FIRE PROTECTION AND SAFETY ANALYSIS
FOR AN OFFICE HIGH RISE BUILDING

Fabio Mazza
June 2016
Introduction

- Codes & Standards
- Building description

Prescriptive based design
- Structural fire safety
- Fire detection and alarms
- Fire suppression
- Egress
- Smoke management

Performance based design
Codes & Standards

LOCAL – São Paulo State

- Enactment 56.819/2011
- IT’s (07, 08, 09, 11, 14, 18, 20, 22)

INTERNATIONAL

- IBC (2012)
- NFPAs (13, 14, 72, 101)
Building Description

- Open office floors
- Theater
- Car parking garage
Building description

- Office floors (1st to 15th)
- Area/floor: 886m²
Building description

- Car parking garage (1st to 5th basement)
- Area/floor: 1,800m²
Building description

- Theater (1st + balcony + 2nd floor)
- Total area: 890m²
Building description

➢ Theater
Structural fire safety

- **Structural fire resistance: 120 min (IBC 2012 – Type I-B)**

- **IBC 2012 - Paragraph 403.2.1.1, item 1:**
  - Supervised automatic sprinklers
  - Building < 128m
  - Type IA criteria for Type IB
  - Columns must not be reduced: 3-h
  - Unlimited area/#floors

- **Local codes**
  - Building < 120m
Structural fire safety

- Exterior walls (glass facades)
  - Gap firestop (concrete/glass)
  - Spandrel girder
Structural fire safety

- Prescriptive fire resistance (IBC 2012)
  - Structural components – dimensions / materials
  - Cover thickness (to be verified – no details)

- Fire resistance – columns: 3-hours
- Fire resistance – beams and girders: 2-hours
- Fire resistance – floors/roofs: 2-hours
- Fire resistance – walls:
  - Internal subdivisions: 2-hours
  - Theater exterior walls: > 4-hours
Fire detection and alarms

Smoke detection
- Office floors
- Theater
- Electrical rooms
- Smoke control / Stairways pressurization mechanical rooms

- Manufacturer: Johnson Controls
- Model: 2951J
- Photoelectric + thermal
- Sensitivity: 0.5%/ft to 5%/ft obscuration
- Temperature of activation: 57ºC

Heat detection
- Car parking garages

- Manufacturer: Johnson Controls
- Model: 5951J
- Thermal
- Temperature of activation: 57ºC

Supervised AS
Fire detection and alarms

**Alarm controller**
- Security room
- Guard house
- No Emergency Voice/Alarm Communication System (EVAC)

- Manufacturer: Johnson Controls
- Model: IFC2-640E

**Notification appliances**
- Visual/sound device
- Sound levels: compliant
- Illumination: not compliant (spacing + shadow areas)
## Fire suppression

<table>
<thead>
<tr>
<th>AREA</th>
<th>Occupancy classification</th>
<th>Type</th>
<th>Installed Sprinkler Heads</th>
<th>Required Design Density Area (gpm/ft²) (ft²)</th>
<th>Required Design Duration (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offices system 1 (gravity)</td>
<td>Light hazard</td>
<td>Wet</td>
<td>Concealed Pendent K-5.6 SR 74°C cover 74°C spk</td>
<td>0.1@1500</td>
<td>30</td>
</tr>
<tr>
<td>Offices system 2 (gravity + pump)</td>
<td>Light hazard</td>
<td>Wet</td>
<td>Concealed Pendent K-5.6 SR 74°C cover 74°C spk</td>
<td>0.1@1500</td>
<td>30</td>
</tr>
<tr>
<td>Garage (gravity)</td>
<td>Ordinary hazard Group 1</td>
<td>Wet</td>
<td>Upright K-5.6 SR 79°C</td>
<td>0.15@1500</td>
<td>60</td>
</tr>
<tr>
<td>Theater (gravity)</td>
<td>Ordinary hazard Group 2</td>
<td>Wet</td>
<td>Main room: Pendent K-5.6 SR 79°C</td>
<td>0.2@1500</td>
<td>60</td>
</tr>
</tbody>
</table>
Fire suppression

- Water supply
  - Duration: 68 min
  - Reliability
    - Equipment certification
    - Pump room installation standard
  - Maintenance and testing standard

![Diagram showing water supply system with various flow rates and connections.](image-url)
Fire suppression

- Water supply analysis – sprinklers: Adequate

- Offices – 15th floor

- Garage – 1st basement

- Theater
Fire suppression

- Water supply analysis – standpipes: Not adequate (12th to 15th floors)
Egress

- Offices
  - IBC 2012: Business Group B
  - Local codes: D-1
  - IBC and LSC: 82 people/floor
  - Occupant load per IT-11/2014: 110 people/floor
  - Exit capacity calculation (IBC x IT)
  - 2 exits
  - Scissor type stairs
  - Distance 10m < 14m
  - Common path of travel
  - Accessibility

<table>
<thead>
<tr>
<th></th>
<th>Office exit door (0.8m)</th>
<th>Stairway inlet doors (0.8m)</th>
<th>Stairway (1.2m)</th>
<th>Stairway exit door (0.8m)</th>
<th>EAST exit capacity</th>
</tr>
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<tbody>
<tr>
<td>Exit EAST</td>
<td>156 / 100</td>
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<td>157 / 75</td>
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<td>157 / 75</td>
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</tr>
</tbody>
</table>

Total exit capacity per floor: 312 / 150
Egress

- Car Parking garages
  - IBC 2012: Low hazard storage Group S-2
  - Local codes: G-2
  - Occupant load per IBC and LSC: 97 people/floor
  - Occupant load per IT-11/2014: 3 people/floor

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<th>Exit 2</th>
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<td>Stairway inlet doors (0.8m)</td>
<td>Stairway (1.2m)</td>
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<td>156 / 100</td>
<td>157 / 60</td>
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</table>

Total exit capacity per floor: 312 / 120
Egress

➢ Theater
  ▪ IBC 2012: Assembly Group A-1
  ▪ Local codes: F-5
  ▪ IBC = 234 people total
  ▪ Local code: 230 people

➢ 2 exits
  ▪ Distance 4.7m < 6.7m
  ▪ Dressing rooms
  ▪ Dead end
  ▪ Accessibility
## Egress

### Theater

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Main exit door (1.65m)</td>
<td>Open stairways (1.20m)</td>
</tr>
<tr>
<td>323 / 300</td>
<td>157 / 150</td>
</tr>
<tr>
<td>First floor secondary exit route</td>
<td></td>
</tr>
<tr>
<td>Sec. exit door (0.80m)</td>
<td>Exterior stairways (1.20m)</td>
</tr>
<tr>
<td>156 / 100</td>
<td>157 / 150</td>
</tr>
<tr>
<td><strong>Total exit capacity – first (main) floor</strong></td>
<td></td>
</tr>
</tbody>
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<th>Balcony main exit route</th>
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</tr>
<tr>
<td>323 / 300</td>
</tr>
<tr>
<td>Balcony secondary exit route</td>
</tr>
<tr>
<td>Sec. exit door (0.80m)</td>
</tr>
<tr>
<td>156 / 100</td>
</tr>
<tr>
<td><strong>Total exit capacity – balcony</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Second floor exit route</th>
</tr>
</thead>
<tbody>
<tr>
<td>Second floor exit (0.80m)</td>
</tr>
<tr>
<td>156 / 100</td>
</tr>
<tr>
<td><strong>Total exit capacity – second floor</strong></td>
</tr>
</tbody>
</table>
Smoke management

- Individual HVAC per floor side
- Smoke exhaust – Local code x IBC
- Smoke exhaust - Offices
  - Design flow: 16,000 m³/h (per side)
  - Calculated NFPA 92: Max. HRR = 600 kW

\[ z_l = 0.166 \times (X \times Q)^{2/5} = 1.33m \]

\[ m_{plume} = \left( 0.071 \times (X \times Q)^{3/5} \times z^3 \right) + 0.018 \times (X \times Q) = 4.51 kg/s \]

\[ T_s = T_0 + \frac{K_s \times X \times Q}{m \times C_p} = 338K \]

\[ \rho = \frac{P_{atm}}{R \times T} = \frac{101,325}{287 \times 338} = 1.04 kg/m^3 \]

\[ V = \frac{m}{\rho \times s} = \frac{4.34 m^3}{s} = 15,600 m^3/h \]
Smoke management

- Smoke exhaust – Car parking garage
  - Design flow: 33,400 m³/h
  - Calculated NFPA 92: Max. HRR = 1,500 kW

\[ V = 34,300 \, m^3/h \]

- Smoke exhaust - Theater
  - Design flow: 88,000 m³/h
  - Calculated NFPA 92: Max. HRR = 2,800 kW

\[ V = 101,300 \, m^3/h \]
Performance based design

- Pre-movement (SFPE HB Table 64.5/64.11)

- Movement times
  - (Method 1) Pauls / Fruin
  - (Method 2) Hydraulic model of egress
  - (Method 3) Theater occupancy: Pathfinder simulation

\[ F_c = F_s \times w_e \]

\[ t_{mov} = P / F_c \]

<table>
<thead>
<tr>
<th>Exit route element</th>
<th>Maximum specific flow (persons/min/ft of effective width)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corridor, aisle, ramp, doorway</td>
<td>24.0</td>
</tr>
<tr>
<td>Stairs (178mm riser / 279mm tread)</td>
<td>18.5</td>
</tr>
</tbody>
</table>

- (Method 3) Theater occupancy: Pathfinder simulation
Performance based design

- Offices
  - Pauls / Fruin

\[
t_{mov_{full\text{egress}}} = 0.70 + 0.0133 \times (1667) = 22.9 \text{ minutes}
\]

- Hydraulic model of egress

\[
t_{mov_{full\text{egress}}} = \frac{1650}{78} = 21.2 \text{ minutes}
\]

\[
t_{mov_{floor}} = \frac{110}{78} = 1.4 \text{ minutes} = 85 \text{ seconds}
\]
Performance based design

- Car Parking garage
  - Pauls / Fruin
  - Hydraulic model of egress

\[ t_{mov_{full\text{egress}}} = 0.70 + 0.0133 \times (490) = 7.7 \text{ minutes} \]

\[ t_{mov_{full\text{egress}}} = \frac{485}{78} = 6.2 \text{ minutes} \]

\[ t_{mov_{floor}} = \frac{97}{78} = 1.24 \text{ minutes} = 75 \text{ seconds} \]
Performance based design

➢ Theater
  ▪ Pauls/Fruin: Not applicable
  ▪ Hydraulic model of egress
    \[
    t_{mov_{full\text{egress}}} = \frac{156}{54} = 2.9 \text{ minutes} = 174 \text{ seconds}
    \]
  ▪ Pathfinder simulation: 132 seconds
Performance based design

- Offices design fire
  - NRIFD Japan (SFPE Hb figure 26.70)
  - $\alpha=0.012$ kW/s$^2$ - medium growth
  - HRR constant after sprinkler activation
Performance based design

➢ Theater design fire
  ▪ $\alpha=0.0469 \text{ kW/s}^2$ - fast growth
  ▪ HRR constant after sprinkler activation
Performance based design

- **Design fire**

- **Tenability criteria**
  - Society of Fire Safety Engineers Australia - NSW Chapter. (2014). Practice Note for Tenability Criteria in Building Fires
  - Exposure less than 10 minutes

<table>
<thead>
<tr>
<th>OCCUPANCY</th>
<th>Yield of species [kg/kg]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yco</td>
</tr>
<tr>
<td>Offices, schools, hotels and nursing homes, etc</td>
<td>0.01</td>
</tr>
<tr>
<td>Dwellings, shopping centers, entertainment centers</td>
<td>0.02</td>
</tr>
</tbody>
</table>
Performance based design
- Visibility @ 1.8m – 255 s
- RSET+1.5 (MoS) = 218 s
- ASET > 255 s
- ASET > RSET+ MoS = PASS
Performance based design
- Visibility @ 1.8m – 388 s
- RSET+1.5 (MoS) = 345 s
- ASET > 388 s
- ASET > RSET + MoS = PASS
- Visibility @ 1.8m – 120 s
- RSET + 1.5 (MoS) = 270 s
- ASET = 107 s
- ASET < RSET + MoS = FAIL
- **PROPOSED scenario**
- Change in smoke exhaust
- Visibility @ 1.8m – 250 s
- RSET + 1.4 (MoS) = 255 s
- ASET = 255 s
- ASET > RSET + MoS = PASS
Performance based design

Main floor Balcony
Performance based design

-balcony
- Visibility @ 1.8m – 140 s
- RSET + 1.5 (MoS) = 120 s
- ASET = 140 s
- ASET > RSET + MoS = PASS

Main Floor
- Visibility @ 1.8m – 370 s
- RSET + 1.5 (MoS) = 321 s
- ASET > 370 s
- ASET > RSET + MoS = PASS
Conclusions

- Occupants layout changes → critical for fire safety

- Exit remoteness (LSC → minimize potential for two exits blocked by fire)
  
  "Core type buildings with elevators, service shafts, and stairs in one central or side core introduce some challenging problems with respect to exit remoteness" (NFPA 101HB, 7.5.1.3.1)

- Local codes positive factors:
  - Conservative for vertical fire spread
  - Larger exit capacity sizing

- Brazilian codes main weaknesses are related to:
  - Means of egress (number, arrangement, scissor stairs, etc)
  - Fire suppression – developed fires (standpipes flow x pressure)
  - Reliability of water supplies: installation, equipment certification, etc
  - Lack of detailed inspection, test and maintenance standards

- Other comments presented in the report
Questions?

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