Investigation into the use of post-fire corridor smoke clearance in the early stages of fire development in super high-rise buildings
Tom Sagris, Group Principal | Design Confidence

Tom Sagris is the Group Principal working in Design Confidence’s Dubai office, where he forms a part of the senior leadership team. As the Group Principal of Design Confidence Consultancy Tom provides strategic leadership the Design Confidence Group both regionally and internationally. A qualified Fire & Life Safety Consultant Tom has extensive fire safety engineering, code consulting and business experience gained over the Last 20 years in the industry. Having worked on some of the largest and most complex developments within Australia, United Kingdom, North Africa and the Middle East tom provides essential experience to project teams with a foresight and design understanding second to none. Afforded with the responsibility of leading the Design Confidence group, he has an unprecedented understanding and respect for local practices and customs which underscore his ability to execute the specialist services provided by Design Confidence.
LEARNING OBJECTIVES

• BUILDING FIRE STRATEGY
  • BASIC PRINCIPLES OF LIFE SAFETY
  • FIRE FIGHTING APPROACH
  • ACTIVE FIRE PROTECTION

• SMOKE AND HEAT VENTILATION
  • SYSTEM TYPES
  • DESIGN CONSIDERATIONS

• FIELD TEST
  • EXPERIMENTAL VS LIVE TRIAL
  • EXPERIMENT SETUP
  • FIELD TEST – CORRIDOR SMOKE CONTROL
BUILDING FIRE STRATEGY

OCCUPANT LIFE SAFETY

Exit Access

Enter Stair or; Exit Passageway

Exit

Exit Discharge

Exit Access

Exit Discharge
BUILDING FIRE STRATEGY

BASIC PRINCIPLE OF FIRE SAFETY

TURN YOUR BACK TO THE FIRE AND EXACUATE
CONTAIN THE FIRE WITHIN THE ROOM OF ORIGIN
BUILDING FIRE STRATEGY
TALLEST BUILDING TO THE TIP

Extracted from CTBUH website: www.ctbuh.org
# Building Fire Strategy
## High Rise Building Definition

<table>
<thead>
<tr>
<th>Code Definition of High Rise Building</th>
<th>Hong Kong</th>
<th>Macau</th>
<th>United Kingdom</th>
<th>United State</th>
<th>China</th>
<th>Australia</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;30m</td>
<td>Class MA</td>
<td>&gt;30m</td>
<td>&gt;23m</td>
<td>&gt;24m</td>
<td>&gt;25m</td>
<td></td>
</tr>
<tr>
<td>&gt;50m</td>
<td>&gt;128m IBC</td>
<td>&gt;25m</td>
<td>&lt;250m</td>
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<td></td>
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</tr>
</tbody>
</table>

**Approved Document:** B

**IBC**

**Code of Practice for Fire Safety in Buildings 2011**

**Code of Practice for Fire Safety in Buildings and Environment**

**The Building Regulations 2000**

**2012 International Building Code**

**UCC**
## BUILDING FIRE STRATEGY

### FIRE FIGHTING STRATEGY

<table>
<thead>
<tr>
<th>BUILDINGS CLASSIFICATION</th>
<th>INTERNATIONAL BUILDING CODES</th>
<th>TYPICAL FIRE FIGHTING STRATEGY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-Rise Building</td>
<td>Buildings &lt; 15.9m</td>
<td>External Fire Fighting</td>
</tr>
<tr>
<td>Mid-Rise Building</td>
<td>Buildings 16m to 22.9m</td>
<td>External Fire Fighting Or Internal Fire Fighting</td>
</tr>
<tr>
<td>High-Rise</td>
<td>Building 23-89m</td>
<td>Internal Fire Fighting</td>
</tr>
<tr>
<td>Super High-Rise</td>
<td>Building &gt; 90m</td>
<td>Internal Fire Fighting</td>
</tr>
</tbody>
</table>
BUILDING FIRE STRATEGY
SUPER HIGH-RISE FEATURES

- Extended evacuation time
- Height beyond reach of fire ladders
- Significant structures – Good performance in Fire?
- Water supply limitation
- Pronounced stack effects
- Mixed occupancies
- Iconic
FIRE FIGHTING STRATEGY
SUPER HIGH RISE BUILDINGS

Occupant Life Safety
Optimal Fire Life Safety Solution
Fire Fighter Safety
Business continuity
SMOKE AND HEAT VENTILATION

WHY SMOKE CONTROL

• Assist to maintain safer conditions for occupant evacuation
• Maintain improved conditions for firefighters operations
• Reduce radiation effect to the environment
SMOKE AND HEAT VENTILATION

TYPES OF SMOKE VENTILATION

• SMOKE CONTROL SYSTEM
• SMOKE PURGING SYSTEMS
• SMOKE CONTAINMENT SYSTEM
SMOKE AND HEAT VENTILATION

SMOKE CONTROL

• Based on fire load present within the space and smoke generated

• Designed to maintain (Smoke Free) tenable environment

• Requires experts input and computer modelling

• Natural or Mechanical ventilation subject to analysis.

• Make-up air by mechanical or natural means
Requirements (Engineered Smoke Control System)
- NFPA 5000 Section 8.12.3 (5)

Acceptance Criteria
- 20 minutes clear layer or;
- Total Evacuation time x 1.5

Tenability Criteria
- Visibility (10m)
- Temperature (60°C)

Engineering Analysis using CFD
SMOKE AND HEAT VENTILATION

SMOKE PURGING

• Fan Capacity based on compartment volume

• Fan Capacity has no relation with the fuel load or complex geometry (Typically 6 ACH)

• Not an active system for maintaining (Smoke Free) tenable environment

• Mechanical means to select fans which provides air changes in the volume.
Smoke and Heat Ventilation

SMOKE CONTAINMENT

- RESTRICT THE SMOKE SPREAD TO OTHER COMPARTMENT

- ACHIEVED THROUGH MECHANICAL INDUCED PRESSURE DIFFERENCE BETWEEN THE COMPARTMENTS

- PRESSURE DIFFERENCE IS DETERMINED BASED ON:
  - AIR VELOCITY WHICH DOES NOT HINDER EVACUATING OCCUPANTS
  - FORCE ON THE EGRESS DOORS WHICH DOES NOT AFFECT DOOR OPENING
## Smoke and Heat Ventilation
### Field Test – Corridor Smoke Control

<table>
<thead>
<tr>
<th>Exposure Conditions</th>
<th>Maximum exposure time (minutes)</th>
<th>Maximum air temperature (degree C)</th>
<th>Maximum radiated heat flux (KW/m²)</th>
<th>Remarks</th>
<th>Recommended distance from apartment door</th>
</tr>
</thead>
<tbody>
<tr>
<td>Routine</td>
<td>25</td>
<td>100</td>
<td>1</td>
<td>General firefighting</td>
<td>15-30 m</td>
</tr>
<tr>
<td>Hazardous</td>
<td>10</td>
<td>120</td>
<td>3</td>
<td>Short Exposure with thermal radiation</td>
<td>4-15 m</td>
</tr>
<tr>
<td>Extreme</td>
<td>1</td>
<td>160</td>
<td>4-4.5</td>
<td>Snatch rescue scenario</td>
<td>2-4 m</td>
</tr>
<tr>
<td>Critical</td>
<td>&lt;1</td>
<td>&gt;235</td>
<td>&gt;10</td>
<td>Life threatening</td>
<td>0-2 m</td>
</tr>
</tbody>
</table>
Smoke and Heat Ventilation
Building Considered for Live Trials
Smoke and Heat Ventilation
Field Test – Corridor Smoke Control
Smoke and Heat Ventilation
Field Test – Corridor Smoke Control

Apartment Considered for Test 1

Camera Location for Test 1

7,767 mm

Camera Location for Test 2

10,000 mm

Apartment Considered for Test 2

Apartment Door
Opening time: 120 seconds from the initiation of smoke generation
Closing time: 150 seconds from the initiation of smoke generation

Supply vent @ 150 L/s each

Extract vent @ 200 L/s each
Smoke and Heat Ventilation
Field Test – Corridor Smoke Control

Extract grill @ 200 l/s each

Supply grill at ceiling of corridor @ 150 l/s each

Fire @ 0.5 MW as per UAEFC-2017
SMOKE AND HEAT VENTILATION

CFD Inputs - Fire Growth Rate

![Graph showing different fire growth rates over time. The x-axis represents time in seconds (0 to 400), and the y-axis represents heat release rate in kW (0 to 500). The graph distinguishes between Slow, Medium, Fast, and Ultra Fast growth rates. Each growth rate is represented by a different colored line.](image)
SMOKE AND HEAT VENTILATION

CFD Inputs - Combustion Properties

100% Cellulose (Wood) 0.5% Soot Yield
Less Smoke per kg of fuel burnt

100% Polymers (Plastic) 10-15% Soot Yield
More Smoke per kg of fuel burnt

Fire Area 1000 kW/m²
(Less smoke and Higher Temp)

Fire Area 250 kW/m²
(More Smoke and Lower Temp)
**SMOKE AND HEAT VENTILATION**

Field Test – Corridor Smoke Control

<table>
<thead>
<tr>
<th>Time (seconds)</th>
<th>Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Fire Ignition</td>
</tr>
<tr>
<td>120</td>
<td>Means of Escape</td>
</tr>
<tr>
<td>123</td>
<td>Means of Escape</td>
</tr>
<tr>
<td>150</td>
<td>Means of Escape</td>
</tr>
<tr>
<td>183</td>
<td>Means of Escape</td>
</tr>
<tr>
<td>1200</td>
<td>End of simulation</td>
</tr>
</tbody>
</table>

- Fire Ignition
- Onset of post – smouldering growth phase
- Means of Escape
- Door of incident apartment open for resident egress
- Lobby door opens for resident egress
- Door of incident apartment closes
- Lobby Door closes
Smoke and Heat Ventilation
Model Calibration

Measuring Extract rate prior experimental test
Smoke and Heat Ventilation
Model Calibration
Smoke and Heat Ventilation
Field Test – Corridor Smoke Control

Field Test System Design (6ACH)
Smoke and Heat Ventilation
Field Test – Corridor Smoke Control

Test Procedure

• Sealed an apartment entry door
• Prepared the smoke generating machine
• Noted the start of the smoke generation
• Open the apartment entry door for 30 sec to simulate the occupant evacuation (120 sec to 150 sec from the start) to let the smoke spilling in to the corridor.
• Monitor the time taken for the system to clear the smoke
• Model the environment in computer smoke model software to compare the results
  • UAE FC compliant design
  • Field test design
Smoke and Heat Ventilation
Field Test – Corridor Smoke Control
Smoke and Heat Ventilation
Field Test – Corridor Smoke Control

[Graphs showing visibility and time vs. distance]
EXPERIMENTAL VS MODELING

Test Procedure

• COMPUTER MODELS CAN BE USED TO ASSESS PROPOSED SYSTEMS

• CORRIDOR SMOKE PURGING CAN BE USED TO ASSIST EARLY OCCUPANT EVACUATION

• FIRE FIGHTING SYSTEM CAN ASSIST OCCUPANTS IN THE EARLY STAGES OF FIRE DEVELOPMENT

• EARLY STAGES OF FIRE DEVELOPMENT ARE KEY COMPONENTS OF OCCUPANT SAFETY