Culminating Project
Elementary School – Main Building

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Presentation Outline

• Building Overview
• Codes and Standards
• Prescriptive Requirements
  – Egress Analysis
  – Structural Protection
  – Fire Alarm System
  – Fire Suppression
• Performance Based Analysis
  – Performance Based Goals
  – ASET / RSET
  – Design Fire Scenarios / Egress Analysis
• Observations / Recommendations
Building Overview

- New Elementary School – Opened Fall 2012
- 4th Iteration of a Proto Type Campus
- 2 Story Building totaling 54,000 SF
- E Occupancy
- Type II-B Construction
- Fully Sprinklered
- Construction Cost of just over 14 million
Building Overview – Site Plan

- **Project Building**
  2-Story Primary Classroom Building
  - 325’x125’x39’

- **Multi-Purpose Building**

- **Future Phase Portable Classroom and Rest Room Buildings**
Building Overview – Front Elevation (North Facing)
Building Overview – Rear Elevation (South Facing)
Codes and Standards for Design

• 2007 CBC (Part2 Title 24), UBC with CA Amendments
• 2007 CEC (Part2 Title 24), NEC with CA Amendments
• 2007 CMC (Part2 Title 24), UMC with CA Amendments
• 2007 CFC (Part2 Title 24), UFC with CA Amendments
• NFPA 13 Standard for the Installation of Sprinkler Systems, 2002
• NFPA 14 Standard for the Installation of Standpipe and Hose Systems, 2003
• NFPA 72 Fire Alarm and Signaling Code, 2002 Edition
Building Reviewing Agencies

• Project plan review was done by the Division of State Architect (DSA) which has three main areas of review.
  – Fire Life Safety
  – Access and Compliance
  – Structural

• Project was also reviewed and approved by the local Fire Agency.
## Occupancy Classification
### 2007 CBC Table 1004.1.1

<table>
<thead>
<tr>
<th>FUNCTION OF SPACE</th>
<th>FLOOR AREA IN SQ. FT. PER OCC.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accessory storage area, mechanical equipment room.</td>
<td>300 gross</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>Library Reading rooms</td>
<td>50 net</td>
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Occupant Classification Areas
# Building Occupant Loads

<table>
<thead>
<tr>
<th>FUNCTION OF SPACE</th>
<th>OCCUPANT LOAD</th>
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</thead>
<tbody>
<tr>
<td>First Floor</td>
<td></td>
</tr>
<tr>
<td>Accessory storage area, mechanical equipment room.</td>
<td>8</td>
</tr>
<tr>
<td>Business areas</td>
<td>57</td>
</tr>
<tr>
<td>Educational Classroom area</td>
<td>539</td>
</tr>
<tr>
<td>Library Reading rooms</td>
<td>26</td>
</tr>
<tr>
<td><strong>First Floor Total</strong></td>
<td><strong>630 Occupants</strong></td>
</tr>
<tr>
<td>Second Floor</td>
<td></td>
</tr>
<tr>
<td>Accessory storage area, mechanical equipment room.</td>
<td>2</td>
</tr>
<tr>
<td>Educational Classroom area</td>
<td>842</td>
</tr>
<tr>
<td><strong>Second Floor Total</strong></td>
<td><strong>844 Occupants</strong></td>
</tr>
<tr>
<td><strong>Building Total</strong></td>
<td><strong>1474 Occupants</strong></td>
</tr>
</tbody>
</table>

Per CBC Table 1019.1 the 2nd floor requires 3 or more exits, the 1st floor requires 3 exits and the building requires a total of 4 or more exits.
Exit Path – First Floor

CBC Table 1016.1 for a E occupancy with sprinklers allows a maximum exit travel of 250 ft. Building maximum from the 2nd floor is just under 200 ft.

Main Exits from Second Floor are shown with circles.
Exit Path – Second Floor
Fire-Resistance Rating Requirements for Building Elements Per 2007 CBC Table 601 (Ratings in Hours)

<table>
<thead>
<tr>
<th>Building Element</th>
<th>Type IIB</th>
</tr>
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<tbody>
<tr>
<td>Structural Frame</td>
<td>0</td>
</tr>
<tr>
<td>Bearing Walls Exterior</td>
<td>0</td>
</tr>
<tr>
<td>Bearing Walls Interior</td>
<td>0</td>
</tr>
<tr>
<td>Nonbearing Walls and Partition Interior</td>
<td>0</td>
</tr>
<tr>
<td>Floor Construction Including Beams and Joists</td>
<td>0</td>
</tr>
<tr>
<td>Roof Construction Including Supporting Beams and Joists</td>
<td>0</td>
</tr>
</tbody>
</table>
Fire-Resistance Rating Requirements

• Per 2007 CBC Table 1017.1 Corridor Fire-Resistance Rating for a Type E Occupancy with sprinklers and with a corridor occupant load of greater than 10 the corridor requires a 1 hour rating.

• Elevator shaft and duct shafts penetrating floors require a 1 hour rating per 2007 CBC 707.4 if building is less than (4) floors. A 2 hour rating is required if 4 or more floors are connected.
Fire-Resistance Rating Requirements for Unenclosed Stairways

• The building uses Exception 9 from Section 1020 of the 2007 CBC to allow unenclosed exit stairways.
  – This building meets the exception because it is a sprinklered E occupancy with only two floors and has two remotely located stairs.

Reference Code

• SECTION 1020 VERTICAL EXIT ENCLOSURES [B]

1020.1 Enclosures required.

Interior exit stairways and interior exit ramps shall be enclosed with fire barriers constructed in accordance with Section 706 of the California Building Code or horizontal assemblies constructed in accordance with Section 711 of the California Building Code, or both. Exit enclosures shall have a fire-resistance rating of not less than 2 hours where connecting four stories or more and not less than 1 hour where connecting less than four stories. The number of stories connected by the exit enclosure shall include any basements but not any mezzanines. An exit enclosure shall not be used for any purpose other than means of egress.

Exceptions:

9. In other than Group H and I occupancies, interior egress stairways serving only the first and second stories of a building equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1 are not required to be enclosed, provided at least two means of egress are provided from both floors served by the unenclosed stairways. Such interconnected stories shall not be open to other stories. Unenclosed exit stairways shall be remotely located as required in Section 1015.2.
First Floor Plan - Fire Rating

Rated wall around elevator shaft and machine room

Typical rated wall using UL Design #U419
Second Floor Plan - Fire Rating

Rated Wall around Elevator Shaft

Rated shafts for HVAC drops from roof to first floor

Typical rated wall using UL Design #U419
Fire Alarm – Key Components and Design Methodology

• The fire alarm system is designed to meet the requirements of NFPA 72. The components as installed cover each individual room or area as required.
• The fire alarm is monitored by an independent central station which conforms to the requirements of NFPA 72 as amended by Article 91.
• Fire Alarm Control Panel is located in the Equipment Room on the ground floor and the expander panel is located in the storage room near the restrooms on the second floor.
  - Fire Alarm Control Panel – Gamewell-FCI – Model E3
• Fire Sprinkler Tamper Switch and Flow Switch are located on the ground floor in the storage room adjacent to the fire sprinkler riser.
• Outside Horn with Black Box are located at fire sprinkler riser.
  - Wheelock – Model AH-24WP-R WBBR
• Manual Pull Stations are throughout the building mounted at 48”A.F.F. at each exterior exit door.
  - Gamewell-FCI – Model MS-7AF-located
Fire Alarm – Key Components and Design Methodology

• The Smoke Detectors are spot-type smoke detectors AND have been designed to meet the requirements of NFPA 72 17.7.3.2 at 30 ft spacing.
  - Typical classrooms have two detectors.
  - Gamewell-FCI – Model ASD-PL2F

• Attic Heat Detectors have been located to meet the requirements of NFPA 72 Ch 17. The heat detectors are UL approved for 50 ft center to center spacing and are mounted above the ceiling in each attic space compartment.
  - Typical classroom layout is one per classroom located in the center of the classroom attic space.
  - Gamewell-FCI – Model ATD-HL2F

• Elevator Equipment Room has a heat detector.
  - Gamewell-FCI – Model ATD-L2F
Fire Alarm – Key Components and Design Methodology

• Duct Smoke Detector are located in the supply drops of each HVAC unit to shut down the units upon detection of smoke. Activation of one detector shuts down all building HVAC units.
  - Gamewell-FCI – Model ADPRF
• Horn / Strobe are Multi-Candela and are located throughout the building mounted on the walls of most rooms including classrooms.
  - Wheelock – Model ZNS-24MCW-FR
• Strobes are Multi-Candela and are located throughout the building mounted on the walls in the storage and restroom areas.
  - Wheelock – Model ZRS-24MCW-FR
Hydraulic Calculations were done using the Room Design Method (NFPA 13 section 14.4.4.1.2)
-the hydraulically most demanding area is the most remote classroom on the second floor.
-Calculations include the 4 sprinkler heads in the classroom and one in the corridor (calculations use a maximum of 5 heads per section 11.2.3.3.6)
-Occupancy classification is Light Hazard with a Density of 0.1 - GPM / SF
-Sprinkler Demand of 175.89 GPM, hose demand of 100 GPM,
-Total demand of 275.89 GPM @ 37.99 PSI
Fire Suppression – System Curve

Model Flow Curve from Local Fire Department:
Static = 45 psi
Residual = 35 psi @ 1800 GPM

(Fire Department does not require a safety cushion, actual flow test results are higher than design criteria of Model Flow Curve they require to be used for the sprinkler calcs)

Hydraulically most demanding area – most remote classroom on the second floor
-Sprinkler Demand of 175.89 GPM, hose demand of 100 GPM,
-Total demand of 275.89 GPM @ 37.99 PSI
Performance Based Analysis

– Performance Based Goals
– ASET / RSET
– Design Fire Scenarios / Egress Analysis
Performance Based Goals

• Life Safety, minimize fire related injuries and loss of life from fire.

• Property Protection, minimize damage to property and minimize down time from fire.

• Maintain Tenable Conditions in Fire Scenarios.
  – Criteria measured at 2m above walking surface.
  – Visibility requirement of greater than 5 m for classrooms and 10 m for corridors and entry areas.
  – Maintain smoke layer above 2 m.
  – Maximum exposure of Carbon Monoxide not to exceed 1,400 ppm.
  – Heat exposure of less than 60 degree C
ASET vs. RSET

• Available Safe Egress Time (ASET)
  – The available safe egress time of the occupants in the event of a fire from the time of fire ignition to the time untenable conditions occur in the evacuation route.

• Required Safe Egress Time (RSET)
  – The time required for occupants to reach an area of safety in the event of a fire from the time of fire ignition to the time evacuation is complete.
Design Fire Scenario - Locations
Design Fire 1: Waste Basket Fire

Location of Design Fire 1

View Looking From the South
Design Fire 1: Waste Basket Fire

• Location
  – Corridor 201, open to the primary entry access to the building and second floor egress corridors.

• Waste Basket in corridor is ignited.

• Similar to NFPA 101 Design Fire Scenario 1

• Fire is based on SFPE data from Figure 3-1.100
  – Standard Trash bag with 110 sheets of crumpled newspaper in a 30 gallon HDPE container
  – Peak HRR of 175 kw
Design Fire 1: Waste Basket Fire

Similar to NFPA 101 Design Fire Scenario 1

• (1) It is an occupancy-specific fire representative of a typical fire for the occupancy.

• (2) It explicitly accounts for the following:
  – (a) Occupant activities
  – (b) Number and location of occupants
  – (c) Room size
  – (d) Contents and furnishings
  – (e) Fuel properties and ignition sources
  – (f) Ventilation conditions
  – (g) Identification of the first item ignited and its location
HRR– Design Fire 1 Waste Basket Fire

HRR from SFPE Figure 3-1.100

HRR vs Time

HRR from FDS Output
Max HRR = 175 kW

Smoke Detector Activation at 20 s

No Sprinkler Activation
# Movement Time – Design Fire 1

## Waste Basket Fire

<table>
<thead>
<tr>
<th></th>
<th>Hydraulic Model Estimate</th>
<th>Pathfinder SFPE Mode w/ Collisions Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detection Time</td>
<td>20 s</td>
<td>20 s</td>
</tr>
<tr>
<td>Alarm Time</td>
<td>5 s</td>
<td>5 s</td>
</tr>
<tr>
<td>Pre-Movement Time</td>
<td>30 s</td>
<td>30 s</td>
</tr>
<tr>
<td>Movement Time</td>
<td>204 s</td>
<td>221 s</td>
</tr>
<tr>
<td>RSET</td>
<td>259 s</td>
<td>276 s</td>
</tr>
</tbody>
</table>

Hydraulic Model Estimate is used for RSET Evaluation

All stairs and doors available
Design Fire 1: Waste Basket Fire

CO at 259 s RSET - CO levels never approach tenability levels

Temperature at 259 s RSET - Temp levels never approach tenability levels

Visibility levels never approach tenability levels

Smoke layer drops below 2 m at 236 s, prior to 259 s RSET
Fire Scenario 1: Waste Basket Fire

ASET is less than RSET for smoke layer height
Design Fire 2: Book Rack Fire

Location of Design Fire 2

View Looking From the South
Design Fire 2: Book Rack Fire

• Location
  – Foyer 101, open to second floor above and is the primary entry access to the building.
  – Room serves as main access to the Media Lab / Library.
  – A built in glass bookcase is on the West wall.
  – Normally space is free of free standing display items.

• Fire Scenario Conditions
  – During the school book fair a rolling magazine / book rack for display is located in the entry in front of the west wall built in glass bookcase.
Design Fire 2: Book Rack Fire

- Design Fire is based on Data for Magazine Rack testing which used magazines, newspapers and books from SFPE data in Table 3-1.14 and Figure 3-1.56
  - Rack Size of 1 X 2.2 m
  - Mass of 15 kg
  - Ignition Source, 2 L of gasoline
  - Peak HRR of 3500 kw
Design Fire 2: Book Rack Fire

Similar to NFPA 101 Design Fire Scenario 2

• (1) It is an ultrafast-developing fire, in the primary means of egress, with interior doors open at the start of the fire.

• (2) It addresses the concern regarding a reduction in the number of available means of egress.
HRR– Design Fire 2 Book Rack Fire

HRR from SFPE Figure 3-1.56

Design Fire
Max HRR 3600 kW

HRR from FDS showing HRR growth capped at 2500 kW at Sprinkler Activation

- Smoke Detector Activation at 178 s
- 1st Sprinkler Activated at 230 s
- (4 of 8) sprinklers in room activate.
# Movement Time – Design Fire 2

## Book Rack Fire

<table>
<thead>
<tr>
<th></th>
<th>Hydraulic Model Estimate</th>
<th>Pathfinder SFPE Mode w/ Collisions Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detection Time</td>
<td>178 s</td>
<td>178 s</td>
</tr>
<tr>
<td>Alarm Time</td>
<td>5 s</td>
<td>5 s</td>
</tr>
<tr>
<td>Pre-Movement Time</td>
<td>30 s</td>
<td>30 s</td>
</tr>
<tr>
<td>Movement Time</td>
<td>347 s</td>
<td>329 s</td>
</tr>
<tr>
<td>RSET</td>
<td>560 s</td>
<td>542 s</td>
</tr>
</tbody>
</table>

Hydraulic Model Estimate is used for RSET

Movement time increases from 204 s to 347 s with stairs and doors removed.

Stairs and Doors Removed from Pathfinder

Main Stairs and Doors Rendered Unusable By Fire
CO levels do not reach tenability level at 560 s RSET or at end of run time of 600 s

Temperature levels do not reach tenability level at 560 s RSET or at end of run time of 600 s

Visibility level begins dropping below 10 m at 235 s

Smoke layer drops below 2 m at 210 s, prior to 560 s RSET
ASET is less than RSET for visibility and smoke layer criteria.
Design Fire 3: Storage Fire

Location of Design Fire 3

View Looking From the South / West
Design Fire 3: Storage Fire

• Location
  – Storage 208 is on the second floor next to one of the main stairs.
  – Room serves as a janitorial and storage room for the floor.

• Fire Scenario Conditions
  – Door is normally closed (and has a closer), for this scenario the door has been propped open as items are being moved into and out of the space.

• Similar to previously discussed NFPA 101 Design Fire Scenario 2
Design Fire 3: Storage Fire

• Design Fire is based on Data for storage units from SFPE data in Figure 3-1.15
  • Metal storage units, with fuel in aisle between units.
  • Peak HRR of 1580 kw
HRR– Design Fire 3: Storage Fire

Design Fire Max HRR 1580 kW

HRR from SFPE Figure 3-1.15

HRR from FDS Capped at
1050 kW at Sprinkler Activation

- Smoke Detector Activation at 162 s
- 1st Sprinkler Activated at 202 s
- All (4) sprinklers in room activate, hall sprinkler does not. First (3) are within a 10 s period.
- Room temperature dropped 30 degree C after sprinkler activation, but never exceeded 110 degree C.
## Movement Time – Design Fire 3

<table>
<thead>
<tr>
<th></th>
<th>Hydraulic Model Estimate</th>
<th>Pathfinder SFPE Mode w/ Collisions Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detection Time</td>
<td>162 s</td>
<td>162 s</td>
</tr>
<tr>
<td>Alarm Time</td>
<td>5 s</td>
<td>5 s</td>
</tr>
<tr>
<td>Pre-Movement Time</td>
<td>30 s</td>
<td>30 s</td>
</tr>
<tr>
<td>Movement Time</td>
<td>256 s</td>
<td>205 s</td>
</tr>
<tr>
<td>RSET</td>
<td>453 s</td>
<td>420 s</td>
</tr>
</tbody>
</table>

Hydraulic Model Estimate is used for RSET

Movement time increases from 204 s to 256 s with stair removed.

Side Stair Removed from Pathfinder

Side Stair Rendered Unusable By Fire
Design Fire 3: Storage Fire

CO levels do not reach tenability level at 453 s RSET or at end of run time of 600 s

Temperature levels do not reach tenability level at 453 s RSET or at end of run time of 600 s

Visibility drops below tenability level at 415 s

Smoke layer drops below 2 m at 358 s, prior to 453 s RSET
Design Fire 3: Storage Fire

ASET is less than RSET for visibility and smoke layer criteria.
Observations / Recommendations

• The building meets the Prescriptive Requirements of the codes it was designed under.

• Actual Movement Times for fire scenarios will be less than used due to actual occupant load being approximately 275 occupants less than used (175 on second floor and 100 on first floor). The state architect requires use of occupancy per CBC values, district occupancy per classroom is at a minimum 10 occupants less per room even when they over load the classrooms.

• It is recommended that any potential fuel load items not be allowed in the egress space even if it is only temporary.

• All fire rated doors should not be propped open.
Observations / Recommendations

• Explore possibility of removing the drop ceilings in the 2\textsuperscript{nd} floor corridors.
  – Rated corridor tunnel extends to just below the roof deck.
  – Removing or raising the drop ceiling in the East and West corridor would provide additional volume to collect smoke and extend the time to which the smoke layer drops below 2 m allowing increased ASET for the smoke layer and visibility.
Questions