11th Conference on Performance-Based Codes and Fire Safety Design Methods

23-25 May 2016 | Hilton Warsaw Hotel | Warsaw, Poland
Outline

• Introduction
• Australian Research on Fire Safety in Shopping Centres
• BCA Solution vs Proposed Performance Design
• Evaluation of Proposed Performance Design
• Conclusion
Introduction – the case study building (Cross-section)
Introduction – the case study building

(Floor Plan – Level 0)

LEGEND
- major store (≥ 2000 m²)
- specialty shop (< 2000 m²)
- mall space
- floor void
Introduction – the case study building

(Floor Plan – **Level 1**)

**Legend**
- Major store (≥ 2000 m²)
- Specialty shop (< 2000 m²)
- Mall space
- Floor void
Introduction – the case study building

*Floor Plan – Level 2*

**Legend**
- Major store ($\geq 2000 \text{ m}^2$)
- Specialty shop ($< 2000 \text{ m}^2$)
- Mall space
- Floor void
Introduction – the case study building
(*Floor Plan – Level 3*)

**LEGEND**
- Blue: major store (≥ 2000 m²)
- Purple: specialty shop (< 2000 m²)
- Pink: mall space
- White: floor void

- Food court
- Cinemas
- Kids play
- Office
Introduction – Design Brief Objectives

1. **Safeguard occupants** from injury due to fire until they reach a safe place.
2. **Safeguard fire fighters** whilst performing rescue operations or attacking the fire.
3. **Minimise smoke and fire spread** inside the building
4. Limit the impact on **business continuity**
Comparison - Australian Code Objectives

1. Occupant safety
2. Facilitate brigade operations
3. Avoid fire spread between buildings
4. Avoid damage to adjacent building
Australian Research Program – FCRC

• Fire Code Reform Centre (FCRC) established in 1994
• A joint initiative Australian Government, industry & research organisations
• Aim to develop a cost-effective, engineered approach to fire safety design and reform the building code
• Total 6 Projects
Used in this Case Study

• FCRC Project 5A Development of Fire Engineering Guideline

• FCRC Project 6 Study of Fire Safety in Shopping Centres
FCRC Project 6 – Shopping Centres

- Review of Building Code requirements for shopping centres
- Detailed survey of 11 shopping centres
- Case studies of retail fire incidents
- Review of retail fire statistics
- Identification of key issues
- Full scale fire testing
- Study of occupant behaviour
- Study of reliability of smoke control systems
Full-Scale Fire Testing
Example results - Unsprinklered Fire

![Graph showing heat release rate vs. time for two tests: Specialty shop fire and Test 4.](chart.png)
BCA DtS Solution vs Performance Solution
<table>
<thead>
<tr>
<th>Fire Safety System</th>
<th>BCA DtS Solution</th>
<th>Proposed Performance Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire Resistance</td>
<td>Type of Construction = A</td>
<td>Type of Construction A</td>
</tr>
<tr>
<td></td>
<td>Min FRL = 180/180/180 (Class 6)</td>
<td>Min FRL = <strong>60/60/60 throughout</strong></td>
</tr>
<tr>
<td></td>
<td>Min FRL = 120/120/120 (Class 9b)</td>
<td></td>
</tr>
<tr>
<td>Compartmentation</td>
<td>Sprinklers</td>
<td>Sprinklers</td>
</tr>
<tr>
<td></td>
<td>Perimeter vehicular access</td>
<td>Perimeter vehicular access</td>
</tr>
<tr>
<td></td>
<td>Fire separation of classes</td>
<td>Fire separation of classes</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>No fire compartmentation</strong></td>
</tr>
<tr>
<td>Egress</td>
<td>Min fire isolated exit per floor = 2</td>
<td>Exits distributed evenly throughout</td>
</tr>
<tr>
<td></td>
<td>Min total exit width</td>
<td>Total exit width</td>
</tr>
<tr>
<td></td>
<td>• L0 = 61 m</td>
<td>• L0 = <strong>44 m</strong></td>
</tr>
<tr>
<td></td>
<td>• L1 = 29 m</td>
<td>• L1 = <strong>14 m</strong></td>
</tr>
<tr>
<td></td>
<td>• L2 = 22.5 m</td>
<td>• L2 = <strong>13 m</strong></td>
</tr>
<tr>
<td></td>
<td>• L3 (including cinema) = 22 m</td>
<td>• L3 = <strong>9 m</strong></td>
</tr>
</tbody>
</table>

<p>| #SFPEPBD16          | SFPE Engineering A Fire Safe World                  |                                          |</p>
<table>
<thead>
<tr>
<th>Fire Safety System</th>
<th>BCA DtS Solution</th>
<th>Proposed Performance Solution</th>
</tr>
</thead>
</table>
| Egress (cont) | Max travel distance:  
  • to point of choice = 20 m  
  • to an exit = 40 m  
  • between exits = 60 m  
  • to exit via open stairway = 80 m | Max travel distance:  
  • to point of choice = **65 m**  
  • to an exit = **120 m**  
  • between exits = **130 m**  
  • to exit via open escalators = **260 m** |
| Exit signs and emergency lighting | Exit signs and emergency lighting | Exit signs and emergency lighting |
| Fire Fighting | Sprinklers  
  Hydrants  
  Hosereels  
  Portable fire extinguishers  
  SSIS | Sprinklers  
  Hydrants  
  **(no hosereels)**  
  Portable fire extinguishers  
  SSIS |
<table>
<thead>
<tr>
<th>Smoke management</th>
<th>BCA DtS Solution</th>
<th>Proposed Performance Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Smoke detection system</td>
<td>• Smoke detection system</td>
</tr>
<tr>
<td></td>
<td>• Major store (&gt; 1,000m$^2$) smoke exhaust</td>
<td>• Major store (&gt; 2,000m$^2$) smoke exhaust</td>
</tr>
<tr>
<td></td>
<td>• Mall smoke exhaust</td>
<td>• Mall natural smoke venting</td>
</tr>
<tr>
<td></td>
<td>• Mall baffle at 60 m intervals</td>
<td>• Mall (no baffles)</td>
</tr>
<tr>
<td></td>
<td>• Atrium smoke exhaust</td>
<td>• Atrium natural smoke venting</td>
</tr>
<tr>
<td></td>
<td>• Stairway pressurisation</td>
<td>• (no stairway pressurization)</td>
</tr>
<tr>
<td></td>
<td>• Backup power supply</td>
<td>• (no backup power supply)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Smoke baffles or smoke curtain/shutter to descend to 2m above the floor at the entrance to the</td>
</tr>
<tr>
<td></td>
<td></td>
<td>major stores and cinema complex</td>
</tr>
<tr>
<td>Atrium</td>
<td>Atrium well = min 6 m diameter</td>
<td>(no min atrium dimension)</td>
</tr>
<tr>
<td></td>
<td>Bounding construction</td>
<td>(no bounding construction)</td>
</tr>
<tr>
<td></td>
<td>Protection of atrium roof</td>
<td>(no protection of atrium roof)</td>
</tr>
</tbody>
</table>
Smoke management
The proposed solution
(Floor Plan – **Level 0**)
The proposed solution
(Floor Plan – Level 1)

LEGEND
- Stairway
- Doorway
- Escalator
The proposed solution

(Floor Plan – Level 2)

LEGEND

- Stairway
- Doorway
- Escalator
The proposed solution
*(Floor Plan – Level 3)*

**LEGEND**
- Stairway
- Doorway
- Escalator

- office
- food court
- cinemas
- kids play
- office
Evaluation Against Design Objectives
Objective 1 – ASET Analyses

• CFD model
Objective 1 – ASET Analyses

- Base Case (6 Scenarios)
  - Specialty shop or major store – Fast $t^2$ fire plateaus at 2MW
  - Mall fire (atrium voids) – Fast $t^2$ fire plateaus at 5MW

- Sensitivity Case (4 Scenarios)
  - Specialty shop or major store – Fast $t^2$ fire plateaus at 5MW
  - FCRC specialty shop C3 fire
Specialty shop fire
Objective 1 – ASET Analyses

• Fire scenarios – Level 0

All = 2MW, 5MW and 46.5MW Fire
Objective 1 – ASET Analyses

• Fire scenarios – Level 3
**Objective 1 – ASET Analyses Results**

<table>
<thead>
<tr>
<th>Criterion</th>
<th>L0</th>
<th>L1</th>
<th>L2</th>
<th>L3</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Air Temperature</em></td>
<td>∞</td>
<td>∞</td>
<td>∞</td>
<td>∞</td>
</tr>
<tr>
<td><em>CO Level</em></td>
<td>∞</td>
<td>∞</td>
<td>∞</td>
<td>∞</td>
</tr>
<tr>
<td><em>Radiant Heat Level</em></td>
<td>∞</td>
<td>∞</td>
<td>∞</td>
<td>∞</td>
</tr>
</tbody>
</table>
Objective 1 – ASET Analyses Results

• Temperature, CO, radiation
  • Base and sensitivity scenarios = infinite tenability

• Visibility
  • Base case scenario > 10 m
  • Sensitivity scenario < 10 m in some cases
    (however sufficient for occupants to see exit when queuing at exits)
Objective 1 – RSET Analyses
Objective 1 – RSET Analyses

• Assumed population
Objective 1 – RSET Analyses Results

The diagram shows the time to move outside the building in seconds for different levels:
- **Level 0**: 200 seconds
- **Level 1**: 300 seconds
- **Level 2**: 600 seconds
- **Level 3**: 700 seconds
- **Total Building**: 900 seconds

The x-axis represents the time to move outside the building in seconds, ranging from 0 to 1000 seconds.
Objective 1 – Conclusion

• ASET > RSET for all cases
• Visibility > 10 m for all base cases
• Sensitivity scenarios sufficient visibility is maintained for occupant egress
• Fire modelling conducted is worst case as fire is assumed on Level 0
• **Objective 1 is achieved**
Objective 2 – FBIM analysis

- Metropolitan region:
  Standard fire brigade response time = 7.7 minutes
- Site attendance: 2 fire appliances + 8 fire fighters
- Assumed Fire: Level 3 (worst case scenario)

<table>
<thead>
<tr>
<th>Fire Brigade Activity</th>
<th>Time from Fire Start (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arrival on site</td>
<td>682 s</td>
</tr>
<tr>
<td>Apply water to fire</td>
<td>2,715 s</td>
</tr>
<tr>
<td>Complete walk through “search &amp; rescue” of Level 3</td>
<td>3,381 s</td>
</tr>
</tbody>
</table>
Objective 2 – Conclusion

• Fire brigade tenability is maintained in building
• Fire fighters can attack the fire with the internal fire hydrants
• Fire fighters commence applying water within 60 minutes. Temperatures below limiting temperatures of steel and concrete

• **Objective 2 is achieved**
Objective 3 – Fire and Smoke Spread

- Fire Spread
  - Sprinklers
  - Ceiling space barriers

- Smoke spread
  - Major store and cinema complex shutters which automatically drop to 2m above the floor on fire alarm.
  - Natural vents to mall space and cinema.
  - Mechanical exhaust to majors (> 2,000 m²)
Objective 3 – Smoke Spread

- Ground Floor major store fire (32 m³/s exhaust)
Objective 3 – Smoke Spread

- Mall space or specialty shop fire (natural vents)
Objective 3 - Conclusion

• Minimal fire and smoke spread
• **Objective 3 is achieved**
Objective 4 – Business Disruption

• During fire
  • Smoke and fire damage
  • Repair and clean up
  • Extent of Shopping Centre needed to be evacuated

• After fire
  • Extent of repair and clean up of the fire and smoke affected areas
Objective 4 – Business Continuity

- Minimise need for full evacuation of shopping centre
- Fire wardens to investigate alarm
- Evacuation zones
  - Mall space East, Centre and West
  - Major stores
  - Cinema
- Zoned evacuation
Each major provided with own zone

West atrium zone

Central atrium zone

East atrium zone

Cinema zone
Objective 4 - Conclusion

• Full shopping centre evacuation is minimized
• Business disruption is limited
• **Objective 4 is achieved**
Conclusions

• Objective 1 – ASET > RSET
• Objective 2 – Fire brigade provided with tenable conditions
• Objective 3 – Fire and smoke spread is minimized
• Objective 4 – Disruption to business operation and damage due to fire minimized.
Thank you