used

Results of Babrauskas Studies				
	Loveseat		Chair	
	Pk HRR (kW)	Flashover time (s)	Pk HRR (kW)	Flashover time (s)
Furniture calorimeter	2890	230 *	1970	280 *
Room 1 (2.0 m x 1.13 m)	2490	373		
Room 2 (2.0 m x 1.50 m)	3550	377		
Room 3 (1.29 m x 2.0 m)	2660	410		
Room 4 (1.29 m x 2.0m)			2260	302
Flashover time assessed as 20 kW/m ² heat flux on floor				
* In furniture calorimeter, time to peak HRR is reported				
Room dimensions refer to opening width & opening height				

Scenario 1: ASET

In Fire Alcove Max Temperature: 456 C at 210 seconds

In Corridor Max Temperature: 579 C at 1060 seconds

Criteria in Fire Alcove at 65 seconds and in Corridor at 82 seconds

After 120 Seconds

After 210 Seconds

Scenario 1: Heat Release Rate

- Max Heat Release Rate: 7722 kW at 180 seconds

Scenario 1: Smoke Level

- Room at 55 seconds
- Corridor at 90 seconds

Scenario 1: Smoke Movement

After 30 seconds

After 55 seconds

After 90 seconds

Scenario 1: Visibility

- Using Soot to approximate visibility in meters at the height of 1.5 m
- Optical Density
 - Room at 38 seconds
 - Corridor at 75 seconds

After 40 seconds

After 75 seconds

Fire Scenario: 2

- Fourth floor there is a supply room and staff break room
- Both fire doors and window are open
- Several sources of ignition
- High fuel load

Fire Scenario: 2

Fire Scenario: 2 ASET

In Fire Room Max Temperature: 875 C at 240 seconds

In Corridor Max Temperature: 418 C at 1190 seconds

Criteria in Fire Room at 35 seconds and in Corridor at 105 seconds

Fire Scenario: 2 ASET

After 35 Seconds

After 240 Seconds

After 105 Seconds

After 1190 Seconds

Scenario 2: Heat Release Rate

- Max Heat Release Rate: 3180 kW at 350 seconds

Scenario 2: Smoke Level

- Room at 72 seconds
- Corridor at 145 seconds

Fire Scenario: Smoke Movement

After 72 Seconds

After 145 Seconds

Scenario 2: Visibility

- Using Soot to approximate visibility in meters
- Optical Density
 - Room at 115 seconds
 - Corridor at 240 seconds

After 115 seconds

After 240 seconds

Fire Scenario: 3

- Fourth Floor
- Pinch point in the T in the floor plan
- There is a fire door propped open that leads to a dead-end
- Not analyzed based on time limitations and significance

Egress Analysis

- Entire Building Evacuation

CASE	Scenario	Hand Calculation SFPE Estimate (min)	Hand Calculation Paul's Estimate (min)	Pathfinder Estimate (min) steering mode	Pathfinder Estimate (min) SFPE mode
1	All exits available	5.4	5.4	3.4	4.5
2	Only Vertical Exit Available	9.0	7.9	5.0	6.2
3	Silo	2.5	4.2	1.1	1.7

Travel Time: Fourth Floor

SFPE Method: 49 Seconds

Steering Mode: 70 Seconds

Hand Calculation SFPE: 80 Seconds

Evacuation of fourth Floor 70 seconds

RSET vs. ASET

Mowrer, F. W., & Rosenbaum, E. R. (2008). Fire Protection Handbook Information and Analysis for Fire Protection.

RSET

- Time to Alarm:
 - Occupants can detect a fire much quicker than detection system
 - If detected by human or manual means: time to detection + time to activate the pull station
 - Comparable to Smoke detection activation
- Scenario 1
 - Smoke detection activation 30 seconds
- Scenario 2
 - Smoke Detection Activation: 110 seconds

RSET Assumptions

- Pre-movement Time
 - Occupants:
 - Familiar with their surroundings
 - Trained staff member in every classroom
 - Occupants preference to be elsewhere
 - Belongings are mobile
 - Mild climate
 - False alarms
 - NFPA HB and SFPE HB estimates
 - Assume 45 seconds based on these factors

Conclusions and Recommendations

RSET				
		Limit	Scenario 1 (sec)	Scenario 2 (sec)
Maintain tenable conditions in corridor	CO ppm	1,400	850	1160
	Temperature (c)	60	82	105
	Optical density (1/m)	0.2	75	240
	Smoke level (m)	6.1	90	145
Prevent Flashover in room of origin	Temperature (c)	600	-	135
ASET				
	Scenario 1 (sec)		Scenario 2 (sec)	
Time to Alarm	30		110	
Pre-Movement Time	45		45	
Travel Time	70		70	
Total	145		225	

Scenario 1: Performance Criteria Bar Graph

Scenario 2: Performance Criteria Bar Graph

Recommendations

- Automatic Fire Sprinklers
 - Containment/Suppression of Fire
 - Damage to Property
 - Cost Benefit Analysis

Recommendations

- Upgrade Fire Alarm and Detection System
 - Reduce Detection Time
 - Improve Notification Appliances
- Fire Management Plan
 - Regulate Fire Hazards
 - Eliminate Hazardous Conditions
 - Inspection, Testing and Maintenance

Q&A

Special Thank You To:

- Professor Christopher Pascual
- Professor Frederick Mowrer
- Professor Thomas Korman
- Professor Lonny Simonian
- Professor David Rich
- Professor Lautenberger
- Professor Daniel Gemeny
- Professor John Chen