Fire Strategies for Super-high Rise

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Cities in the sky –
Challenging their safety
Challenging their safety

• We know what we’re trying to do, but;
  • we don’t know whether that’s good enough,
  • we don’t know whether we’re actually doing it,
  • it’s not the right thing to be doing anyway.
Caveat

• Definition: We – a generalisation of the industry.

• Fine print: These are broad generalisations to illustrate the point.
Contents

• We know what we’re trying to do, but;

• we don’t know whether that’s good enough,
• we don’t know whether we’re actually doing it,
• it’s not the right thing to be doing anyway.
• However:
  - we have many of the tools that we need, and
  - through ‘total safety engineering’ we can design safe buildings.
Typical Fire Strategy Concepts
Typical High Rise Strategy Components
Typical High Rise Strategy Components

• Contain fire:
  - Sprinklers
  - Compartments
Typical High Rise Strategy Components

• Contain fire:
  - Sprinklers
  - Compartments

• Contain smoke
  - Compartments
  - Smoke Control
Typical High Rise Strategy Components

- Contain fire:
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- Prevent collapse
  - Fire resistance
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  - Detect and alarm
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• Fire fighting
  - Provide access
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Acceptability through Precedent
Fire Strategy Development

- Build what we want
- Learn from fire incidents and disasters
- Amend legislation and strategies when risk is unacceptable.

This has led to established fire strategy concepts for:
- Low rise,
- Medium rise, and
- High rise.
Low Rise – 1 to 2 Storeys

- Evacuation possible directly to outside
- Rescue possible from outside
- Collapse not a significant risk
- Fire spread not a significant life risk
- Fire fighting possible from outside

- Limited protection to evacuation routes
- Single stairs permissible
- Limited fire resistance requirements
- Limited compartmentation
- No specific fire fighting provisions
Medium Rise – 3 to 8 storeys

- Evacuation reliance on stairs
- Rescue not possible from outside
- Stability required for a short period
- Fire spread starts to impact on risk
- Fire fighting difficult from outside

- At least two protected stairs
- Medium fire resistance requirements
- Some compartmentation required
- Fire fighting shafts introduced
High Rise – 8+ Storeys

- Prolonged evacuation
- Rescue not possible from outside
- Stability required for a long period
- Risk associated with vertical
- Fire fighting difficult from inside

- Phased evacuation strategy
- High fire resistance requirements
- Compartment floors
- Sprinklers
## Precedent

<table>
<thead>
<tr>
<th>Height</th>
<th>Buildings</th>
<th>Time (years)</th>
<th>Building Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Many millions</td>
<td>Thousands</td>
<td>1,000,000,000</td>
</tr>
<tr>
<td>Medium</td>
<td>Many hundred thousands</td>
<td>Hundreds</td>
<td>10,000,000</td>
</tr>
<tr>
<td>High</td>
<td>Many thousands</td>
<td>Tens</td>
<td>10,000</td>
</tr>
<tr>
<td>Super-high</td>
<td>Hundreds?</td>
<td>Tens</td>
<td>1,000</td>
</tr>
</tbody>
</table>
Theme (guidance vs. risk)
Acceptable Risk
How does Risk relate to Height

Risk = Frequency x Likelihood x Consequence

Frequency = f (area)

Consequence = f (area)

Area = f (height)

Frequency = f (height)

Consequence = f (height)

Risk = likelihood x f(height)^n
Risk vs Strategy

Height

Risk

Low Rise
Risk vs Strategy

Change in strategy reduces likelihood of failure
Risk vs Strategy

Risk

Low Rise  Medium Rise

Height
Risk vs Strategy

Risk

Low Rise  Medium Rise  High Rise

Height
Risk vs Strategy

Acceptable Risk – Disaster led code development ensures building risk is less than the acceptable risk.

Low Rise  Medium Rise  High Rise
Risk vs Strategy

Risk

Acceptable Risk

Height

Low Rise  Medium Rise  High Rise
Risk vs Strategy

Risk

Acceptable Risk

Height

Low Rise  Medium Rise  High Rise  Super-High Rise
Risk vs Strategy

- Low Rise
- Medium Rise
- High Rise
- Super-High Rise

Acceptable Risk

Risk vs Height graph

ARUP
Risk vs Strategy

- Low Rise
- Medium Rise
- High Rise
- Super-High Rise

Acceptable Risk
Super-high rise Strategy?

- Prolonged evacuation
- Rescue not possible from outside
- Stability required for a long period
- Risk associated with vertical
- Fire fighting difficult from inside

- Evacuation very long / impossible
- Rescue not possible from outside
- **Collapse unacceptable**
- **High risk** associated with vertical
- Fire fighting difficult from inside

Super-high rise risks are different from high rise – shouldn’t the strategies be different?
Contents

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Fire Engineering

- Means of escape
  - Can people really walk down?

- Smoke control
  - Stack and wind effect, building systems, cause and effect

- Fire control
  - Changing fire load

- Fire Resistance
  - Assume single storey fire
  - Don’t assess overall stability

- Fire Fighting
  - Assume single storey fire
Fire Engineering

- Disconnect between design and specification
Fire Engineering

- Construction quality
  - Fire stopping
- Commissioning
  - Systems commissioned separately
Fire Engineering

- **Quality of Handover**
  - Do users know what has been built?

- **Building Management**
  - Quality of house-keeping
  - Quality of maintenance
  - Quality of training and staff

- **Apparent Simplicity masks Actual Complexity**
Tall buildings during construction

Challenges

- Has the fire strategy knowledge been transferred successfully?
- Are fire safety requirements and philosophies adequately protected during ‘Value Engineering’ exercises?
- What is the impact of partial occupation / phased construction/fit-out?
- How are sophisticated technologies / construction techniques incorporated?
Failed knowledge transfer - Case Study

MARKUP ON L40 SIGNAGE

REM khk:
1. Regular "Exit Signs" to remain.
2. Additional signs described below to be green/white & backlit as regular "exit signs", i.e. linked to central battery.
3. Signs giving information in red/white. No back-lighting required.
4. Letters shall be in accordance with NFPA101 and CO/ANSI A117.1, with letter not less than 150mm high and principle strokes of letters not less than 10mm wide.
5. All exit signs/lights shall be in both English and Arabic.
6. Phone handsets shall be provided in the refuge (pink boxes in markup) for use with the jocks in the stairs.
7. Signs of "Do not use lift in case of fire" in L40 lift lobby shall be removed.
Refuge Areas – Pipes and Access to Pump Room
Refuge Areas – Rooms open to corridor + Signage
Sterile Refuge Areas + Evacuation lifts
Changes required during Construction

- Sprinklers added
- Standpipes added
- Appropriate signage added
- Elevator evacuation plan written
- Fire stopping and dampers made good
- Trip hazards removed
- Headroom raised
- Fire load enclosed
- Doors from corridor include self closers on both door leaves + 2 detectors in every room
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Origins of Super-high rise strategies
If fire and smoke protection works...

- **Contain fire:**
  - Sprinklers
  - Compartments

- **Contain smoke**
  - Compartments
  - Smoke Control

- **Prevent collapse**
  - Fire resistance

- **Evacuation**
  - Detect and alarm
  - Stairs
  - Evacuate pairs of floors

- **Fire fighting**
  - Provide access
Why Evacuate?

• Fire and smoke are contained
• Structural stability will be maintained
• Only those in immediate vicinity at risk
• Fire service can extinguish any fire that is not already extinguished
Many Reasons not to Evacuate

• Space requirements (evacuation points)
• Mobility impairments
• Fatigue
• Trips and falls

• Business disruption
• Paperwork
• Security breeches
• Complaints
High Rise – 8+ Storeys

- **Prolonged** evacuation
- Rescue not possible from outside
- Stability required for a **long** period
- Risk associated with vertical
- Fire fighting difficult from inside

- **Inhibit** fire and smoke spread
- **Reasonable** stability
- **Phased** evacuation strategy
- **Evacuation period is relatively short!**
Super-high Rise – 100+ Storeys

- Prolonged evacuation
- Rescue not possible from outside
- Stability required for a long period
- Risk associated with vertical
- Fire fighting difficult from inside

- Evacuation very long / impossible
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Design Fire Scenarios
Fire scenarios

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Consequence</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Low</td>
</tr>
<tr>
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<td>High</td>
</tr>
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</table>

- **Smoking**
- **Open flames**
- **Cooking**
- **Electrical fault**

- **High frequency - low consequence fires**
- **High-rise design fire**
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Fire scenarios

- OK
- Might be OK
- Not OK
Causes of Failure

• Accidental failure
  - Poor design, specification, construction or use
  - System failure
  - Cause and effect failure
  - Combined accidental loads

• Deliberate failure
  - Larger fire or multiple fires
  - Sabotage of systems
  - Combined events

• Low Probability but Extreme Consequence = \textbf{High Risk}?
It happens

High frequency - low consequence fires

Low frequency - high consequence fires

Frequency

Consequence

High frequency - low consequence fires

Low frequency - high consequence fires

Smoking

Open flames

Cooking

Electrical fault

Al Tayer Tower, Sharjah, (UAE)

Islamabad Marriott Hotel 20/9/2008
Time to evacuate the towers was several hours.
• However:
  - we have many of the tools that we need, and
  - through ‘total safety engineering’ we can design safe buildings.
Capability
Fire and smoke modelling
Computational Evacuation Simulation
Computational Fluid Dynamics
Structural Eire Modelling
Fire systems specialists
Risk Analysis
Total Design
All Design Decisions

Evacuation

All credible scenarios

Suppression

Containment

Resistance
Integrate Design

Safety Strategy

Prepare

Design

Specify

Construct

Use
Organised Team

- Structure
- MEP
- Safety Strategy
- Security
- Fire
- Etc.
Conclusions
Conclusions

• Rapid advanced in building design mean that acceptability by precedent is no longer possible.

• Consequence of fire spread in super-tall buildings are very high

• We must proactively identify acceptable levels of risk and design accordingly.
Conclusions

• Great reliance is placed on the efficacy of the fire protection features and systems that we incorporate into our strategies.

• There is limited margin of safety for failure.

• We must design, specify, install, operate and maintain our systems correctly.
Conclusions

• Design assumptions that are valid for high rise design are not necessarily appropriate for super-high rise strategies.
• The consequence of incorrect assumptions is very high.

• We must consider all relevant design fire scenarios and test against potential system failure.
Conclusions

- We have the capability, and the tools, but…

- Fire can no longer be considered in isolation.
Great things can happen when, "all relevant design decisions have been considered together and have been integrated into a whole by a well organised team."
Ove Arup - Total Architecture

Great things can happen when, "all relevant design decisions have been considered together and have been integrated into a whole by a well organised team."

Safety is relevant and must be integrated into design.