Fire Safety Engineering Workshop
Session III A: Case Study on Fire Safety of Tall Buildings

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Quality Fire Safety Management

Presented at the Fire Safety Engineering Workshop at Sichuan Fire Research Institute, May 26, 2015, Chengdu, China

Goal

- Present case study for tall building conducted in New Zealand
- Present issues & critique of case study
- Discuss unique considerations for fire safety of tall buildings
- Recommendations to SCFRI for developing technology base for tall building fire safety

Tall Building Case Study

- Conducted by New Zealand & presented at 9th International Conference on Performance-Based Fire Safety Design
- Building description provided by SFPE
- Both prescriptive & performance-based designs developed
- Issues & critique of case study provided

Building Description

- Super tall building 99-stories, 490 m high
- Retail space on ground floor, office on floors 2-40, & apartments on floors 41-99
- 4.9 m floor height, 4 staircases, 13 passenger & 4 fire fighting elevators
- Occupant density for floors as per C/VM2

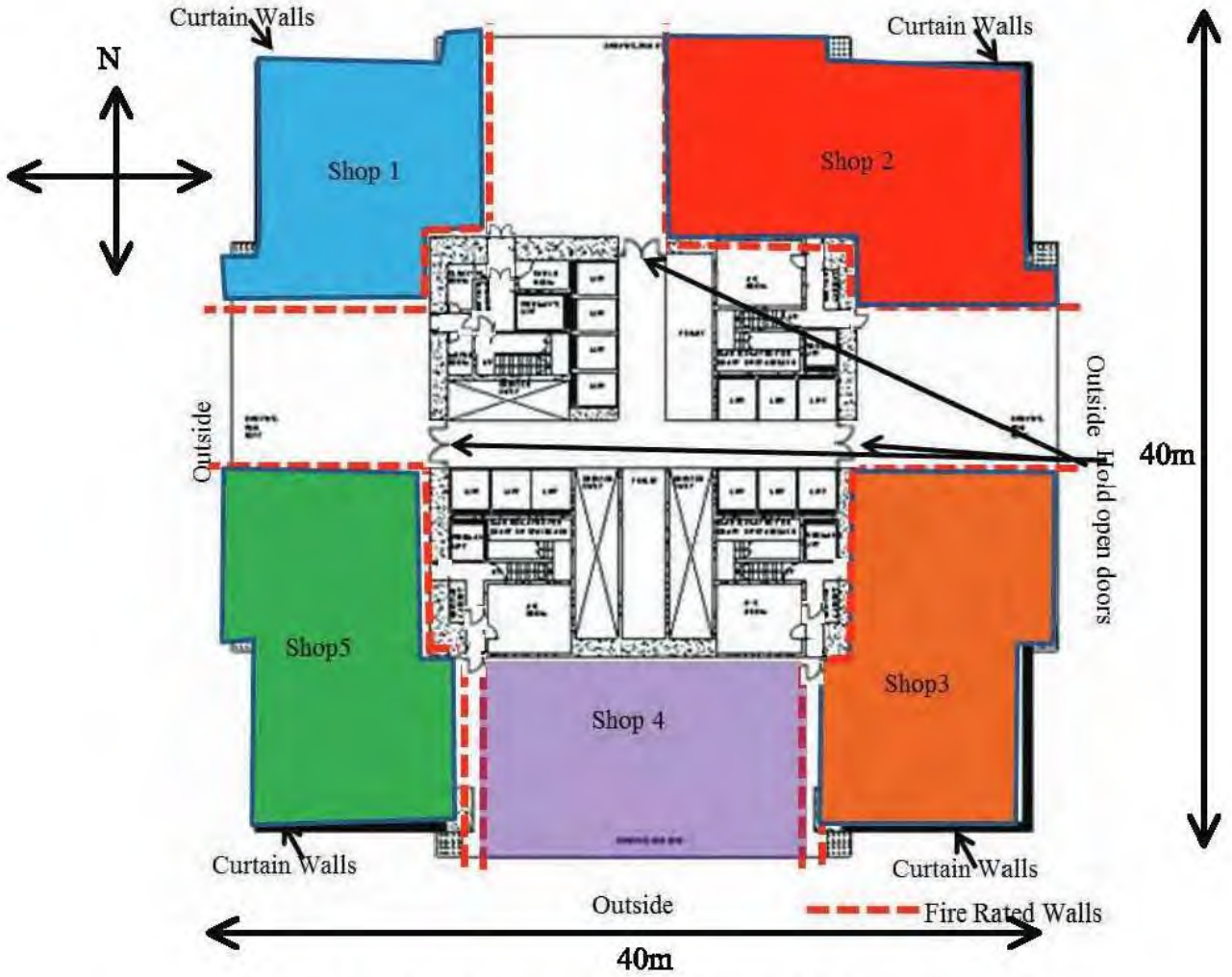

Figure 1 – Typical floor plan for retail space on the ground floor

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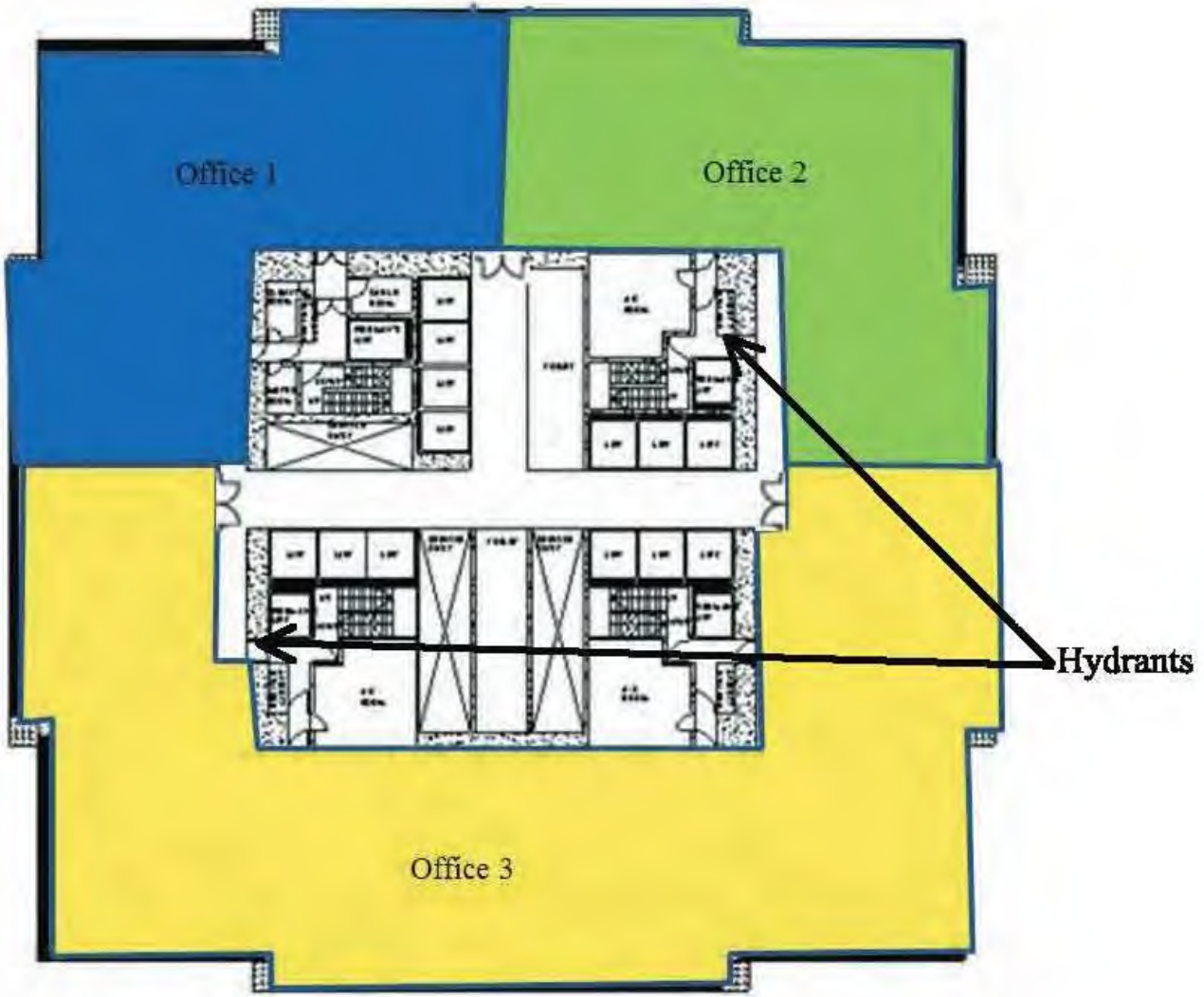

Figure 2 – Typical floor plan for offices on Floors 2-40

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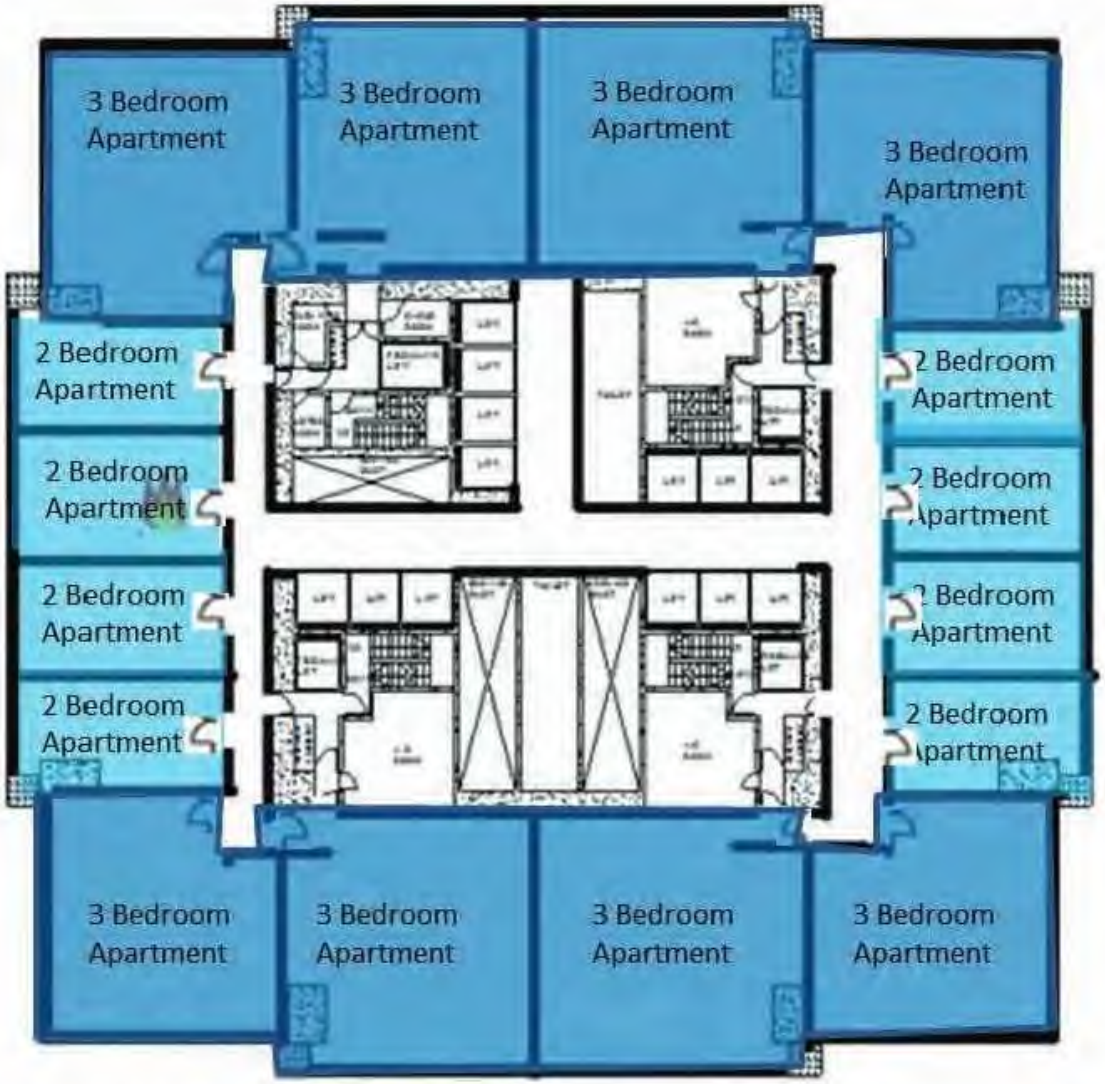

Figure 3 – Typical floor plan for residential floors (41-99)

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Prescriptive Solution

- Show compliance with New Zealand Building Code (NZBC), design in accordance with C/AS1
- Purpose groups & occupant densities
- Fire safety precautions required in C/AS1

Occupant Load Distribution per C/AS1

	Location	Purpose Group	Fire Hazard Category	Occupant Density (p/m^2)	Gross Area (m^2)	Occupant Load
Level 1 (Ground floor)	Shop	CM	2	0.3	930	279
					Total:	**279**
Level2- Level 40th	Offices	WL	2	0.1	1200 per Level	120 per Level
					Total:	**4680**
Level41 – Level 99	Residential	SR	1	As number of beds	1200per level	80 per Level
					Total:	4720
Total of the building occupant load						**9679**
Note1:Spaces(e.g.storage,wardrobe,backstage,toiletfacilitiesetc.)used for intermittent activities are not assessed for occupant load.						

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Fire Safety Precautions in C/AS1

- Fire cell in greatest escape height governs requirements for that purpose group
- FRR for fire cells specified in C/AS1
  - Level 1: F0
  - Level 2-40: F 90
  - Level 41-99: F 60
- Alarm types based on height of floor, modified if any floor height > 25 m

Buidling	Purpose Group	Occupant load	Escape height	F Rating (min)	Other Protection Required
Level 1	CS	100<279<500	0 m (for single floor)	F60	6,16, 18c
Level 2-Level 40	WL	100<120<500	>58m	F 90	7,9,13,15,16,18,19,20
Level 41-Level 98	SR	0>80>100	>58m	F 60	7e,13,15,16,18,20

Legend

FRR of F60 60/60/60 shall apply for level 1

No F-rating for Level 99 but S-rating may apply in case of separate titles.

According to clause 6.9.2 the safe path shall be separated from all adjoining firecells by fire separations having the same FRR throughout its length and that will be F90.

FRR of F90 F 90/90/90 will apply from Level 2 - Level40 for life safety

FRR of F60 F 60/60/60 will apply from Level41-Level98 for life safety

6	Automatic fire sprinkler system with manual call points
7	Automatic fire sprinkler system with smoke detectors and manual call points.
e	The smoke detection element is Type 5 within firecells containing sleeping accommodation. (See Appendix A of C/AS1 for description of Type 5.)
9	Smoke control in air handling system.
13	Pressurization of safe paths.
15	Fire Service elevator control.
16	Visibility in escape routes.
18	Fire hydrant system.
19	Refuge areas.
20	Fire systems center.
C	Required where Fire Service hose run distance, from the Fire Service vehicular access to any point on any floor exceeds 75m.

(*Note the above only gives the F-rating for all the purpose groups. The final fire resistance rating shall be decided after evaluating the S-rating for the above purpose groups and then the higher of the two shall apply)

Fire Safety Precautions in C/AS1

- S-rating for all primary elements > 25 m
- Final resistance rating
  - Level 1 S90
  - Level 2-40, F90
  - Level 41-98, F60
- Separation of legal titles

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Fire Safety Precautions in C/AS1

- Fire & sprinkler alarm systems
  - Automatic fire sprinkler system
  - Smoke detectors
  - Manual call points
- First aid fire fighting
  - Fire hose reels
  - Extinguishers
- Emergency Lighting

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Fire Safety Precautions in C/AS1

- Signage
- Means of escape
  - Travel distance based on groups
  - Minimum of 2 exits
  - Dead end distance
  - Height & width of escape routes
- Refuge areas

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Fire Safety Precautions in C/AS1

- Fire spread
  - Surface finishes
  - Internal fire spread
  - External fire spread/requirements for cladding systems

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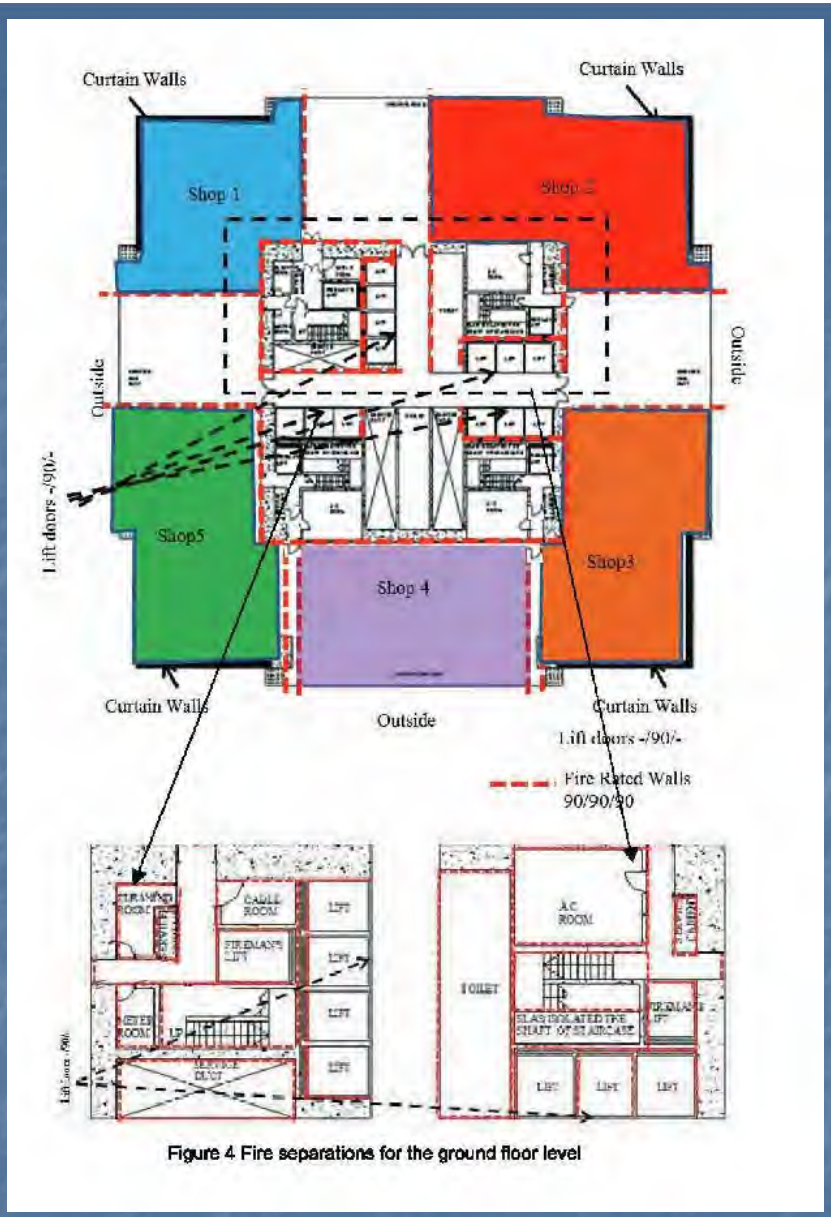

Figure 4 Fire separations for the ground floor level

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Performance-Based Design

- In accordance with New Zealand Building Code (NZBC)
- Based on Verification Method C/VM2 *Framework for fire safety design for NZBC*
- C/VM2 methodology discussed earlier
- New Zealand has unique building code for performance-based design

Table 1.1 Key features of design scenarios

Design scenario	Building Code objectives	Performance criteria	Expected method
Keeping people safe			
Fire blocks exit (Par 4.1)	C1 (a)	C4.5	Solved by inspection
Fire in a normally unoccupied room threatening occupants of other rooms (Par 4.2)	C1 (a)	C4.3, C4.4	ASET/RSET analysis or provide fire separations/suppression complying with a recognised standard
Fire starts in a concealed space (Par 4.3)	C1 (a)	C4.3	Provide fire separations/suppression or automatic detection complying with a recognised standard
Smouldering fire (Par 4.4)	C1 (a)	C4.3	Provide automatic detection and alarm system complying with a recognised standard
Challenging fire (Par 4.9)	C1 (a)	C4.3, C4.4	ASET/RSET analysis
Robustness check (Par 4.10)	C1(a), C1(b), C1(c)	C3.9, C4.5, C5.8, C6.2(d)	Modified ASET/RSET analysis
Protecting other property			
Horizontal fire spread	C1(b), C1(a)	C3.6, C3.7,	Calculate radiation from unprotected areas as

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(Par 4.5)		C4.2	specified
Vertical fire spread involving external cladding (Par 4.6)	C1 (a), C1 (b)	C3.5	Suitable materials used (proven by testing) and construction features specified (e.g. aprons/spandrels/sprinklers) as required to limit vertical fire spread
Rapid fire spread involving internal surface linings (Par 4.7)	C1 (b)	C3.4	Suitable materials used (proven by testing)
Firefighting operations			
Firefighting operations (Par 4.8)	C1(b), C1(c)	C3.8, C5.3, C5.4, C5.5, C5.6, C5.7, C5.8, C6.3	Structural fire design

Performance-Based Design

- Fire Engineering Brief process
- Fire safety features included in PB design:
  - Automatic sprinkler systems
  - Automatic fire alarm systems
  - Refuge floors
  - Local & express elevators
  - Internal hydrant system
  - Fire control center

Performance-Based Design

- Occupancy
  - Occupant loads given in C/VM2
- Evaluation of shops on ground floor
  - Isolated from each another
  - No sharing of common egress paths
  - Fire separation required between property owners
  - Design scenarios need not be evaluated

Performance-Based Design

- Evaluation of floors 2-39
  - Floors 20 & 40 designated as refuge floors
  - Fire design scenario – Fire blocks exit
    - Two means of escape available
    - Scenario is achieved
  - Fire design scenario –Fire in unoccupied room
    - Sprinkler system installed
    - Scenario is achieved

Performance-Based Design

- Fire design scenario – Fire starts in concealed space
  - Sprinkler system installed
  - Scenario is achieved
- Fire design scenario–Horizontal fire spread
  - Building in city with 4 lanes on each side
  - Distance requirement exceeded
  - Scenario achieved

Performance-Based Design

- Fire design scenario – Vertical fire spread
  - Spread over façade materials
  - Spread through fire plumes via openings
    - Concrete building
    - Automatic fire sprinklers
    - Scenario achieved

Performance-Based Design

- Fire design scenario – Fire spread involving internal linings
  - Wall/ceiling lining materials to meet ISO 5660
  - Floor surface materials meet ISO 9239 Part 1
- Fire design scenario–firefighting operation
  - Clauses to be satisfied in C/VM2
  - Met with other requirements, except need to install fire hydrants, examine structural rating

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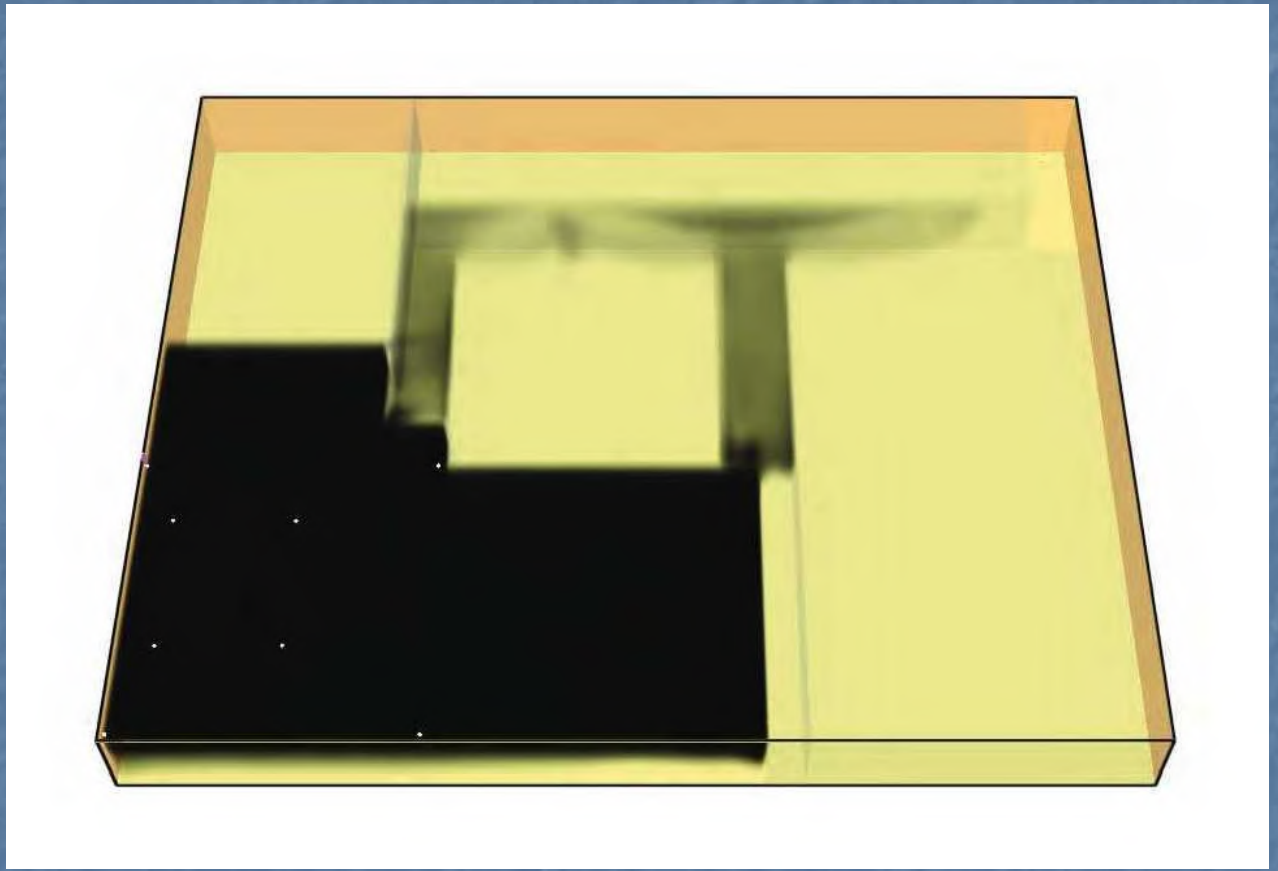
Performance-Based Design

- Fire design scenario – Challenging fire
  - ASET>RSET
  - FDS used to analyze 1 floor for ASET
  - Design fire with species yields in C/VM2
  - Performance criteria:
    - FED not >0.3 CO
    - FED not > 0.3 thermal effects
    - Visibility not < 10 m
    - Only FED CO applies because < 1000 people & sprinklered

Fire & Smoke Growth Modeled with FDS



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Performance-Based Design

- Fast t**2 growth to 870 kW when sprinklers activate
- Full smoke detection & sprinkler system installed & modeled with FDS

Performance-Based Analysis

ASET based on FDS analysis of apartment	
Criteria	**Time reached (s)**
Visibility =10 m (Room of origin)	40
FED(CO)=0.3 (Room of origin)	515
Visibility = 10 m (Corridor) min/max	80/281
FED(CO)=0.3 (Corridor) min/max	>600

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RSET Analysis from C/VM2

RSET analysis in the residential floors (41st – 99th)	
Time to detection t_{det}	30s for smoke detection in room of origin 136s for sprinkler activation everywhere else
Time for notification	30s for polling etc
Time for pre-travel activity t_{pre}	30s Room of origin 60s for occupants in other areas of the building
Time for travel t_{trav}	20s to travel from room to stairway (Travel time governs in the corridor.
t_{last} (Room of origin to stairway)	$= t_{det} + t_n + t_{pre} + t_{trav}$ $= 30 + 30 + 20+20$ $= 100s$ (time to evacuate room of origin)
t_{last} (Other offices to stairway)	$= t_{det} + t_n + t_{pre} + t_{trav}$ $=136+30+60+20=246s$

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Performance-Based Analysis

- Fire design scenario – Robustness check
  - Assume key safety feature fails
  - Assumed 1 office door fails to close
  - FED(CO) = 0.3 in office at 540 s
  - ASET-RSET = 296 s

Performance-Based Analysis

- Residential floors also modeled
  - C/VM2 requires tenability maintained only outside room of origin if < 500 m**2, i.e. only in corridor
  - FED(CO) not reached for 600 s for challenging & robustness scenario

Conclusions of Case Study

- Refuge areas added in PB design
- PB design meets performance-criteria without:
  - Smoke management system
  - Pressurization of stairways

Critique of Case Study

- From authors:
  - C/AS1 not intended for tall buildings
  - Refuge floors, elevator evacuation, enhanced sprinkler systems, increased fire resistance, phased evacuation beyond scope
  - C/VM 2 beneficial but no special scenarios included for extra safety features
  - Unique features require fire engineering approach, current codes not applicable

Critique of Study

- Lack of assessment of uncertainties in calculation of ASET:
  - Under ventilation of fire?
    - Soot production
    - CO production
  - Effect of ventilation conditions
  - Validation of FDS for scenario
- Consideration of other conservative assessments, e.g., algebraic equations

Special Considerations for Tall Buildings

- Façade fires, vertical & horizontal
- Elevator evacuation
- Structural failure
- Advanced sprinkler systems
- Fire fighter access
- Local infrastructure
- Stack effect

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Special Considerations for Tall Buildings

- Water supply
- Maintenance
- Iconic nature of buildings
- Integration of Systems
- Systems reliability
  - Defense in depth
  - Eliminate single point failures
- Information system

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Special Considerations for Tall Buildings

- Refuge floors
- Structural fire resistance
  - Limitations of standard tests
    - Does not consider real fires
    - Only single elements tested
- Advanced detection & alarm system
- Life cycle management
- Inspection, testing, & maintenance

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Recommendations to SCFRI

- Use ISO 23932 to develop safety requirements for tall buildings
  - Specific safety objectives, functional requirements & performance criteria for tall buildings
  - Special designs scenarios & design fires with ISO 16733-1
  - Special engineering analysis & assessment with performance criteria

Recommendations to SCFRI

- Benefit of ISO FSE standards is to address special features & requirements
- Special considerations must be overlaid over fire safety engineering analysis
- Fire safety engineering provides process to identify key hazards and engineering understanding

Questions

- Comments and discussion
- Thank you

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