This document is the consolidated Expert Report of Prof. Asif Sohail Usmani and Prof. Jiang Liming (incorporating the Expert Report dated 15 June 2026 and Corrigendum dated 24 June 2026)

Independent Committee in relation to the fire at Wang Fuk Court in Tai Po

Expert Report

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1. INTRODUCTION

1.1. Objectives of the report

1.1.1. On 26 November 2025, a catastrophic fire broke out at Wang Fuk Court, Tai Po. The fire originated in Wang Cheong House and rapidly spread to the other six residential blocks within the estate, resulting in 168 fatalities and 79 injuries.

1.1.2. In response, the Government of the Hong Kong SAR established an Inter-departmental Fire Investigation Task Force (**IFITF**) to investigate the incident. The IFITF issued its interim report in February 2026, providing extensive information on the fire's origin, development and spread; the involvement of combustible materials; and the fire-fighting and rescue operations (**IFITF Interim Report**). The report also includes an expert report by Professor Richard Yuen of the City University of Hong Kong dated 10 February 2026 (**Yuen Interim Report**). The IFITF issued its final report in May 2026 (**IFITF Final Report**), and Professor Richard Yuen issued his final expert report on 8 May 2026 (**Yuen Final Report**).

1.1.3. Concurrently, the Chief Executive of the Hong Kong SAR announced the establishment of an Independent Committee (**IC**), chaired by a judge, to inquire into the fire, its rapid spread, and the broader issues arising from the incident. The IC's terms of reference include examining how the fire started, why it spread so rapidly, and how this led to the resulting casualties and property damage.

1.1.4. We, as appointed fire experts, are tasked with assisting the IC by examining in detail the mechanisms and pathways of fire and smoke spread within Wang Fuk Court, and by providing expert analysis to support the Committee's findings and recommendations.

1.2. Scope of work

1.2.1. To assist the IC in discharging its Terms of Reference, our scope of work focuses on examining the rapid vertical and lateral spread of fire and smoke, and how this contributed to the resulting casualties and property damage.

1.2.2. The areas of focus were specified in the appointment letter issued by Lo & Lo, Solicitors and Notaries Public, on 6 February 2026, and form the scope of our services. For the purposes of this report, we have conducted the following work:

- Analysing the rapid vertical and lateral spread of fire along the external walls;
- Conducting a detailed fire and smoke spread analysis;
- Analysing the ignition and combustion behaviour of building materials on the external walls (including scaffolding nets, foam boards, etc.);
- Reviewing existing fire safety standards and assessing their adequacy;
- Conducting independent tests on relevant building materials and analysing their fire spread characteristics; and
- Identifying and commenting on recent technological developments that may assist fire-fighting.

1.3. Scope of the report

1.3.1. The present report contains our findings to date. Subject to the without prejudice meeting to be held with IFITF experts, as well as further experiments or tests to be conducted (including but not limited to experiments or tests on concrete coring samples), we may supplement this report with a further report.

1.3.2. Appendix A to this Report contains the detailed results of computational fluid dynamics (**CFD**) simulations. The simulations address (i) the chimney effect in re-entrant geometries and its influence on flame height and vertical fire spread, and (ii) smoke spread from the re-entrant into staircases and lift lobbies.

2. INTRODUCTION TO FIRE SPREAD CONCEPTS

2.1. Basics of fire spread concepts

2.1.1. The fire triangle is a fundamental concept in fire science that illustrates the three essential elements required for a fire to ignite and sustain itself: fuel, oxygen, and heat. Fuel represents any combustible material, such as wood, paper, flammable liquids, or gases. Oxygen, typically drawn from the surrounding air, serves as the oxidizing agent necessary to sustain the chemical reaction of combustion. Heat provides the initial energy required to raise the fuel to its ignition temperature. These three components must exist simultaneously and in the correct proportions; if any single element is removed—whether by cooling the heat with water, smothering the oxygen with a fire blanket, or starving the fire of its fuel—the chemical reaction ceases and the fire is extinguished.

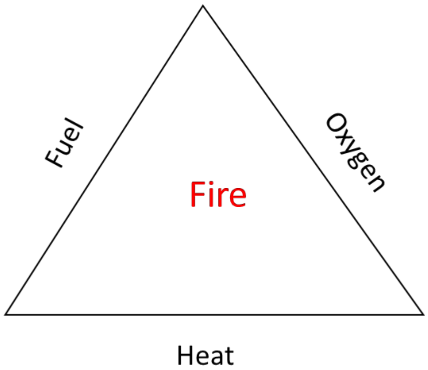

Figure 2.1. Fire triangle

2.1.2. However, modern fire science has evolved this model into the fire tetrahedron to provide a more complete picture. The tetrahedron adds a critical fourth element: a self-sustaining chemical chain reaction. Once ignition occurs, the heat generated by the flame breaks down nearby fuel molecules into volatile gases. These gases react with oxygen, producing more heat, which in turn volatilizes more fuel. This continuous feedback loop is what allows a fire to transition from a localized ignition to a spreading blaze.

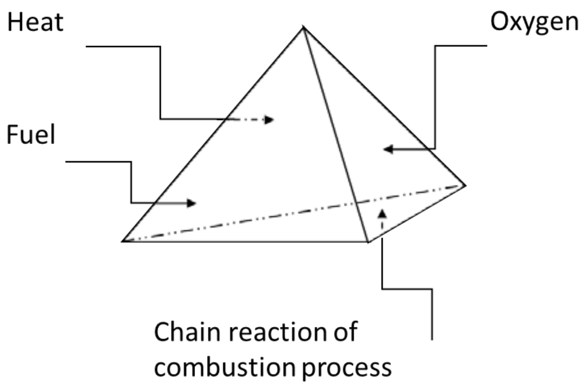

Figure 2.2. Fire tetrahedron

2.1.3. Fire spread occurs when this heat is transferred to adjacent, unburnt fuels, raising them to their ignition temperatures through three primary mechanisms:

(a) Conduction: Direct heat transfer through solid materials (e.g., walls exposed to fire inside a compartment heating objects adjacent to the other side of the wall outside the compartment).

(b) Convection: Heat transfer through moving liquids or gases (e.g., hot smoke rising inside stairwells or hot gases flowing out of cracks in walls igniting combustibles on the other side).

(c) Radiation: Heat transfer through electromagnetic waves (e.g., intense heat radiating across the building separation space to ignite combustible objects in an adjacent building).

2.2. Internal fire

2.2.1. For a fire occurring in an enclosure (compartment fire or room fire), the fire is either fuel-controlled or ventilation-controlled (if a sprinkler system is installed, the fire might be a sprinkler-controlled fire). Fuel controlled fires are typically represented by short period fires, with steeply rising heat release rate (**HRR**) curves. If the ventilation is limited within the compartment, then the HRR will be limited, due to the limited oxygen available for combustion. Ventilation controlled fires are typically represented by longer duration fires with HRR curves that have a less steep curve.

2.2.2. A typical schematic heat release curve for a compartment is shown in Fig. 2.3. This curve illustrates the main aspects that will typically describe the rate of heat release, within a compartment. Each phase is further described in the following section.

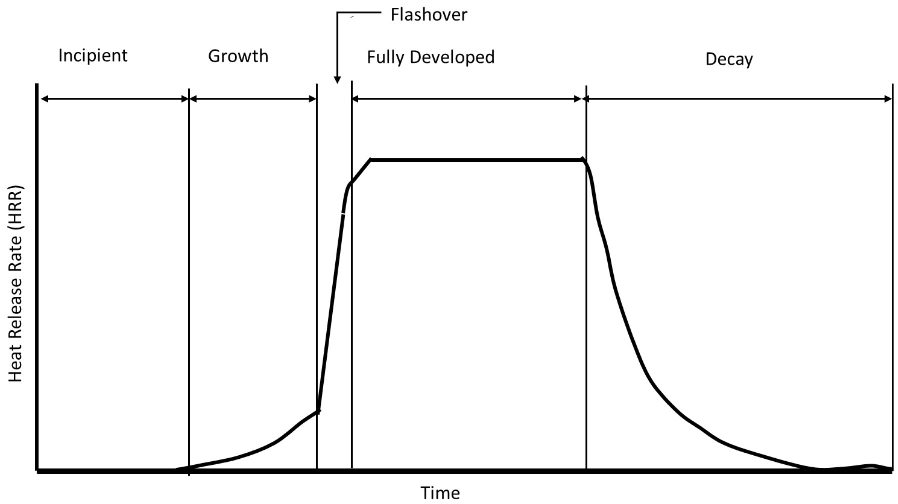

Figure 2.3. Typical phases of a fire curve

2.2.3. Incipient Phase:

(a) The incipient stage of a fire may last from a very short time to days depending on the initial fuels involved, ambient conditions, ignition source, etc. Current understanding of the early stages of fire development does not allow for reliable modelling of the incipient phase. In most cases, the incipient phase is ignored and the growth phase is considered to be time zero.

2.2.4. Growth Phase:

(a) The growth phase is considered to begin when the radiation feedback from the flame governs the mass loss rate. Assuming the compartment is vented, the burning rate is primarily influenced by the fuel properties and orientation. During the growth phase the fire spreads across the fuel surfaces, increasing the burning area and corresponding heat release rate. The mass loss rate is assumed to be independent of the fire enclosure and governed more by the flame-spread rate.

(b) The ability to predict flame spread through empirical models have given encouraging results but have been limited to comparatively simple geometries such as room corners. Research on the growth rate for complex objects like upholstered furniture and complex storage arrays is ongoing. Among the various stages of a fire, the growth phase is the most important aspect. This is typically modelled with a t-squared rate of growth.

2.2.5. Flashover:

(a) Although there is no universally accepted definition of flashover, it is commonly described as the transition from a developing fire to full room (or compartment) involvement. This transition typically occurs rapidly, often within seconds. The increase in thermal radiation intensity from the rapidly thickening hot gas and smoke layer that collects in the ceiling cavity gradually ignites all combustibles in the room and accelerates the mass loss rate of burning objects (indicating rapidly increasing production of pyrolysis gases).

(b) Typical criteria used to define flashover include:

- Gas temperatures near the ceiling reaching approximately 600°C;
- Radiant heat flux at floor level exceeding 20 kW/m^2; and
- Flames emerging from compartment openings such as windows or vents.

(c) These criteria are practical for physical observation. Considering that the average temperature at the tip of a buoyant diffusion flame is about 550°C, once the flame tips reach the ceiling, the onset of flashover is imminent.

(d) In fire models, flashover is treated as a rapid, nearly linear transition from a growing fire to a fully developed fire, occurring over a very short time span.

2.2.6. Fully Developed / Post-Flashover:

(a) In the fully developed or post-flashover phase of a fire, all combustible objects in the compartment are burning, including the floor if it is combustible. The mass loss rate is controlled either by the available fuel surface area or by the available air supply. In most cases, the fire becomes ventilation-controlled, meaning the rate of combustion is limited by the amount of oxygen entering the compartment.

(b) Some fire models calculate the ventilation rate into and out of a compartment and can adjust the heat release rate (HRR) within the compartment accordingly. Any excess fuel that cannot burn within the compartment due to insufficient oxygen remains available to burn in other locations where more oxygen is present.

(c) In a ventilation-controlled fire, the combustion rate during the post-flashover stage is restricted by the fresh air entering and the hot gases exiting the room. Due to insufficient oxygen, not all pyrolysis gases can burn inside, causing flames to extend out of windows or other openings. Additional combustion occurs where these hot, unburned gases mix with outside air.

(d) For ventilation-controlled fires, the maximum fire size or HRR is governed by the available oxygen (air) through ventilation openings. An empirical correlation has been recommended and is widely used in practical design and analysis to estimate the maximum HRR:

$$Q_{max} = 750\ A_v\sqrt{H_v}$$

where Q_{max} is the maximum HRR (kW), A_v is the area of the ventilation opening (m^2), and H_v the height of the ventilation opening (m).

2.2.7. Decay Phase:

(a) Once a fire has consumed most of the available fuel, the heat release rate (HRR) will diminish. This is primarily of interest when determining the required fire resistance of structural elements.

(b) In the tragic fire incident at Wang Fuk Court, many flats caught fire. Those classified by the IFITF as having suffered 'Extremely Severe Damage' or 'Severe Damage' (Section 8.3.1.1 of IFITF Final Report) must have experienced all of the fire development stages described above, indicating that the fire lasted for a considerable duration.

2.3. External fire

2.3.1. While traditional structural fire safety focuses on containing a fire within an internal room, or "compartment", external facade fires bypass these interior defenses. When a fire reaches a building's exterior, it can potentially propagate upward and laterally, threatening the entire structure, assuming that the building façade contains combustible cladding, either continuously or intermittently. This rapid external spread is driven by specific aerodynamic and thermodynamic phenomena.

(a) The Chimney (Stack) Effect in Cavities: Modern high-rises often use rainscreen cladding systems, which feature an outer aesthetic panel, an inner layer of insulation, and an open air cavity between them. If fire penetrates this cavity, the air gap acts as a chimney. The rising hot air draws in oxygen, creating a powerful upward draft that rapidly pulls flames up the building. The Grenfell Tower tragic fire is an example of this type of fire.

(b) The Leap-Frog Effect: When an internal fire breaks through a window, the flames naturally plume upward. The effect causes these flames to hug the exterior facade. This intense radiant and convective heat may ignite the cladding above and/or break windows and spread the fire to the room above, allowing the fire to "leap-frog" from floor to floor, re-entering the building through upper windows.

2.3.2. In the Wang Fuk Court case, the trapezoidal re-entrants acted as a chimney-like shaft. The combination of a continuous path of combustibles within the re-entrant space and a narrow, full-height opening on one side created the perfect conditions for rapid vertical fire spread.

2.3.3. Where and when the fires that started inside the flats (as a result of the original re-entrant fire penetration through broken windows), developed into the flashover stage, other windows broke and allowed the collected unburnt pyrolysis gases to spill out from the windows that reignited as oxygen became available, forming a vertical fire plume. This triggered the ‘leap-frog’ effect, creating another path externally for the fire to spread to the flat above.

3. REVIEW OF FIRE SPREAD AT WANG FUK COURT

3.1. References and evidence for timeline analysis

3.1.1. The timeline of fire spread from the initial observation to the spreading among buildings is analysed according to the videos provided to us. The various time points corresponding to the critical events of fire spreading are estimated with reference to the video creation time (the starting point of capturing), which may have minor discrepancies within 1 minute.

3.2. Critical events of fire spread

3.2(a) Initiation of Wang Fuk Court fire

3.2.1. The initial fire at Wang Fuk Court was reported at 14:51, 26 November 2025 (referring to Section 5.1.1 of IFITF Final Report). Witness reports suggested that the earliest found products of fire (e.g., smoke) might be around 14:30, but it cannot be verified by clear evidence. However, the first available video footage showing the initial fire at re-entrant flat roof indeed showed that the fire had already developed for a short period. The video was captured at 14:50:43 according to the time stamp of video, and there existed flames at various locations, including the floor of re-entrant roof (1st floor, between Unit 104 and Unit 105) and safety net pieces attached to bamboo sticks. At 14:53 (Fig. 3-1), the fire had developed to a localised fire of certain height, which was then able to initiate the massive fire in the re-entrant region. Here the growing size of localised fire is likely due to the stacked fuel on re-entrant flat roof forming a fuel base of the fire.

Figure 3-1. Initial fire development at re-entrant of Block F

3.2(b) Critical events of fire spreading among multiple building blocks

3.2.2. The first massive vertical-spreading fire along the re-entrant region occurred after the initially observed fire at re-entrant flat roof of Wang Cheong House (Block F) between Unit 104 and Unit 105. The subsequent fire spreading follows similar patterns among various buildings. If taking a vertical re-entrant fire as the most critical event, it would always be initiated by a localised fire of certain size, which was likely to have resulted from the ignition of building block façade. Window glass breakage at various locations such as kitchens, bathrooms, and living rooms (depending on room unit types) occurred immediately during the massive vertical re-entrant fire. The correlation of glass breakage and room unit fires is discussed in Section 3.4 below.

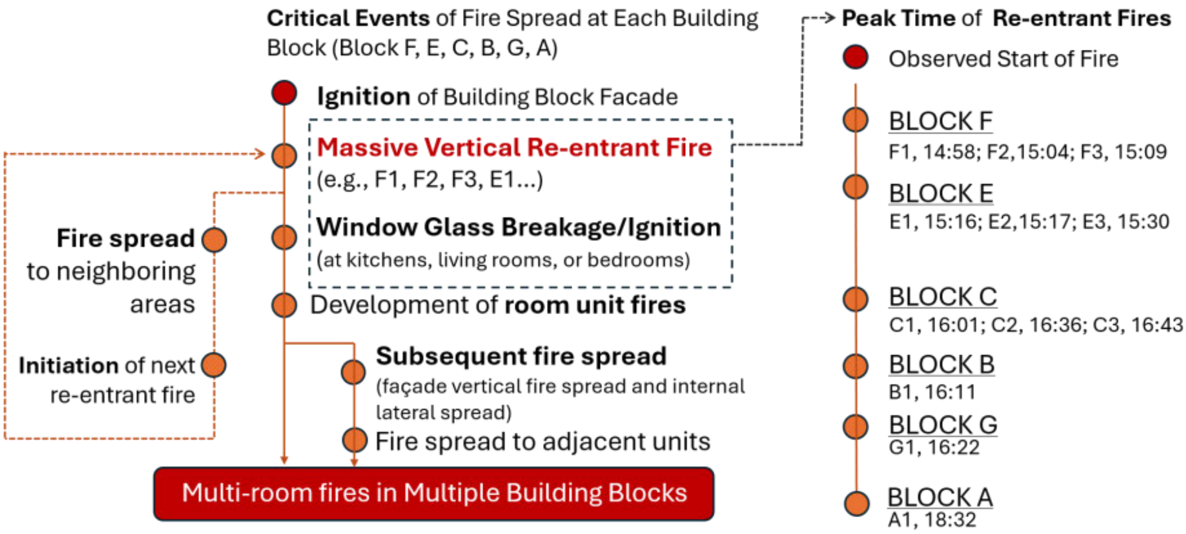

Figure 3-2. Critical events of fire spread among building blocks

3.3. Timeline of fast vertical fire spread in re-entrant regions

3.3.1. The severe fire impact to each building was always initiated by the extremely fast vertical fire spread at re-entrant region. The first vertical re-entrant fire spread followed the visible fire at re-entrant flat roof between Units 104 and 105 of Wang Cheong House (Block F), which is marked as “F1” in the following figure showing the timeline of vertical fire spread at different buildings. Here “F” represents the building block, while “1” represents the 1st re-entrant region experiencing rapid vertical fire.

(F1) 1st fast-spreading Re-entrant fire of Block F   14:58 Time point of fast vertical fire spread

Figure 3-3. Timeline of fast spreading vertical fires at re-entrant regions

3.3.2. The first vertical fire spread at Wang Cheong House (Block F) re-entrant “F1” was first captured at 14:50 on 26 November 2025. The full development stage of “F1” was around 14:59, and the decay stage was observed at 15:02. At the decay stage, the building was engulfed by a huge amount of smoke as the photographic evidence shows.

Figure 3-4. Initiation and development of F1 re-entrant vertical fire

3.3.3. The second vertical fire spread along the re-entrant region between Units 6 and Unit 7 (F2) was initiated at 15:02, which underwent fast development at 15:03-15:04. According to visual evidence, the vertical fire entered its decay stage at 15:06. It indicated that the intense heating period due to vertical fire spread along re-entrant region was very short, only <u>lasting for 2-4 minutes</u>.

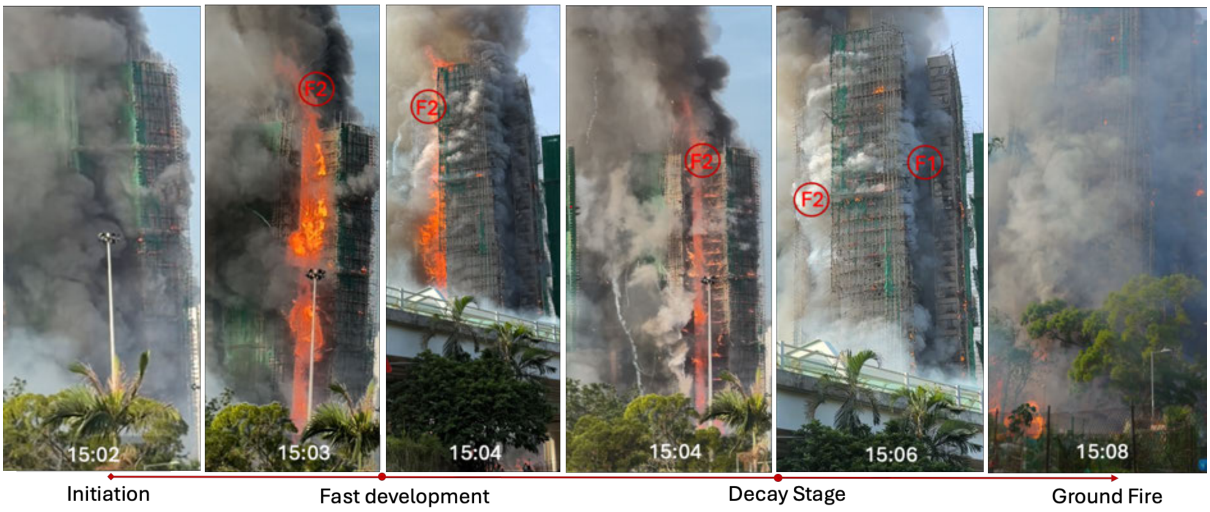

Figure 3-5. Initiation and development of F2 re-entrant vertical fire

3.3.4. The third vertical fire spread along the re-entrant region between Units 1 and Unit 8 (F3) of Wang Cheong House was observed at 15:09, undergoing fast development at 15:09-15:10.

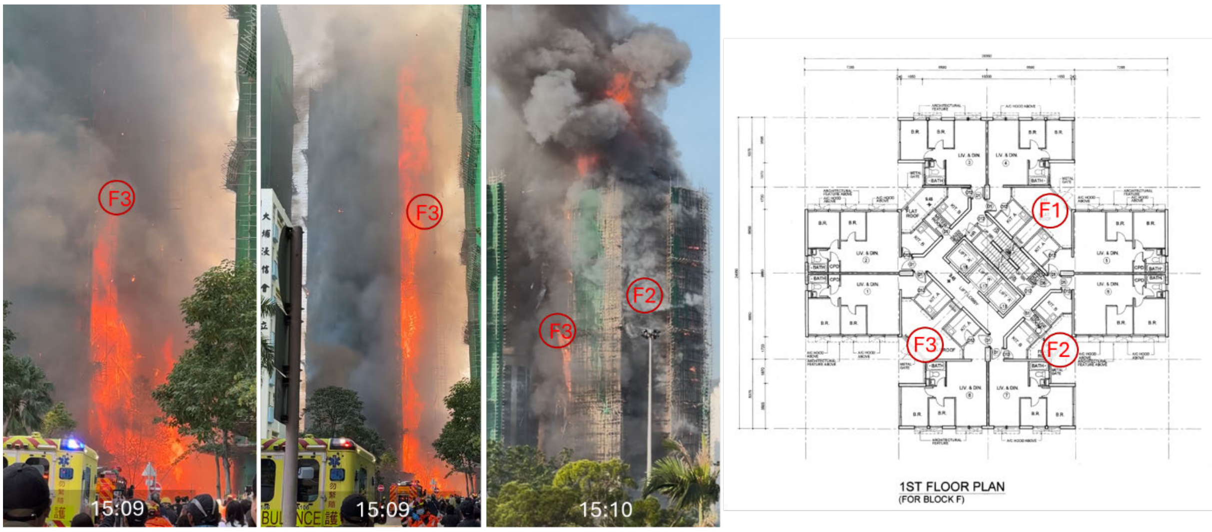

Figure 3-6. Initiation and development of F3 re-entrant vertical fire

3.3.5. Wang Tai House (Block E) had the peak stage of its first vertical re-entrant fire spread (E1) around 15:16 and soon the second vertical fire spread of E2 occurred at 15:17. In the meantime, E1 already entered its decay stage as the flames became invisible at the facade. Similarly, a large amount of smoke engulfed the building at the decay stage of re-entrant fire. At 15:30, the third re-entrant vertical fire of Wang Tai House was observed. Note that the order of E1 to E3 is identical to the order of F1 to F3.

Figure 3-7. Initiation and development of E1, E2, and E3 re-entrant vertical fire

3.3.6. While Wang Kin House (Block D) did not have any re-entrant fires that were developed, the first vertical fire spread of Wang Sun House (Block C) (C1) was initiated at 16:00, which underwent fast development at 16:01. The second vertical fire of a Block C re-entrant was observed at 16:36. The third vertical fire spread along the re-entrant of Block C was captured at 16:43.

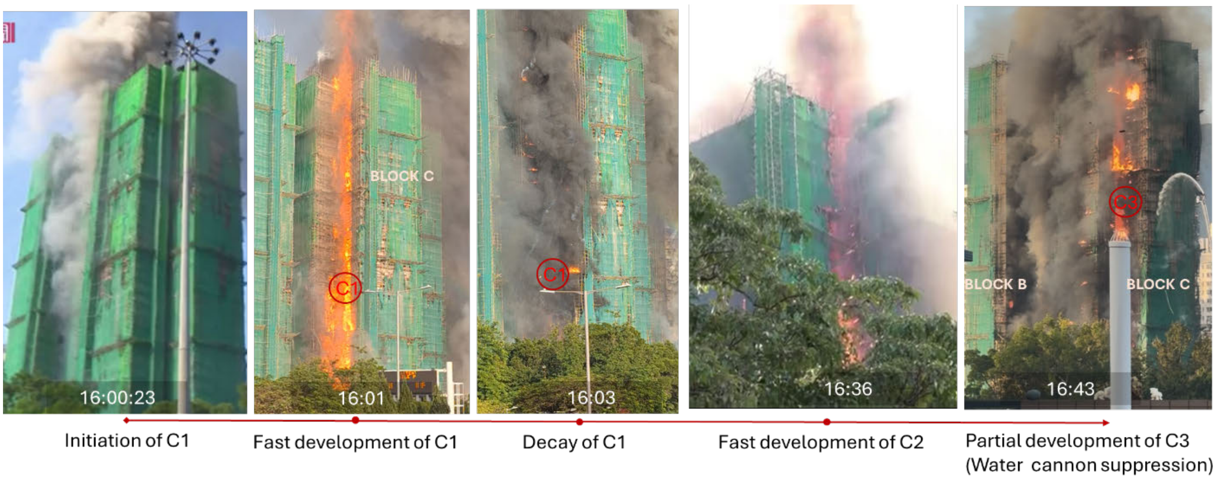

Figure 3-8. Initiation and development of C1, C2, and C3 re-entrant vertical fires

3.3.7. For Wang Tao House (Block B), Wang Shing House (Block G) and Wang Yan House (Block A), there was only 1 re-entrant region for each building which underwent vertical fire spread according to the available video footage. The development of B1 was clearly captured in the live coverage of "Cable News", which exhibited the initiation starting at 16:10-16:11 with visible flames near the ground. It very quickly developed to an intensive re-entrant fire at 16:11 and entered its decay stage at 16:13. The peak of the first and only re-entrant fire of Wang Shing House (Block G) was seen at 16:22, whereas a re-entrant fire of Wang Yan House (Block A) (A1) was seen in the evening at 18:32.

Figure 3-9. Development of B1, G1, and A1 re-entrant vertical fires

3.4. Fire spread to flats due to re-entrant vertical fire spread

3.4.1. As a result of the intense re-entrant fires, many window glass panels have been broken, such as the kitchen windows facing the re-entrants and the living room windows facing flames which extended beyond the re-entrants. It has been noted that the re-entrant fires were of a very short duration (2-4 minutes) but had a very high heating impact. An extensive analysis on the glass breakage evidence collected was conducted on the basis of the well-documented post-fire photos of all the room units.

3.4(a) Glass breakage and flame spread to flats

3.4.2. From the damage analyses of room units, it is found that the room units with living room windows exposed to extended vertical re-entrant fires were more heavily damaged. This is because the extended flames created sufficient heat fluxes on window glass panels, causing glass breakage and flame penetration, which thereafter initiated room unit fires.

3.4.3. During the vertical re-entrant fire, the kitchen windows and bathroom windows directly exposed to the vertical re-entrant fire were broken by the intense heating impact, but they were mostly not associated with the fully developed fires in room units.

3.4.4. Regarding the damage and fire penetration mechanisms, it can be categorized as two types: (A) the room units with living room windows exposed to extended re-entrant fire; (B) the room units with bedroom side windows exposed to extended re-entrant fire.

Type A: Typical unit with living room windows exposed to re-entrant fire

3.4.5. The relatively large living room windows were broken during the short-period of re-entrant fires, which thereafter ignited any combustible items in living rooms. Moderate fire burning was observed in some room units as there was no or there was limited fuel near the living room.

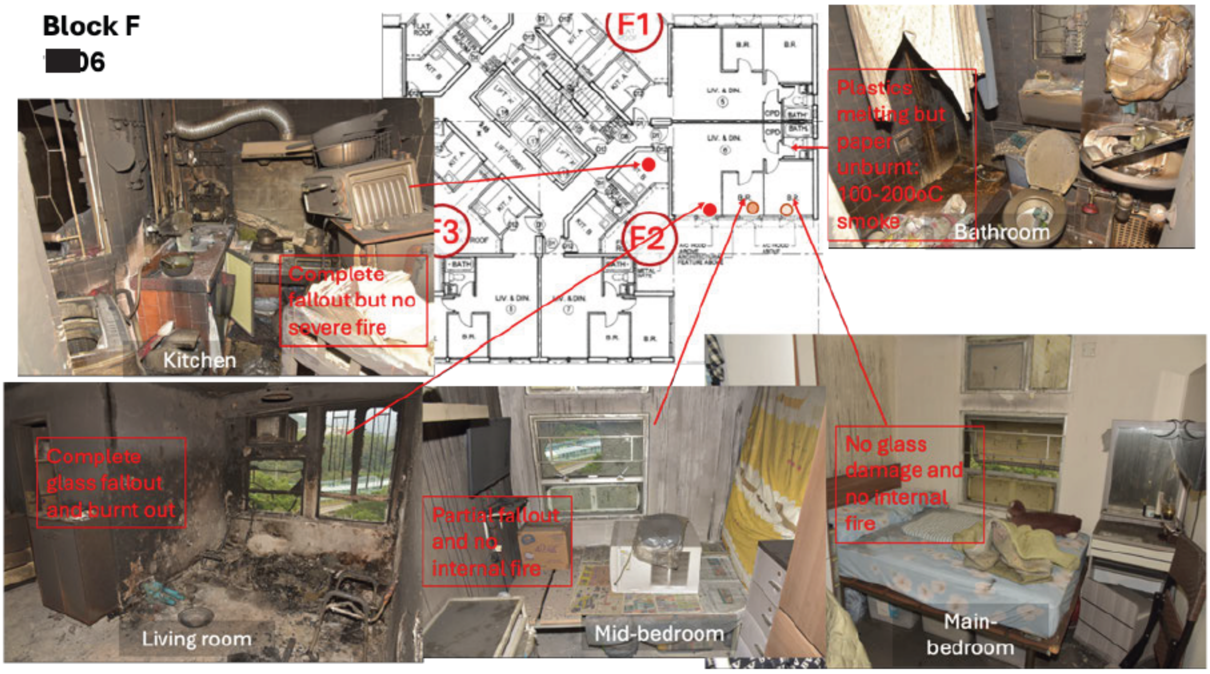

Figure 3-10. Typical unit (Block F [redacted]06) with living room windows exposed to re-entrant fire

Type B: Typical unit with bedroom side window exposed to re-entrant fire

3.4.6. These room units only have kitchen windows, bathroom windows and side windows of bedrooms facing the extended re-entrant fire. After analysing the photos of post-fire room units, it is clearly seen that glass breakage at kitchens and bathrooms did not introduce fire spreading into room units, except in some rare cases. This is because limited combustible items existed near the windows of kitchens and bathrooms. The side windows of main bedroom are relatively far from the re-entrant area, which caused limited fire impact on the glass windows.

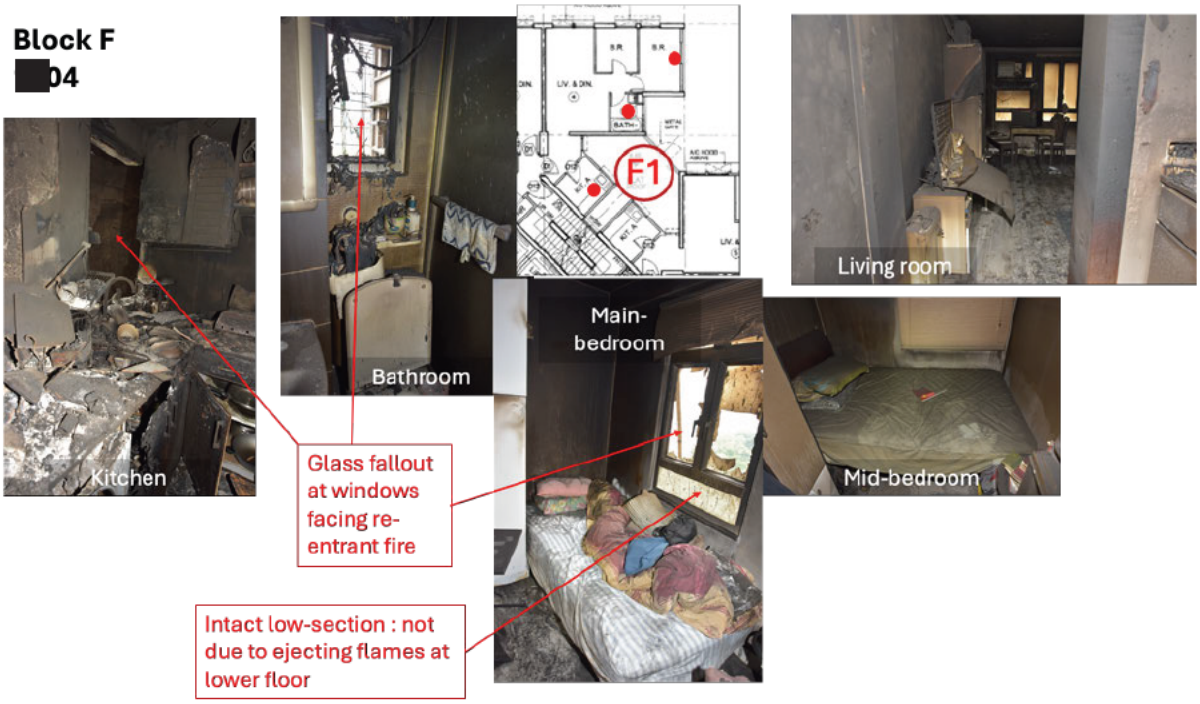

Figure 3-11. Typical unit (Block F[redacted]04) with bedroom windows exposed to re-entrant fire

<u>3.4(b) Glass breakage and flame spread to rooms of Block B unit 2 (Type A)</u>

3.4.7. The re-entrant fire development of Wang Tao House (Block B) was captured by "Cable News", which may facilitate the follow-up analysis on the effect of glass breakage. Unit 2 of Block B on each floor falls into the Type A category. Here only the living rooms of Units 802 to 3102 are shown as the glass windows of lower floors may be affected by ground fire exposure and water cannon impact. The possible causes of glass breakage and fallout of the living room windows can be: (i) fire impact of short-duration extended flames from the re-entrant vertical fire; or (ii) heating impact from the ejecting flames from the lower floor compartments; or (iii) heating impact due to fully developed fire in the room unit. The key findings are:

(a) All the glass windows of Wang Tao House (Block B) Unit 2 living rooms were broken after the fire.

(b) The short duration re-entrant fire was able to break the living room window glass panels. This is based on the evidence of Unit 2302 and Unit 2402. Because Unit 2302 only had minor fire damage after glass breakage, no strong ejecting flames came from Room 2302 to break the glass windows of Unit 2402 (i.e. Reason (ii) is not valid). Moreover, there was tiny fire burning trace developed in Unit 2402, which suggested that

Reason (iii) is not valid. Therefore, Reason (i) must be valid and so it is deduced that the re-entrant fire impact was able to break the glass. This finding was also supported by other room unit damage analyses based on the post-fire photos.

(c) The fire damage in room units varied because of the different distributions of combustible items to be ignited after window glass fallout during re-entrant fires.

(d) It shows a sequence of fully developed fires at adjacent floors, which may due to the unfortunate ignition of living rooms, or the secondary spreading along the building façade. The ejecting flames of one unit reignited the remained façade scaffolding and caused fire spread to upper floors.

Block B Unit 2 living rooms

[redacted]

[redacted]

Figure 3-12. Post-fire photos of Unit 2 living rooms of Wang Tao House (Block B)

<u>3.4(c) Glass breakage and flame spread to rooms of Block B unit 3 (Type B)</u>

3.4.8. Unit 3 flats of Wang Tao House (Block B) were also affected by the re-entrant fire. The kitchens were directly impacted by the re-entrant fire, while the side windows of main bedrooms were also heated by the extended flames from re-entrant region. Hence, they represent Type B scenarios. According to the post-fire photos, the glass windows of kitchens were all broken in Block B Unit 3 flats. The fire induced damage to Unit 3 rooms is generally lighter as it might be highly linked to the fire spreading to main bedrooms through the cracked side windows.

[redacted]

Figure 3-13. Post-fire photos of Unit 3 rooms of Wang Tao House (Block B)

3.5. Fire spread from fully developed unit fires to upper floor units

3.5.1. As stated above, the fast-developed vertical re-entrant fire quickly caused glass breakage of some room units, especially those room units of living room windows facing the vertical fire. In other words, each building would have multiple rooms being ignited after its 2-4 minute re-entrant fire. Subsequently, these room unit fires continue to develop to flashover (intense burning at each ignited unit), with ejecting flames out of nearly all the windows of the unit.

Figure 3-14. Remaining scaffolding to fuel the subsequent fire spread

3.5.2. During the re-entrant vertical fire, only the combustible items of bamboo scaffolding in the re-entrant and near the re-entrant were burnt. The bamboo scaffolding on other sides of the façade remained attached, and remaining bamboo scaffolding including safety nets, wood planks, bamboo tubes, and other combustible materials could be ignited by the ejecting flames of post-flashover room fires to enable subsequent fire spread from lower floors to upper floors as shown in Fig. 3-15. Therefore, after the series of fast-developed re-entrant fires, many rooms of the six buildings (Block F, Block E, Block C, Block B, Block G, Block A) were ignited at different time points. The whole progression of room unit fires lasted from the evening of 26 November to 27 November 2025.

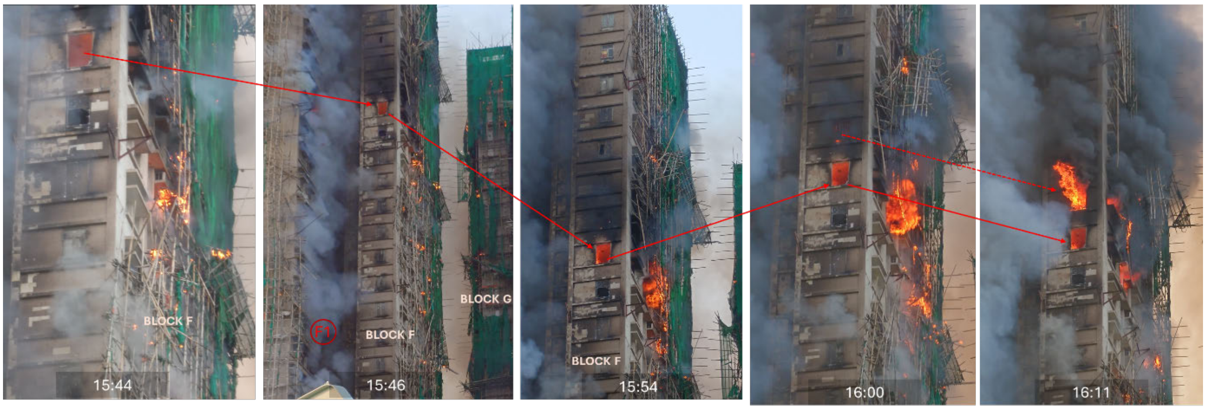

Figure 3-15. Subsequent fire spread from lower floor to upper floor

3.5.3. Having described the visual evidence illustrating how the fire spread at Wang Fuk Court during different stages, we now turn to the contribution of various materials found on the external walls on the day of the fire.

3.6. Experimental tests - Ignition and combustion behaviour of materials on external walls

3.6(a) Foam boards

3.6.1. The samples of polystyrene foam boards were provided by the Hong Kong Police Force on 20 March 2026, which were collected from Wang Shing House (Block G) (for Tests A1-A3) and Wang Chi House (Block H) (for Test A4). The foam boards were tested using the Radiant Panel Testing System in the PolyU fire laboratory. This radiant panel can apply high-intensity heating boundary conditions equivalent to real building fires (up to 200 kW/m^2) on building materials, which facilitates direct observation of fire responses of those materials without reproducing large fire test scenarios.

Table 3.1 List of experimental tests on polystyrene foam boards

Test No	Gauge Heat Flux at upper corner (kW/m²)	Testing Characteristics	Foam board behaviour
Test A1	38.1	Radiant heating only/ no flame for pilot ignition	Melted and fell off after 5 seconds
Test A2	21.0	Radiant heating + pilot ignition	Fell off after 13 seconds
Test A3	8.0	Lower half panel heating	Melted to upper section and fell off later
Test A4	Approx. 100	Radiant heating + pilot ignition	Melted and fell off, causing flames under window

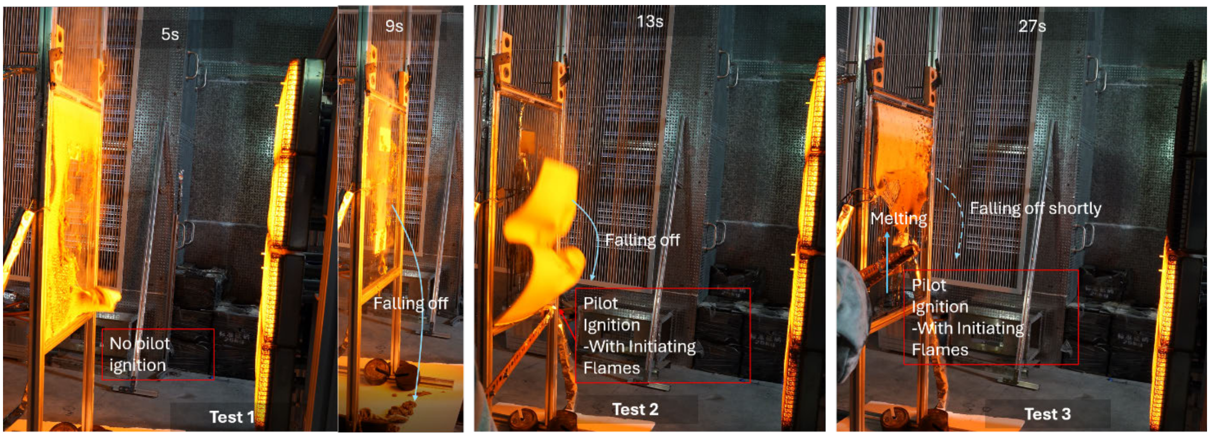

Figure 3-16. Radiant panel heating tests on polystyrene boards on glass panels (Tests A1-A3)

3.6.2. Test A1 to Test A3 showed that the polystyrene foam boards would quickly melt and drop off from the glass panels when subjected to heating. The rates of melting and timing of drop-off of the foam boards depended on the heating conditions.

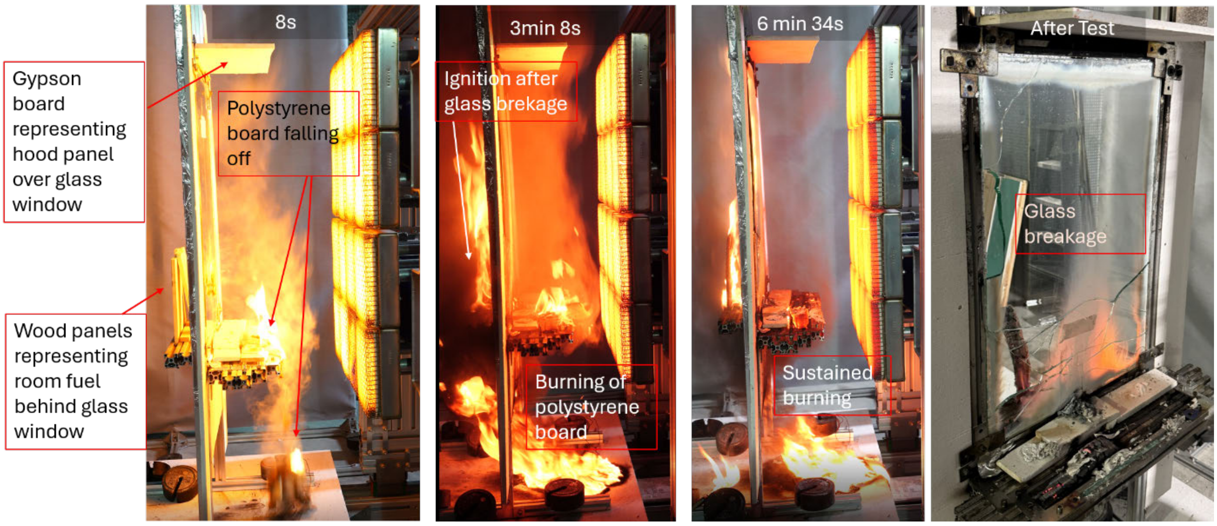

Figure 3-17. Radiant panel heating tests on polystyrene boards on glass panel (Test A4)

3.6.3. As to Test A4, the polystyrene board panel quickly fell off, leading to sustained flames at the lower board and the wood sticks in front of glass window. At 3 minutes 8 seconds, the glass panel cracked and the wooden board behind glass window was ignited, exhibiting flames (representing the ignition of in-room fuel). At 6 minutes 34 seconds, the melted polystyrene board remains burning. After radiant panel heating, glass breakage and fallout can be seen.

3.6.4. Our findings in relation to the experimental tests of polystyrene boards are that these boards pasted on the glass window would quickly melt and fall off when subjected to fire. The melted polystyrene boards could be ignited by flames, and the burning process lasts for nearly 10 minutes.

3.6.5. These experimental results should be read together with our full analysis on the impact of polystyrene foam boards during the fire, set out below. In brief, according to our simulations, foam boards located near the window openings acted as additional local fuel sources and increased the thermal exposure to the window region once involved in burning (Section 3.7.14 below). Further, according to our analysis of the IFITF's full-scale fire test data, the presence of polystyrene foam covers directly caused or accelerated the thermal shock and subsequent breakage of window glass, enabling lateral fire and smoke spread into the interior (Section 4.1(c) below). We agree with Key Observation (12) that although the total heat release from foam boards was minimal due to their small mass, they promoted fire spread to other combustibles (particularly during the subsequent façade fire spreading stage from lower units to upper units, as described in Section 3.5 above) due to their ease of ignition and production of burning droplets, and additionally released toxic smoke, further increasing fire hazards (Section 2.11.9 of the Yuen Final Report).

3.6(b) *Scaffolding safety nets*

3.6.6. We note from the Yuen Final Report that the IFITF tested four categories of safety nets: Sample 1 (procured without certification but found by the Government Laboratory to have a certain degree of FR properties[1]), Sample 2 (certified FR safety nets), Sample 3 (non-FR safety nets[2]) and Sample 4 (safety net samples collected from Wang Chi House which appear to be non-FR[3]).

3.6.7. Comparable tests have been conducted in PolyU fire laboratory on the samples of fire-retardant (**FR**) safety nets and non-FR safety nets provided by the Hong Kong Police Force. Fire retardancy refers to the property of a material that enables it to resist ignition and self-extinguish once the external heat source is removed, rather than sustaining and propagating the flame. In our Test B1, the safety net sample was provided by the Hong Kong Police Force and collected from the ground level of Wang Kin House (Block D), which exhibits FR behaviour. The samples used in Test B2 and the later introduced tests (Tests D1 and D2) are sourced from Wang Chi House (Block H), which appear to be non-FR according to the observed testing behaviour.

3.6.8. In our Tests B1 and B2, the height of the safety net attached to the frame was approximately 1.5 m, and the length was also approximately 1.5 m for each sample. The heating source was a square pool fire, to generate a 90 kW small localised fire. The key findings are as follows:

(a) The FR safety net (Test B1) only slowly melted and shrank at 1 minute and 3 minutes after being heated by the pool fire. No visible flames can be seen after the pool fire exhausted.

[1] Three of four samples in Sample 1 passed GB 5725-2009 and one failed (footnote 6 of the Yuen Final Report).
[2] The non-FR properties were artificially produced by thermally deteriorating uncertified nets at 120°C for at least 4 hours to render them non-compliant with both GB 5725-2009 and BS 5867-2:2008 (Section 2.7.3, footnote 21 of the Yuen Final Report).
[3] These Wang Chi House safety nets were collected by the HK Police and were manufactured by the same company (滨州市源进化纤绳网有限公司) that supplied 2,500 nets marked "綠不阻燃網" to Wang Fuk Court on 28 September 2025 (Section 2.8.1, footnotes 22–23). In direct comparison tests, the Wang Chi House nets spread fire faster than both the FR and the artificially degraded non-FR samples and were entirely consumed, indicating that they very likely lacked fire-retardant properties (Section 2.8.7 of the Yuen Final Report).

(b) The non-FR safety net sample (Test B2) quickly melted and the propagation of ignition was much faster as compared with the FR safety net at 3 minutes after pool fire heating.

(c) After the pool fire exhausted and extinguished, flames sustained on the non-FR safety net in Test B2. After 11 minutes, the burning front still moved forward and flames were seen on the net.

(d) Dripping flames were seen during the burning of non-FR safety net in Test B2, and the flames of net dripping on the floor can sustain for a few minutes.

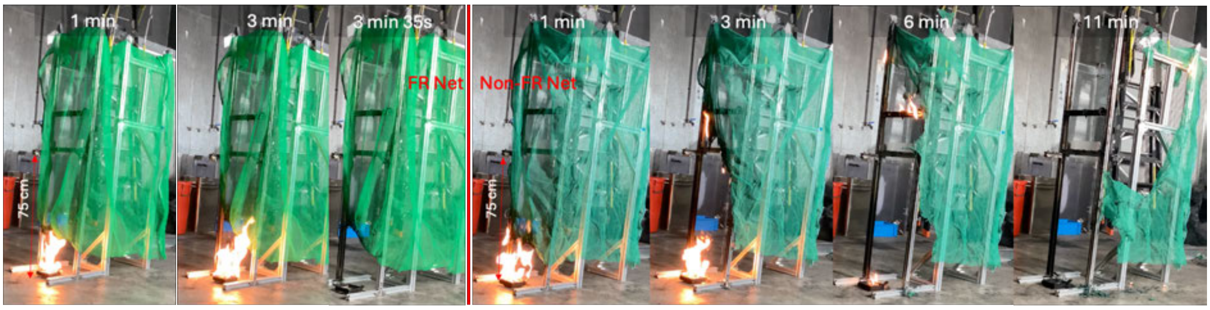

Figure 3-18. Burning tests on FR and non-FR safety net samples (Tests B1 and B2)

3.6.9. The results of the experimental tests are consistent with Key Observations (10) and (15) of the Yuen Final Report, i.e. the large-scale tests showed that small fires propagated on the uncertified or non-FR safety nets and flaming droplets from the safety nets first ignited the nylon strips used for knotting (Section 2.9.6 of the Yuen Final Report). As noted above, our own experimental observations are consistent with this finding, as dripping flames were seen during the burning of non-FR safety nets.

<u>3.6(c) Scaffolding bamboo</u>

3.6.10. A test using radiant panel has been conducted on the bamboo stick samples provided by HK Police. The test was conducted at PolyU fire laboratory using the radiant panel system as mentioned in Section 3.6.1 above.

3.6.11. During the test (Test C1), the initial heating boundary condition applied by radiant panel was measured as 50 kW/m^2. A small amount of paper was placed at the bottom to represent the existence of igniting flames.

(a) After 1 minute 47 seconds, fast evaporation of moisture from the bamboo stick could be seen, which represents the drying of bamboo (around 100°C).

(b) At 1 minute 49 seconds, flames suddenly appeared at the whole surface of bamboo, which suggested that pyrolysis gas has been released during the fast-drying period and the pyrolysis gas was ignited.

(c) At 3 minutes 23 seconds, the cracking of bamboo can be seen and an explosive sound was heard.

(d) At 3 minutes 52 seconds, the radiant panel was turned off, and the whole surface of bamboo became black, indicating its charred section.

(e) Flames sustained over the surface for about another minute and then the bamboo self-extinguished.

3.6.12. The combustible behaviour of bamboo sticks is similar to timber or wood products. Small heating energy cannot ignite it, whereas fast pyrolysis and burning can occur when subjected to relatively high heating conditions (such as 50 kW/m^2 of radiant heat flux in this test).

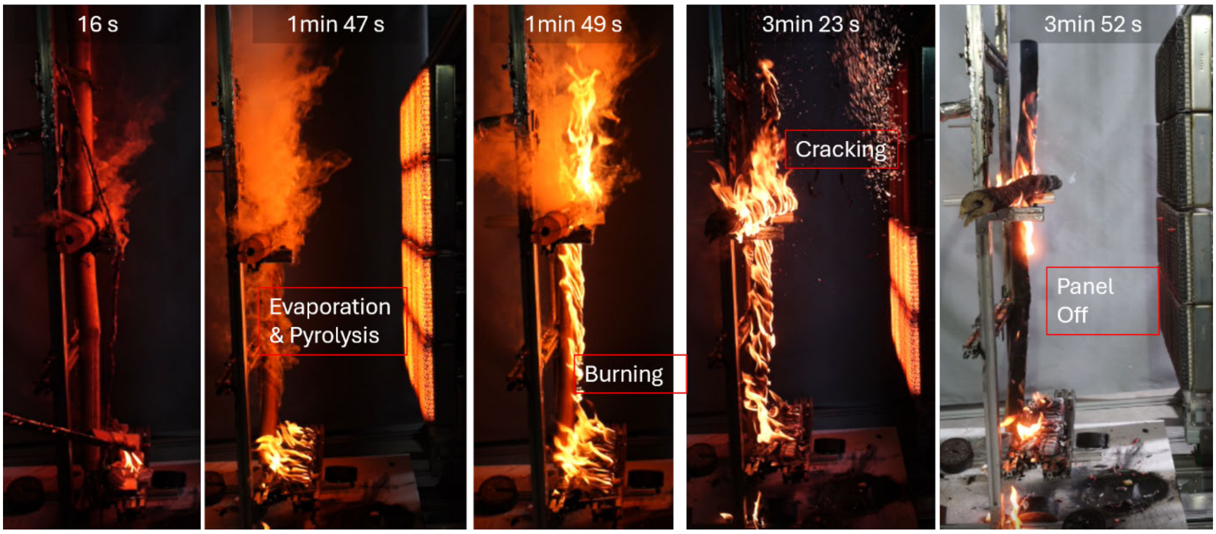

Figure 3-19. Burning tests on bamboo samples (Test C1)

3.6.13. The relatively longer period of time required to ignite the bamboo sticks during our experimental tests is consistent with the Time-to-Ignition (**TTI**) data obtained from cone calorimeter tests performed by the IFITF on various construction materials. In the Yuen Final Report, a comparison of the TTI for these materials reveals that toe-boards and nylon strips have relatively low TTI values (less than 36 seconds), polystyrene window covers are moderately ignitable at approximately 60 seconds, while bamboo demonstrates a significantly higher TTI of over 110 seconds (Section 2.12.19, 2.12.20). Based on these TTI values, Professor Yuen regarded FR safety nets and bamboo to be "Delayed Ignitable Materials" with a TTI of over 75 seconds and exhibited greater resistance to ignition, requiring prolonged exposure or high heat conditions.

3.6(d) Other combustible materials

3.6.14. Regarding the existence of other materials at building façade during the renovation of Wang Fuk Court, we have not conducted specific laboratory tests due to limited availability of samples.

3.6.15. Nevertheless, we have considered the test results reported in the Yuen Final Report in relation to other combustible materials, in particular, the use of non-FR and FR canvases in the IFITF's large scale fire test. In Section 4.2.13 of the Yuen Final Report, Professor Yuen observed that Tests 12 and 13 highlighted the critical role of non-FR canvas in accelerating fire growth, transforming limited and localized fires into a widespread and intense blaze across 31 levels. Key Observation (16) recorded the fact that non-FR canvas accelerated fire growth, transforming limited localized fires into a widespread intense blaze with excessive heat release sufficient to ignite bamboo sticks and thereby significantly increasing the HRR.

3.6.16. While we have not conducted tests on FR or non-FR canvas, the observations above are supported by the test results reported in the Yuen Final Report. Tests 12 and 13 of the large scale fire tests both included safety nets obtained from Wang Chi House, but Test 12 used FR canvas whereas Test 13 used non-FR canvas. The result was that Test 12 yielded a peak HRR of 0.62 MW (bamboo unaffected), whereas Test 13 yielded a peak HRR of 11.58 MW (bamboo sticks ignited) (Sections 2.12.24, 4.2.10, 4.2.12).

3.6(e) Tests on joint effect of combustible materials

3.6.17. The first test on joint burning effect (Test D1) was conducted as shown in Fig. 3-20, which includes non-FR safety net (approximate size of 1.5 m*1.5 m), an initiating fire (90kW square pool fire), cardboard underneath the left side of safety net, and wood panel under the right-hand side of safety net.

3.6.18. We note the dripping flames of non-FR safety net seen in Test B2, as stated above. The ignition of cardboard due to the dripping flames from the non-FR safety nets is clearly shown in Test D1 at 3 minutes. At 9 minutes, the flames have propagated to the right-hand side of safety net, and an area of the wood panel was ignited by the dripping flames as shown in the test photo at 16 minutes and Fig. 3-21. After the fire extinguished, the cardboard had been burnt out and the charring of wood panel had propagated to deeper section.

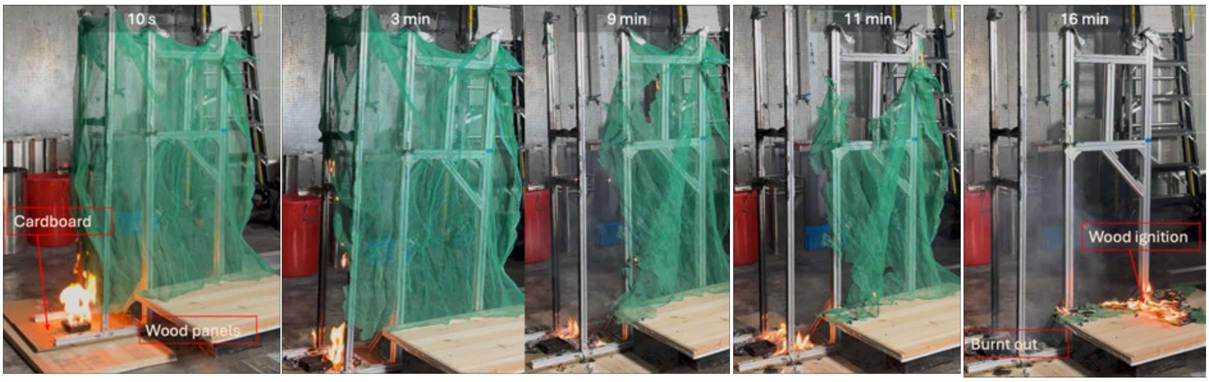

Figure 3-20. Joint burning test on non-FR safety net and cardboard, and wood panels (Test D1)

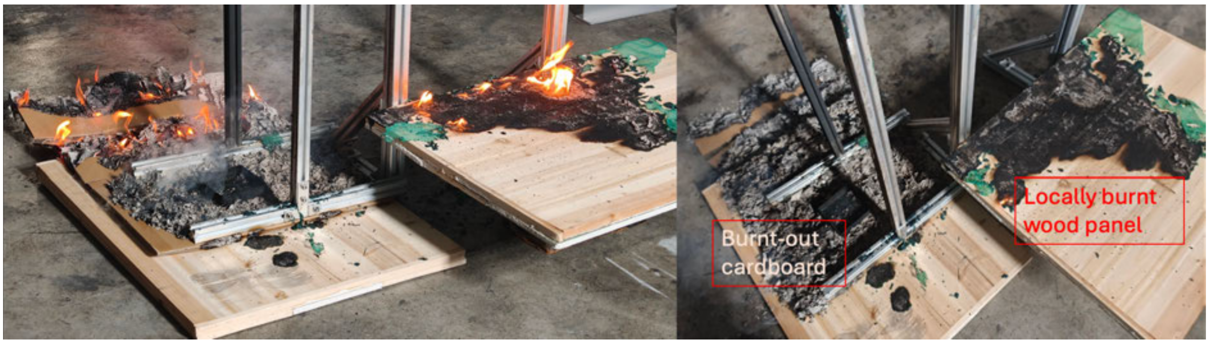

Figure 3-21. Burning behaviour of cardboard, and wood panels subjected to dripping fires in Test D1

3.6.19. Another joint burning effect fire test (Test D2) was conducted by increasing the volume of non-FR safety net (approximately 3 m*1.5 m), and the net was wrapped only on the right-hand side frame of Test D1. This is to represent the accumulated dripping of safety net above the flat roof of re-entrant regions. Additionally, two vertical bamboo sticks were bound to the frame to consider the burning contribution of bamboo. A small amount of non-FR safety net was used as igniter in the form of dripping flames, which is to consider the igniting sources such as flying embers and burning pieces of safety nets.

3.6.20. We observed in Test D2 that:

(a) At 1 minute after the ignition, the visible flames at the top area moved fast, and half of the net melted and fell to ground wood panel at 3 minutes, which led to ground distributed flames.

(b) Later on, as shown in Fig. 3-22, the flame height increased at 5 minutes, 7 minutes, 9 minutes, and 10 minutes, which reached nearly 1 meter.

(c) This joint burning test may explain the initial fire growth at the flat roof of re-entrants leading to the massive re-entrant fire.

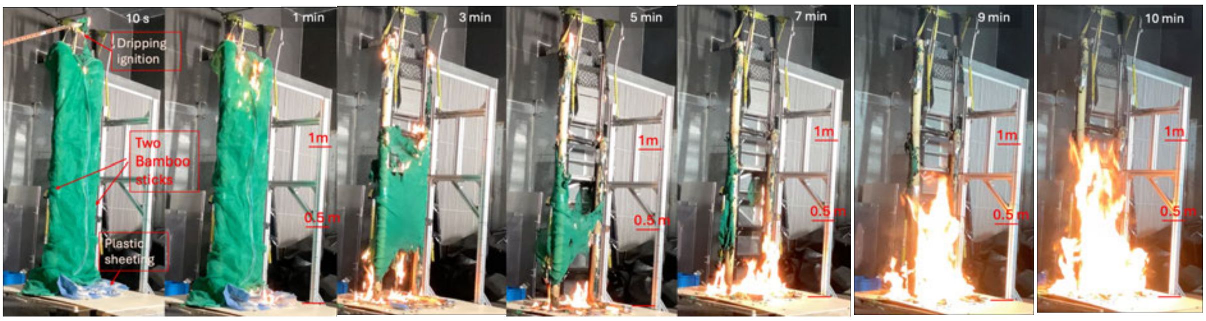

Figure 3-22. Joint burning test on non-FR safety net and cardboard, and wood panels (Test D2)

3.6.21. From 7 minutes to 10 minutes, it was observed that the bamboo stick had joined the localised fire, and the fire was further intensified along the charring and pyrolysis of bamboo. As shown in Fig. 3-23, the bamboo stick was burnt out and a large area of the wood panel was ignited. Since the bamboo stick was ignited after a sufficiently large fire through the dripping flames igniting cardboard and wood panels on the ground, this demonstrates the likely role played by the dripping effect of non-FR safety nets and the burning of combustible items at flat roofs in initiating the re-entrant fire.

Figure 3-23. Burning behaviour of cardboard, and wood panels subjected to dripping fires in Test D2

3.6.22. The results of Tests D1 and D2 are consistent with the observations from the large scale fire tests in Sections 2.12.24 and 2.12.25 of the Yuen Final Report, where it was observed that FR safety nets and FR canvas yielded a much lower total heat of 281.57 MJ (Test 11) compared to the tests with non-FR safety nets from Wang Chi House, which yielded a total heat of 1453.57 MJ and 6885.78 MJ respectively (Tests 12 and 13). In particular, it was observed that where non-FR safety nets and canvases were used, the fire spread along the safety nets, causing the canvases on 3/F of the scaffolding setup to catch fire and subsequently spreading the fire along the floor horizontally. The flaming droplets from 3/F caused the combustible materials on 2/F to catch fire. The resulting excessive heat release might be sufficient to ignite bamboo sticks, significantly increasing the HRR, as we saw from Test D2.

3.6.23. As we observed from Tests B1 and B2, the FR safety net only slowly melted and shrank at 1 minute and 3 minutes after being heated by the pool fire, and no fire droplets appeared. Based on these test results, we agree with the conclusion in the IFITF Final Report that FR safety nets play an important role in mitigating fire risks, through reducing the likelihood of fire propagation by preventing secondary ignitions and self-extinguishing once external heat source was removed (Section 8.6.1.1).

3.7. Simulation on fire spread

3.7(a) Simulation of chimney effect

Overall description of the model

3.7.1. A three-dimensional numerical model was established to investigate the vertical fire spread and chimney effect in the re-entrant during the Tai Po fire. PyroSim 2024.2, a graphical interface for FDS 6.9.1, was used to simulate the fire scenarios.

3.7.2. To maintain a reasonable computational cost, the model was simplified to represent 15 storeys of the building. The fire source was located near the bottom of the re-entrant at ground level and was defined by a prescribed fire area and heat release rate per unit area. The fire area was 2.07 m^2, and the heat release rate per unit area was 2000 kW/m^2, resulting in a maximum total heat release rate of 4140 kW.

3.7.3. The analyses focused on the upward transport of hot smoke within the re-entrant and on the effects of combustible façade-related components, namely bamboo scaffolding, safety netting, and foam boards at window locations, on the development of vertical fire spread. The key material parameters are summarized in Table 3.2. The bamboo scaffold, netting, and foam boards were modelled using material-governed pyrolysis assumptions, with heat of combustion and kinetic parameters selected from reported values for bamboo, polypropylene-type netting, and XPS-type foam insulation materials.

Table 3.2. Key material parameters used in the fire spread simulation

Component	Modelling assumption	Key parameters
Bamboo scaffold	Charring lignocellulosic combustible material	Heat of combustion[4, 5]: 18 MJ/kg ; Single-step Arrhenius pyrolysis [6, 7, 8]; A = 1.0 × 10^{10} s^{-1}; E = 1.45 × 10^5 J/mol; char yield: 25%
Net	Discretized as grid-like combustible obstructions to retain ventilation	Heat of combustion[9, 10, 11, 12]: 43 MJ/kg; E = 2 × 10^5 J/mol; A = 1.0E13 s^{-1}
Foam board	Combustible foam boards arranged at selected window locations	Heat of combustion[13]: 27 MJ/kg; Single-step Arrhenius pyrolysis[14]; A = 2.0 × 10^9 s^{-1}; E = 1.55 × 10^5 J/mol

[4] Engler, B., Schoenherr, S., Zhong, Z., and Becker, G. (2012). "Suitability of bamboo as an energy resource: Analysis of bamboo combustion values dependent on the culm's age." International Journal of Forest Engineering, 23, 114–121
[5] Posom, J. and Sirisomboon, P. (2017). "Evaluation of lower heating value and elemental composition of bamboo using near infrared spectroscopy." Energy, 121, 147–158
[6] McGrattan, K., Hostikka, S., Floyd, J., Baum, H., Rehm, R., Mell, W., and McDermott, R. (2010). Fire Dynamics Simulator Technical Reference Guide, Volume 1: Mathematical Model. NIST Special Publication 1018-5, National Institute of Standards and Technology, Gaithersburg, MD
[7] Lei, J., Wang, Y., Wang, Q., Deng, S., and Fu, Y. (2024). "Evaluation of kinetic and thermodynamic parameters of pyrolysis and combustion processes for bamboo using thermogravimetric analysis." Processes, 12(11), 2458. doi:10.3390/pr12112458
[8] Jiang, Z., Liu, Z., Fei, B., Cai, Z., Yu, Y., and Liu, X. (2012). "The pyrolysis characteristics of moso bamboo." Journal of Analytical and Applied Pyrolysis, 94, 48–52. doi:10.1016/j.jaap.2011.10.010
[9] Isam Janajreh, Idowu Adeyemi, Sherien Elagroudy. Gasification feasibility of polyethylene, polypropylene, polystyrene waste and their mixture: Experimental studies and modeling. Sustainable Energy Technologies and Assessments, 2020, 39: 100684. https://doi.org/10.1016/j.seta.2020.100684.
[10] A. Aboulkas, K. El harfi, A. El Bouadili. Thermal degradation behaviors of polyethylene and polypropylene. Part I: Pyrolysis kinetics and mechanisms. Energy Conversion and Management, 2010, 51(7): 1363-1369. https://doi.org/10.1016/ j.enconman.2009.12.017
[11] I. Dubdub. Kinetics Study of Polypropylene Pyrolysis by Non-Isothermal Thermogravimetric Analysis. Materials 2023, 16(2), 584
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[13] Biao Zhou, Hideki Yoshioka, Takafumi Noguchi, et al. Fire Performance of EPS ETICS Façade: Effect of Test Scale and Masonry Cover. Fire Technology, 2022. https://doi.org/10.1007/s10694-021-01195-x
[14] Y.C. Zhang, B. Wang, L. Xu, et al. Pyrolysis Modeling and Kinetic Study of Typical Insulation Materials for Building Exterior Envelopes. Buildings 2024, 14(12), 3956; https://doi.org/10.3390/buildings14123956

Geometry and description of the object

3.7.4. The model mainly consists of the following components: the main re-entrant space, building enclosure boundaries, the bamboo scaffolding system, netting, foam boards at window locations, and measurement and monitoring regions. To identify the influence of different combustible components on this process, 5 cases were established, as shown in Fig. 3-24.

3.7.5. **Case 1:** Re-entrant + non-combustible materials

In Case 1, although the scaffold, safety netting, and foam boards were geometrically retained, all materials were treated as non-combustible.

3.7.6. **Case 2:** Re-entrant + bamboo scaffold

Based on the re-entrant model, combustible bamboo scaffolding was added, while safety netting and foam boards were not included.

3.7.7. **Case 3:** Re-entrant + bamboo scaffold + safety net

Based on Case 2, combustible safety netting was further added to the bamboo scaffolding system.

3.7.8. **Case 4:** Re-entrant + bamboo scaffold + safety net + foamboard

Based on Case 3, combustible foam boards were further added at the window locations. This case is the closest to the actual fire scenario.

3.7.9. **Case 5:** Re-entrant + non-combustible scaffold + combustible safety net and foamboard

Modified from Case 4, this case treats the bamboo scaffolding as a non-combustible material (retaining only its physical geometry).

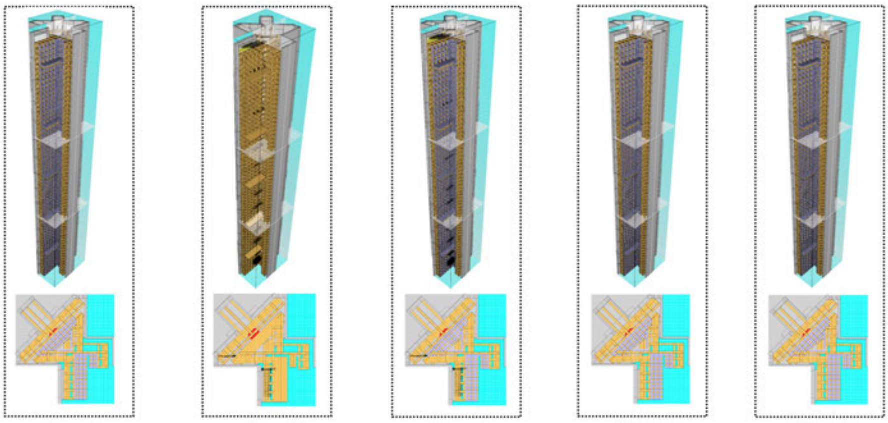


Figure 3-24. Chimney effect model cases

Fire spread in the re-entrant

3.7.10. Fig. 3-25 compares the fire spread process in the re-entrant for Cases 1-5 at selected times, while Fig. 3-26 further compares the fire development of all cases at the same time of 40 seconds.

3.7.11. In Case 1, where only non-combustible materials were considered, the fire plume was mainly transported upward by the re-entrant-induced chimney effect, but no sustained flame spread occurred due to the absence of additional combustible façade components.

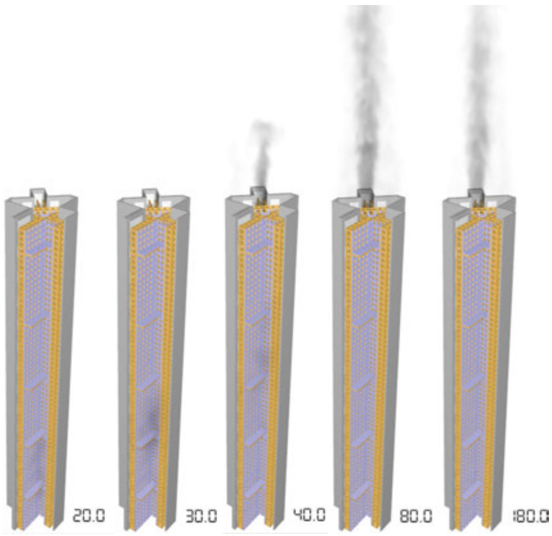
3.7.12. In Case 2, after the bamboo scaffold was introduced, flames rapidly propagated upward along the scaffold members, indicating that the bamboo scaffold provided a continuous vertical fuel path. As noted above, what was simulated was a large fire with a fire area of 2.07 m^2, HRR per unit area of 2000 kW/m^2, and maximum total heat release rate of 4140 kW. We note however that the position may be different where the fire is a smaller fire. Key Observation (10) of the Yuen Final Report notes that regardless of what types of safety nets were used, most of the bamboo remained unaffected throughout the IFITF's large scale fire tests (using small fire size). This is consistent with our view that small heating energy cannot ignite bamboo, whereas fast pyrolysis and burning can occur when subjected to relatively high heating conditions (Section 3.6.12 above).

3.7.13. Compared with Case 2, Case 3 showed more intensive and continuous flame spread after the addition of combustible safety netting, suggesting that the net further promoted flame attachment and vertical fire propagation within the re-entrant.

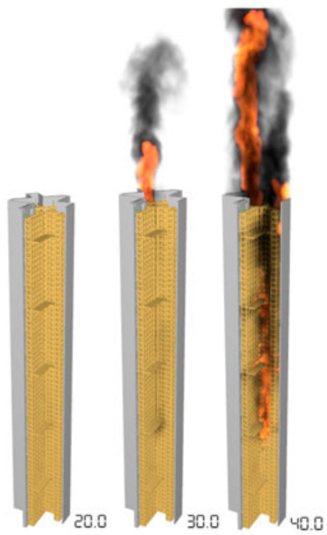
3.7.14. Case 4 exhibited severe fire development with the combined presence of bamboo scaffold, combustible safety netting, and foam boards. Although the visible flame extent in Case 4 at 40 seconds was not necessarily larger than that in Case 3, the foam boards located near the window openings acted as additional local fuel sources and increased the thermal exposure to the window region once involved in burning. Therefore, the influence of foam boards should not be evaluated only by the visible flame height, but also by their contribution to localized heating and potential window failure.

3.7.15. By contrast, in Case 5, where the scaffold geometry was retained but treated as non-combustible, the fire did not develop into large-scale vertical flame spread even with the presence of safety netting and foam boards. Consistent with the experimental tests, the combustibility of non-FR safety nets and foam boards primarily affect the ignition and propagation of the fire in smaller fires, such as during the earlier stages of a fire or in relation to secondary ignition, i.e. they determine whether a small fire escalates into one large enough to involve the bamboo scaffolding and trigger full re-entrant spread.

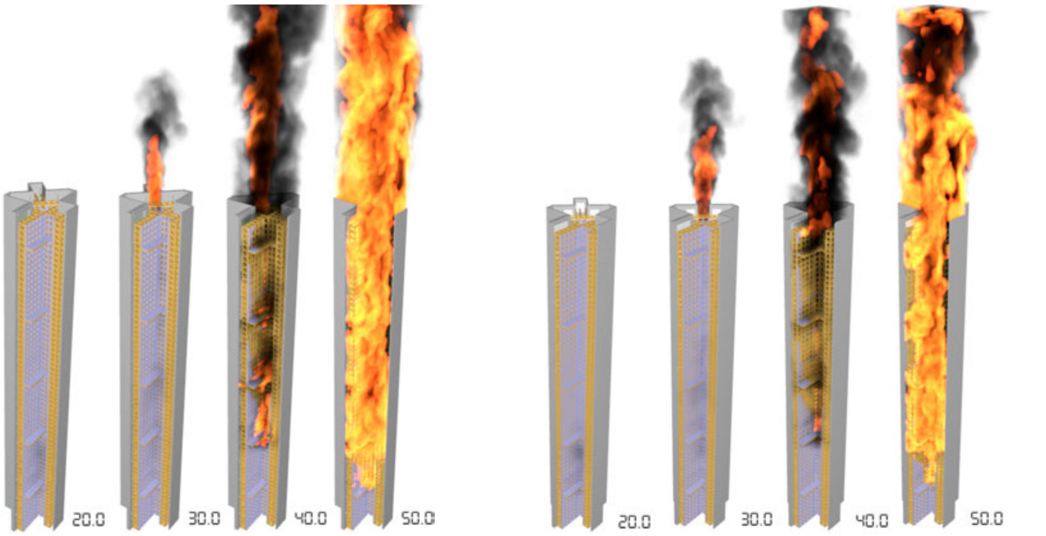
3.7.16. These comparisons indicate that the chimney effect can enhance upward smoke and heat transport, but rapid vertical fire spread is mainly governed by the availability of continuous combustible materials. Among these components, the netting enhances flame continuity, the foam boards further intensify local façade and window exposure, and where the fire is sufficiently large, bamboo scaffold will also provide a vertical fuel path.



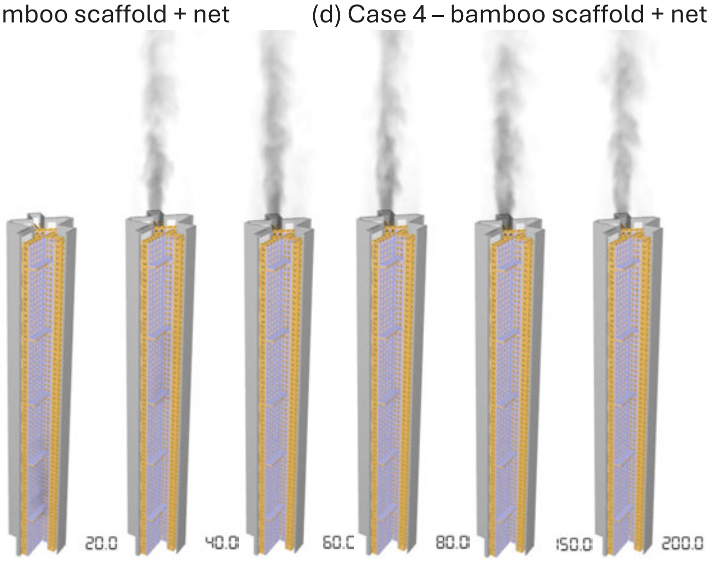
(a) Case 1 – non-combustible materials



(b) Case 2 – bamboo scaffold

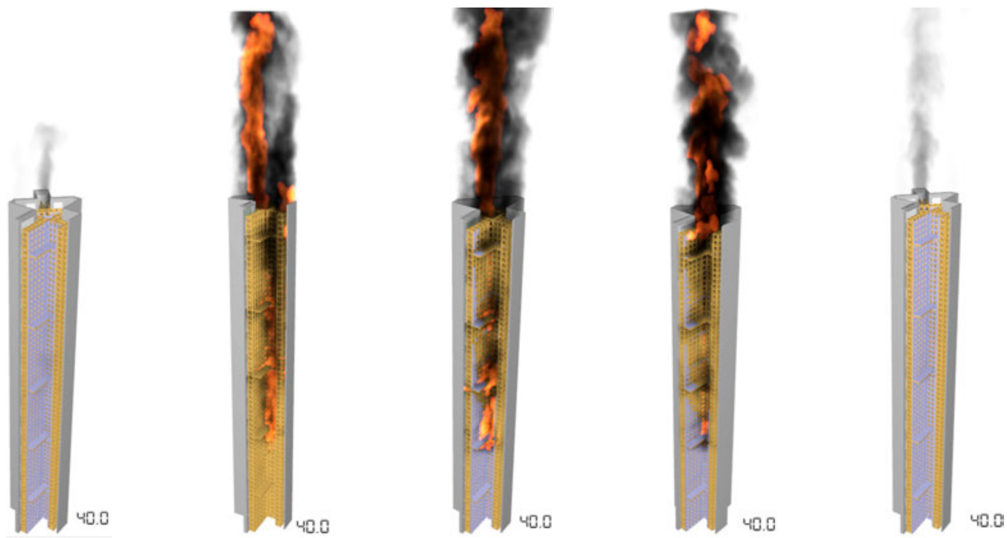


(c) Case 3 –bamboo scaffold + net (d) Case 4 – bamboo scaffold + net + foam board



(e) Case 5 –non-combustible scaffold + combustible net + foam board

Figure 3-25. Fire spread



(a) Case 1 (b) Case 2 (c) Case 3 (d) Case 4 (e) Case 5

Figure 3-26. Comparison of phenomena at the same time

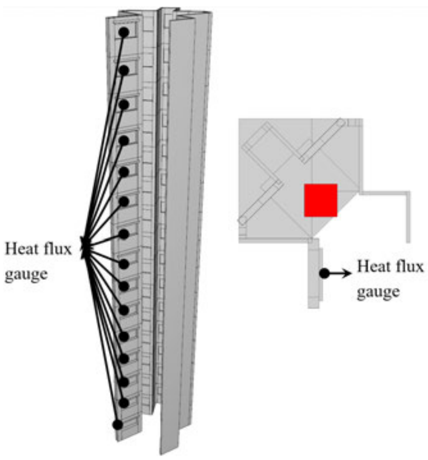
Heat flux around the window

3.7.17. Fig. 3-27 compares the heat flux received by windows under different façade fire configurations. In Case 2, where only the bamboo scaffold is considered, the window is directly exposed to the external flame and hot plume. As a result, the heat flux increases earlier and reaches a high level within a short period.

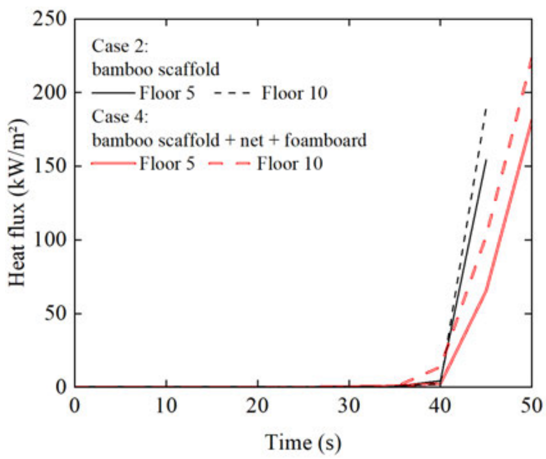
3.7.18. In Case 4, the addition of safety nets and foam boards provides temporary shielding to the window, leading to a slight delay in the heat flux rise. However, once the foam boards ignite, melt, or are consumed, this protective effect rapidly disappears, and the accumulated burning of the scaffold, safety nets and foam boards produces an even more severe thermal exposure.

3.7.19. Consequently, the heat flux in Case 4 rises more sharply and reaches a higher level than that in Case 2.

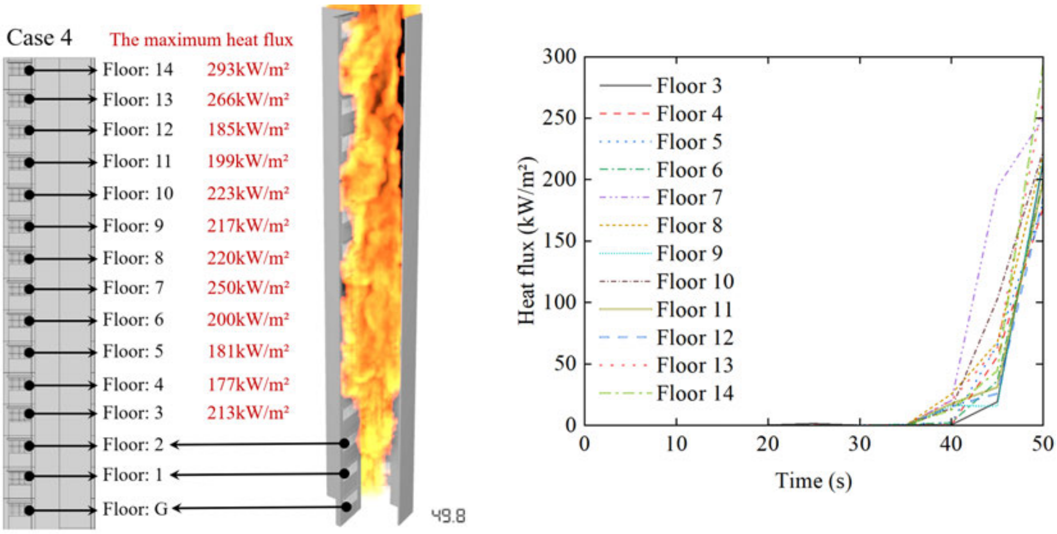
3.7.20. Although glass breakage depends on glazing type, size, edge restraint, and exposure duration, previous studies have shown that ordinary float glass may crack at approximately 4-6 kW/m^2, while significant fallout can occur at around 9-20 kW/m^2; even tempered glass generally has a critical fallout heat flux of only about 40-60 kW/m^2. Therefore, the heat flux levels predicted in Cases 2, 3, and 4, which exceed 150 kW/m^2, are far above the reported critical ranges for window glass failure. This indicates a high probability of glass cracking and fallout, allowing flames and hot gases to penetrate into the interior and promoting fire spread from the exterior façade to indoor spaces.



(a) Arrangement of heat flux gauge



(b) Comparison between case 2 and case 4



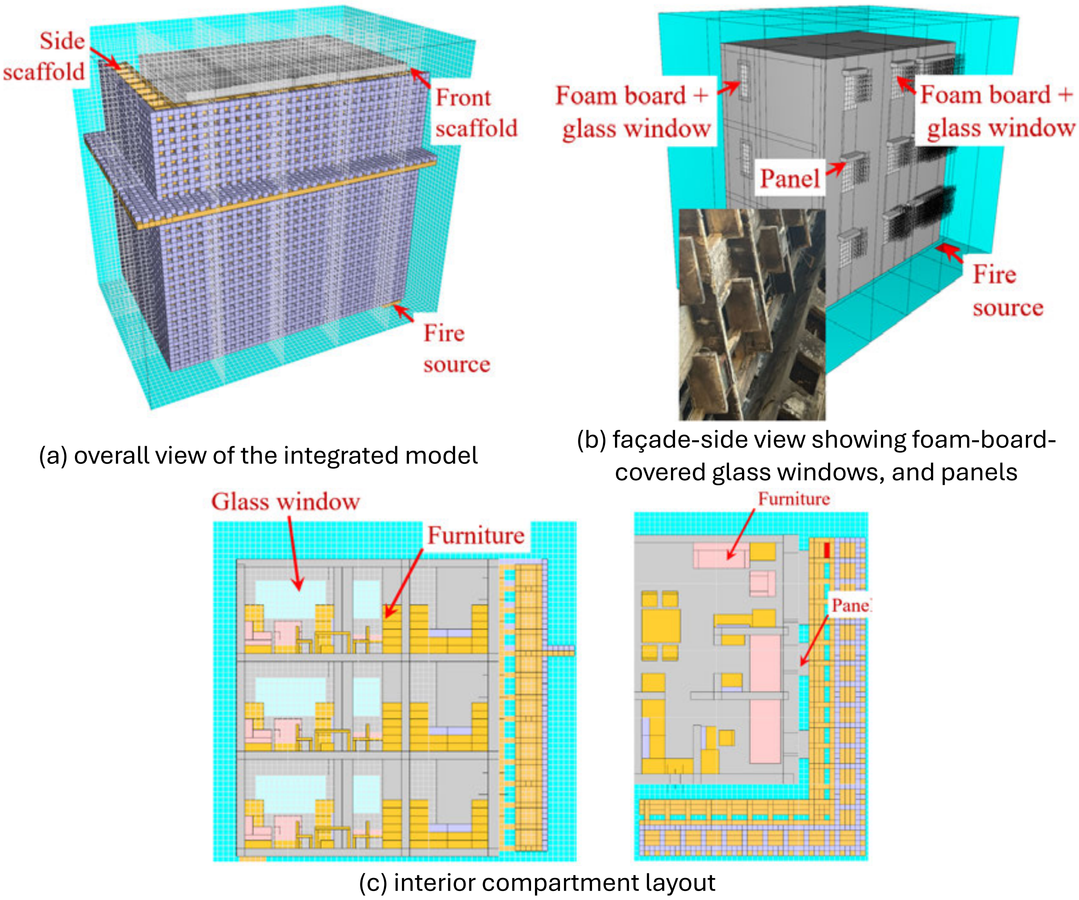
(c) Heat flux in Case 4

Figure 3-27. Heat flux gauge

<u>3.7(b) Simulation of subsequent fire spread at facade</u>

3.7.21. This simulation was developed to investigate the subsequent fire spread mechanism after the ignition of the external scaffold system. Different from the previous model focusing on the chimney effect between the façade and the scaffold, this model represents a local building segment with both exterior scaffold systems and indoor compartments, as shown in Fig. 3-28. The model includes the building enclosure, front and side bamboo scaffolds, protective netting, foam boards installed near selected window openings, projecting façade panels, glass windows, and simplified indoor compartments. Representative furniture was arranged inside the rooms to provide indoor combustible fuel after possible window failure. Therefore, the model was not intended to reproduce the entire high-rise building in full detail, but to capture the key physical interfaces involved in subsequent fire spread, including the exterior scaffold, façade openings, glass windows, indoor combustibles, and adjacent scaffold regions.

3.7.22. As shown in Fig. 3-28(a), the integrated model contains the main building segment and the external bamboo scaffolds arranged along both the front and side façades. Fig. 3-28(b) shows the façade-side details, where foam-board-covered glass windows and projecting panels were included to reproduce the local façade configuration observed in the fire scene. Fig. 3-28(c) presents the internal compartment layout, in which simplified rooms and furniture were modelled to represent the potential indoor fuel load. Glass windows were treated as key interfaces between the exterior scaffold fire and the indoor compartments. For modelling simplification, glass fallout was represented using a temperature-based failure criterion. When the glass temperature reached 450 °C, the corresponding window obstruction was removed to represent glass breakage and fallout. This simplified treatment enables the model to examine how external façade fire exposure may lead to indoor fire involvement after window failure.



(a) overall view of the integrated model

(b) façade-side view showing foam-board-covered glass windows, and panels

(c) interior compartment layout

Figure 3-28. Numerical model for simulating subsequent fire spread

3.7.23. Fig. 3-29 presents the simulated subsequent fire spread after the ignition of the external scaffold system.

(a) Before glass fallout, the fire mainly develops along the exterior bamboo scaffold, as shown in Fig. 3-29(a).

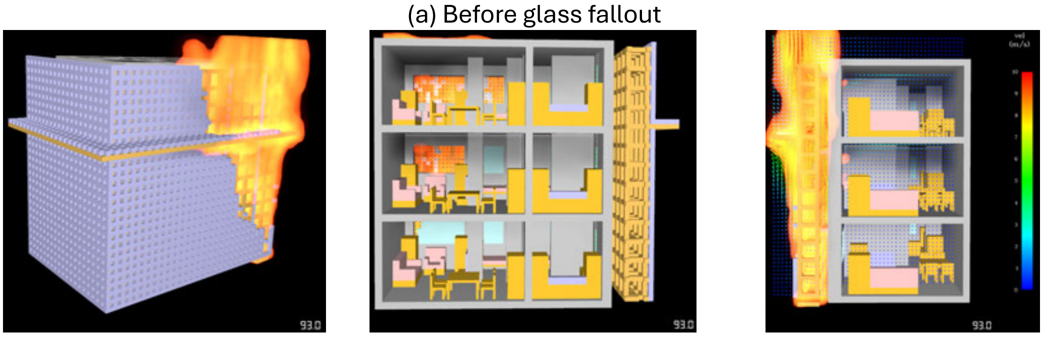
(b) After the window glass falls out, flames and hot gases penetrate into the adjacent rooms, causing ignition of indoor furniture and rapid fire development, as shown in Fig. 3-29(b) and (c). The failed windows become important exchange paths for flame, hot gases, and entrained air between the external scaffold region and the indoor compartments.

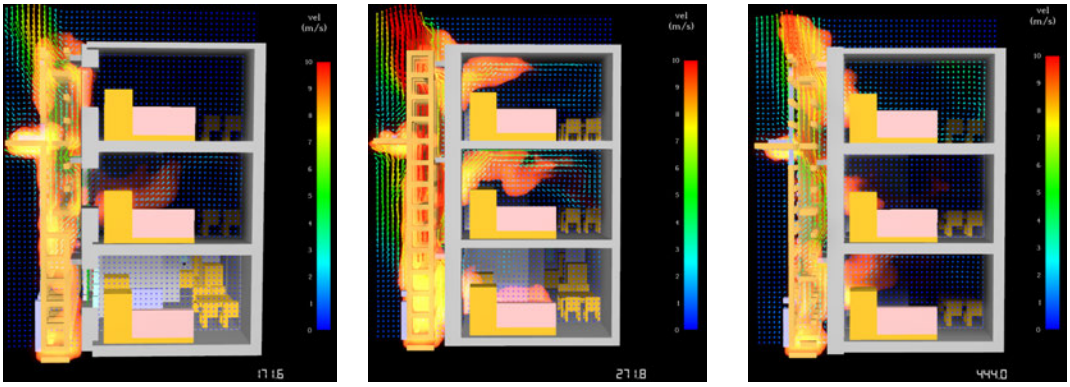
(c) As the indoor fire develops further, flashover occurs in the compartment. The resulting high-temperature gases and flames then break through the windows on the opposite side, where the glass has not been directly exposed to the initial external scaffold fire. As shown in Fig. 3-29(d), the flame ejection from these newly failed windows impinges on the nearby side bamboo scaffold and causes its ignition.

(d) At the later stage, the compartment fire continues to eject flames outward, sustaining the combustion of the bamboo scaffold and promoting further vertical and lateral fire spread, as shown in Fig. 3-29(e).

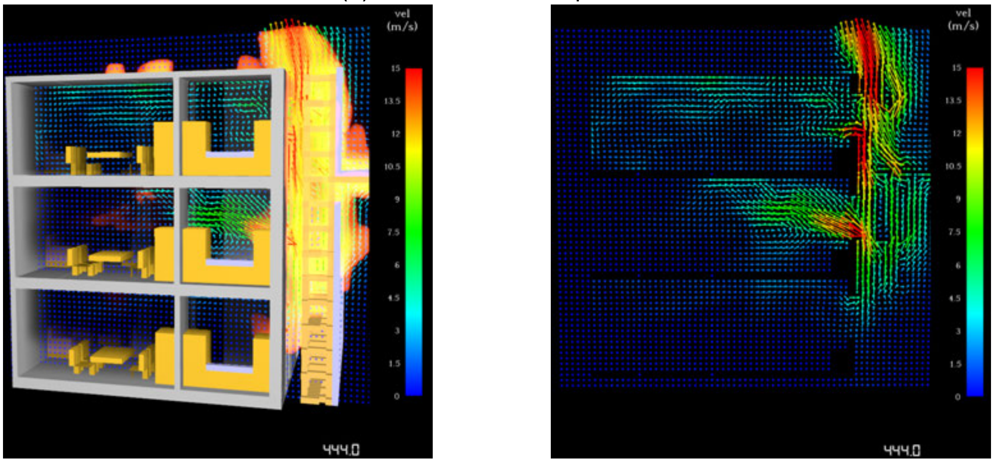
(e) These results indicate that the subsequent fire spread is strongly governed by the coupled interaction among external scaffold combustion, glass fallout, indoor fire development, flashover-induced flame ejection, and secondary ignition of scaffold materials. These results also corroborate the visual evidence of the development of the Wang Fuk Court fire, as analysed in Section 3.4 and 3.5 above.


(a) Before glass fallout

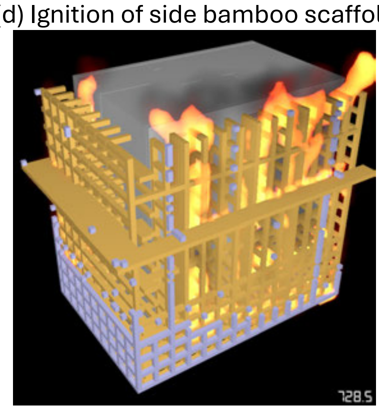

(b) Glass fallout



(c) Indoor fire development



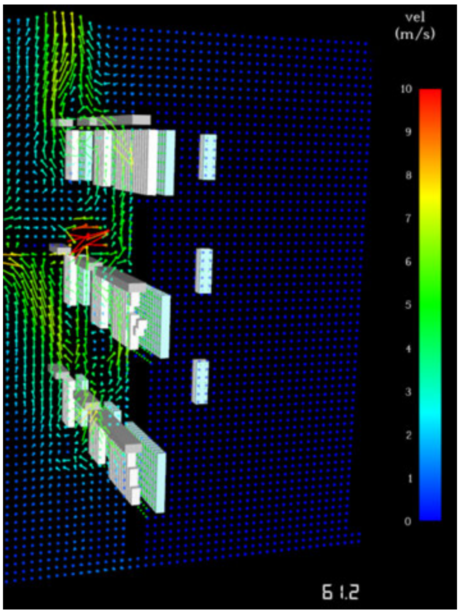
(d) Ignition of side bamboo scaffold



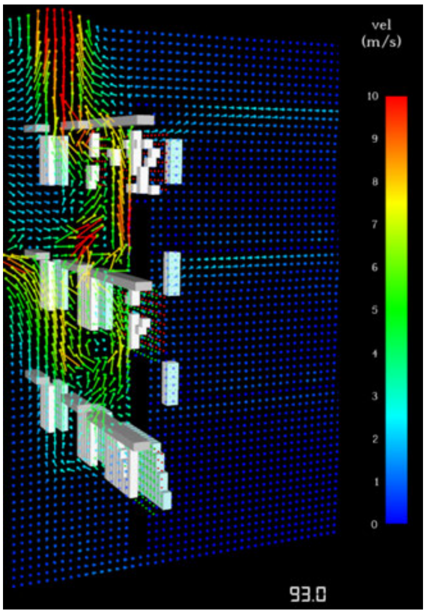
(e) Continuous burning of bamboo scaffold driven by compartment fire.

Figure 3-29. Simulation results

3.7.24. Fig. 3-30 shows the velocity field near the foam-board-covered glass windows. The concrete hoods above the windows significantly disturb the upward movement of the external hot plume. Instead of allowing the hot gases to rise smoothly along the façade, the hoods partially block the vertical flow and redirect the plume toward the window region. As a result, high-temperature gases repeatedly impinge on the foam boards and glass windows beneath the hoods. This local flow obstruction increases the residence time of hot gases near the window surface and enhances convective heating, while the surrounding flames also intensify radiative exposure. With the development of the external scaffold fire, this impingement effect becomes more pronounced, especially at the upper edges of the window openings. Therefore, the concrete hoods can unintentionally promote the thermal degradation of foam boards and accelerate glass cracking or fallout by concentrating hot gases and flame exposure around the window area. This indicates that the façade hoods do not simply act as passive barriers; instead, they can modify the local fire-induced flow field and increase the likelihood of window failure.



(a) early-stage plume deflection at 61.2 s



(b) intensified hot-gas impingement near window openings at 93.0 s

Figure 3-30. Effect of façade hoods on the local velocity field near foam-board-covered glass windows

3.8. Contributions of scaffolding materials in Wang Fuk Court fire spread

3.8(a) Contribution of materials to initiation of fire at Block F leading to widespread fire

3.8.1. The current findings suggest that the subsequent fire spreading among various buildings of Wang Fuk Court was initiated from the fast-spreading vertical fire at the re-entrant region (F1). To initiate such intense fire in the re-entrant region, a large enough localised fire (such as the 1.5-2.5 MW fire assumed in the large scale fire tests by the IFITF) is needed to trigger the combustion of bamboo and wood panels, which contain the bulk of the total energy to be released among all the external scaffolding materials.

3.8.2. From our analysis of the evidence, this localised fire was formed at the flat roof of re-entrant of Wang Cheong House (F1). By comparing the videos and photos from 14:50 to 14:59 on 26 Nov 2025 and the experimental observations reported in Section 3.6 above, the following findings are suggested:

(a) The scattered flames on safety nets at 14:51 suggests the ignition of non-FR safety nets at re-entrant F1 of Wang Cheong House (Block F).

(b) The accumulated dripping and burning of these non-FR safety net over the flat roof could cause a large localised fire as there exists many cardboards and wood panels (reproduced by the test).

(c) Bamboo sticks joined the combustion when the localised fire is large enough (flame height reaching 1 m), which further enhanced the localised fire and eventually leading to the re-entrant fire due to chimney effect.

Figure 3-31. Visual evidence of fire initiation VS fire test observations

3.8.3. The tests in Section 3.6 above indicate that bamboo members are only ignited after the fire droplets of non-FR safety nets built up a sufficiently large fire through igniting cardboard and wood panels on the ground, which is consistent with the video and photo evidence. This demonstrates that the dripping effect of non-FR safety nets played a role in unlocking the energy contained in bamboo sticks which would not otherwise have been ignited. Similarly, the Section 2.13.3 of the Yuen Final Report observes that "the rapid development of the fire (which could even be presumably small) at the origin of the actual fire is likely due to the use of non-FR safety nets and non-FR canvases". We agree that using FR safety nets could have reduced the likelihood of a sustained secondary ignition developing and may have prevented the first re-entrant fire at F1 of Wang Cheong House (Block F). However, large scale tests need to be conducted for this conclusion to be stated with more confidence.

3.8(b) Contribution to fast-spreading vertical fire in re-entrant region

3.8.4. Once the intense and fast-spreading fire at re-entrant region was formulated, all the combustible materials (including bamboo, safety net, polystyrene foam boards, wood panels) in the re-entrant region would have contributed to the extremely rapid fire development.

3.8.5. The localised fire at flat roof (bottom of re-entrant region) would heat these combustible items and a huge amount of pyrolysis gas would have been generated from bamboo and wood, while the burning of pyrolysis gas would in turn further intensify the fire. Moreover, due to the semi-confined space, significant energy conservation occurred and the burning efficiency is extremely high. This is a possible reason for the fact that the vertical re-entrant fire of a massive size only maintained for 2-4 minutes.

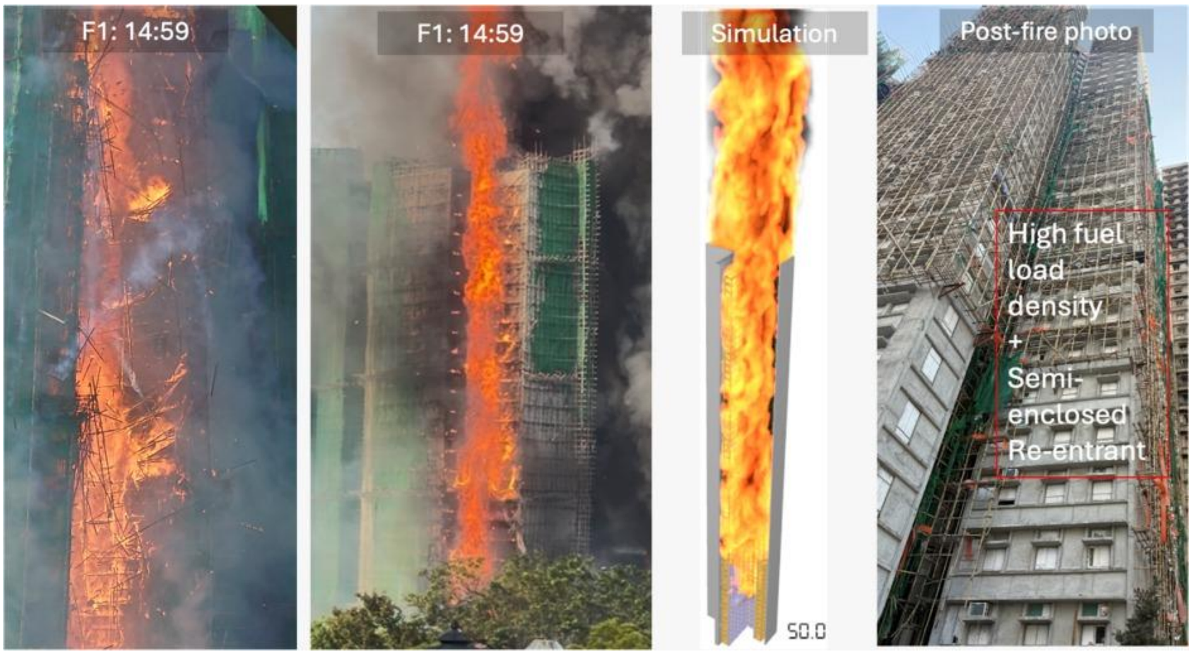


Figure 3-32. Typical re-entrant fire

3.8(c) Contribution to ignition of adjacent building façade

3.8.6. The combustible materials at building façade would have facilitated the spreading of fires from neighbouring buildings if massive re-entrant fires occurred.

3.8.7. If the safety net of a neighbouring building is not fire retardant, it is possible to catch small fires at the building façade, which may lead to a re-entrant fire depending on the location where the neighbouring building's safety nets caught fire (e.g. Wang Kin House (Block D)). The ignition of façade materials would generally have to form a localised fire at the flat roof, so as to be able to initiate a re-entrant fire.

3.8.8. It should be also noted that the progression of re-entrant fires at Wang Cheong House (Block F) and Wang Tai House (Block E) was extremely fast, which may be more likely due to the ignition of stacked renovation materials at ground floor.

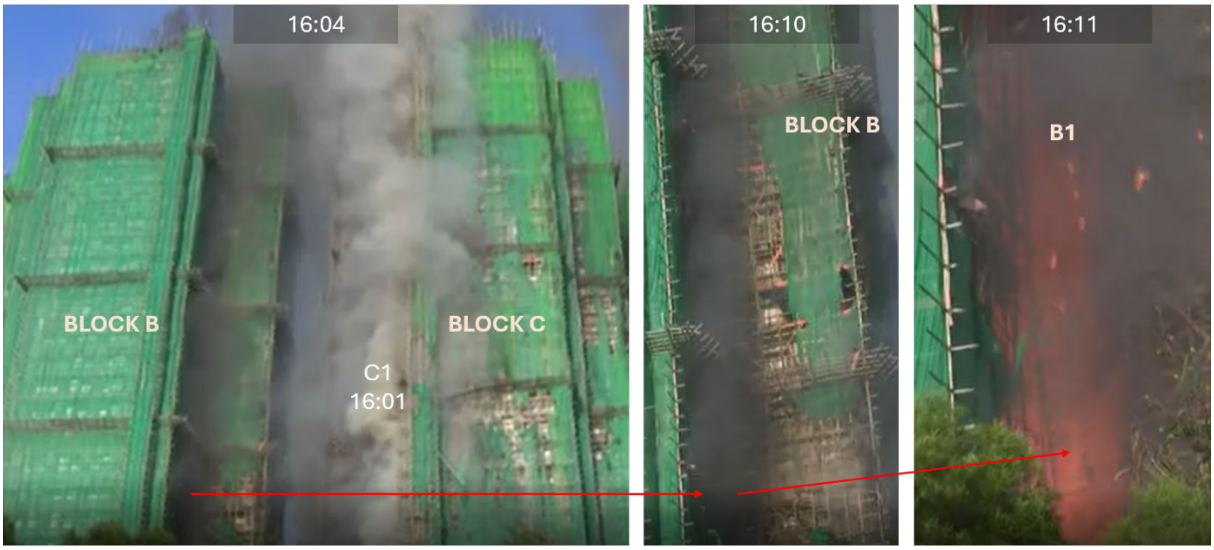


Figure 3-33. Visual evidence of re-entrant fire initiation of B1

3.9. Spread of fire to living rooms of room units

3.9(a) How living room window breakage correlated with unit internal damage

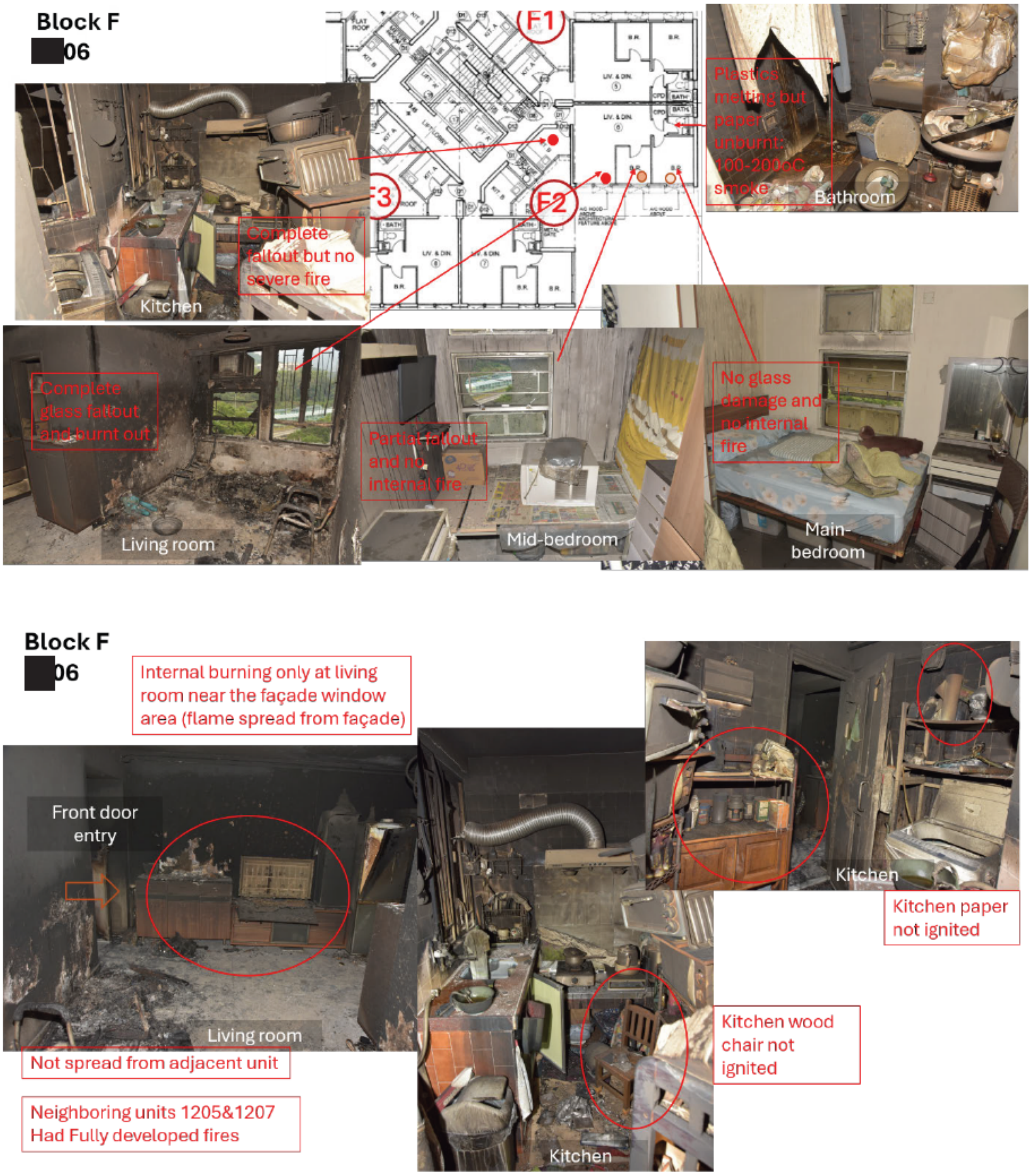


Figure 3-34. Fire spreading characteristics of Block F Room [redacted]06

3.9.1. Table 3.3 summarizes the glass breakage indices at the living rooms of Unit 5 flats of Wang Cheong House (Block F) and Unit 2 flats of Wang Tao House (Block B). The indices of qualitative fire intensities are also given, where 0 represents no fire, L represents small localised fire, F represents fully developed fires.

Table 3.3. Summary of living room glass breakage and fire statuses in Wang Cheong House (Block F) and Wang Tao House (Block B)

Block F	Living Room Glass Breakage	Fire	Block B	Living Room Glass Breakage	Fire
805	Y	0	802	Y	0
905	Y	F	902	Y	F
1005	Y	F	1002	Y	0
1105	Y	F	1102	Y	F
1205	Y	F	1202	Y	F
1305	Y	F	1302	Y	F
1405	Y	L	1402	Y	L
1505	Y	0	1502	Y	L
1605	Y	F	1602	Y	F
1705	Y	F	1702	Y	0
1805	Y	F	1802	Y	0
1905	Y	L	1902	Y	F
2005	Y	F	2002	Y	0
2105	Y	0	2102	Y	L
2205	Y	F	2202	Y	F
2305	Y	0	2302	Y	0
2405	Y(p)	0	2402	Y	0
2505	Y	F	2502	Y	F
2605	Y(p)	0	2602	Y	F
2705	Y	F	2702	Y	0
2805	Y	F	2802	Y	F
2905	Y	F	2902	Y	L
3005	Y	L	3002	Y	F
3105	Y	F	3102	Y	0

3.9(b) Preliminary explanation on living room windows failure due to re-entrant fire

3.9.2. As shown in the timeline analysis of vertical fire spread (Section 3.2 above), the development of vertical fire in a re-entrant region was extremely fast (2-4 minutes from visible flames to decay), which was due to the strong chimney effect and high fuel load in the semi-enclosed re-entrant regions.

3.9.3. The fast developing vertical fire created high-intensity heating impact over the façade walls in the vicinity of each re-entrant. Meanwhile, the extended flames of vertical fire impinged on the façade walls, including the side walls. Due to the high-intensity heating, the glass windows of kitchens would fail first, causing severe damage at kitchens facing the re-entrant fire. However, this might be not a devastating factor leading to the widespread room unit fires, as the kitchens were isolated from living rooms by fire-rated doors in most units (it is noted that some units had their kitchen doors changed to non-fire rated doors).

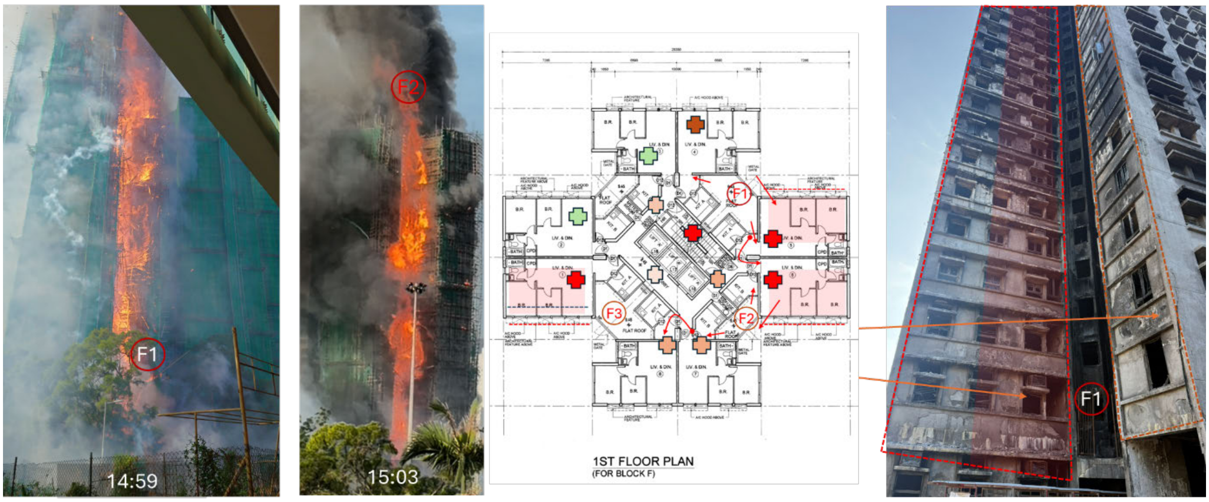


Figure 3-35. Room units with living room windows facing to extended re-entrant fire

3.9(c) Effect of foam boards on living room glass breakage

3.9.4. The glass breakage and flame penetration of living rooms are highly linked to the re-entrant fire and particularly the extended flames over the living room windows. The experimental tests (Section 3.6(a) above) suggest that polystyrene foam boards pasted on glass panels would quickly melt and fall off, and the melted boards would contribute to the burning process as observed in the laboratory tests. That being said, in our analysis below, we note the impact of polystyrene foam covers in directly causing or accelerating the thermal shock and subsequent breakage of window glass to enable lateral fire and smoke spread into the building's interior (Section 4.1(c) below).

3.9.5. While we have not conducted tests to reproduce the extreme heating conditions of re-entrant fires, we consider that the high heat fluxes due to forced hot gas convection and high radiation of flames are the main reasons causing glass breakage.

3.9.6. It is noted from the evidence of witnesses that the foam boards of Unit 2 and Unit 3 windows at Wang Cheong House (Block F) were removed before the fire (transcript of day 4 of the Evidential Hearing, p.47 lines 1-3), which corresponds to the fact that the fire damage in those units was mostly minor. While we note that correlation, in this particular case we consider the key reason for the minor fire damage in Unit 2 and Unit 3 windows at Wang Cheong House here should be the absence of re-entrant fire between Unit 2 and Unit 3. This also occurred at Wang Tai House (Block E) for Unit 6 and Unit 7.

3.10. Further analysis on vertical fire spread and re-entrant geometry

3.10.1. This section further analyses how the re-entrant geometry amplified vertical fire spread through the chimney effect, supported primarily by our review of the CFD simulations detailed in Appendix A.

3.10(a) Re-entrant space and fuel load

3.10.2. As discussed in Section 2 above, oxygen, heat, and fuel are the three elements that determine how a fire develops and referred to as the "fire triangle." A fire occurs when all of these elements are present and mixed in the right proportions. Fire can be prevented or extinguished by removing any one of them. Conversely, a fire can grow rapidly if any of the elements in the fire triangle are increased.

3.10.3. In Wang Fuk Court, the geometric configuration of the re-entrant corners, together with additional combustible materials within it, significantly enhances all three elements of the fire triangle and accelerates vertical fire spread in this semi-open space. Fig. 3-36 shows the trapezoid-shaped space located between Flat 4 and Flat 5 in a typical block of the estate. A slot between the kitchens of these two flats connects this trapezoid-shaped space to the external wall of the staircase and the staircase wired-glass window (**WGW**), forming the plan layout of the re-entrant. This space extends continuously from the first-floor roof up to the building roof level.

Figure 3-36. Typical re-entrant of building blocks of Wang Fuk Court

3.10.4. When a fire starts in the re-entrant, the surrounding walls reflect thermal radiation back onto the fuel, establishing a thermal feedback loop, greatly accelerating its pyrolysis (hence more heat is released).

3.10.5. Fig. 3-37 shows a photo of the re-entrant during renovation. A large amount of combustible material is present in this space, including bamboo scaffolding and safety nets. Because of the peculiar geometry of this space, the fuel density per unit volume is significantly higher than it would be on a planar façade (so more fuel is available).

3.10.6. The fire plume inside the re-entrant entrains as much fresh air as required from the open side of the trapezoid for more pyrolysis of the fuel vapours, accelerating the combustion process. The combination of all these three enhanced elements leads to rapid fire development and vertical spread within the re-entrant.

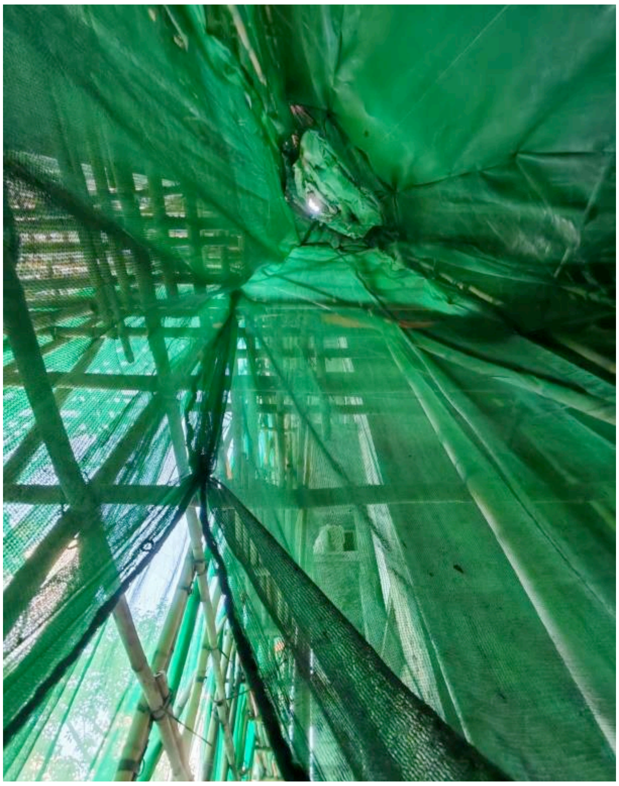


Figure 3-37. Fuel load in re-entrant

3.10(b) Chimney effect and vertical fire spread

3.10.7. The trapezoidal re-entrant, with its narrow open side spanning all 31 floors, created a chimney effect as hot gases rose within the space. However, compared to a standard chimney, the re-entrant space in the Wang Fuk Court buildings contained a large volume of combustible materials, including safety nets, bamboo scaffolding, and polystyrene foam window covers. When a fire started in this space, the chimney effect propelled the flames upward, igniting these combustibles along the re-entrant. This process created a positive feedback loop, accelerating both vertical fire spread and the upward flow of hot gases. As a result, the fire spread and gas velocity escalated exponentially, likely surpassing the thermal draft of a clean chimney. Fig. 3-38 depicts the extensive flame propagation across the full height of the re-entrants in three of the Wang Fuk Court blocks.

Figure 3-38. Chimney effect observed at (a) Wang Cheong House west re-entrant and (b) Wang Yan House south re-entrant, and (c) combustible scaffolding burning along the re-entrant

4. RESULTING CASUALTIES AND SPREAD OF SMOKE IN BUILDINGS

4.1. Lateral spread of fire and smoke into buildings

4.1.1. To assess the consequences of the spread of fire and smoke on the significant fatalities and injuries, it is necessary to conduct further analysis as to how fire and smoke spread from the external façade into the building. The following analysis supplements the review of the video and photographic evidence in Section 3 above.

4.1.2. This Section reviews the typical floor plan layout of the Wang Fuk Court blocks from the IFITF Final Report and provides detailed interior configurations of the flats based on as-built drawings. We have reviewed Sections 6.2.2 and 8.3 of the IFITF Final Report, which touch upon lateral fire spread from the exterior into the flats and subsequent fire development. The information supplements the IFITF Final Report and is required to understand how fire and smoke could spread into and within a flat and migrate into the common corridor. Consequently, this data is essential for the analysis of the fatalities in Flat 1202 and Flat 2602 of Wang Cheong House, which are addressed later in this report.

4.1(a) Fire separation of flats at Wang Fuk Court

4.1.3. In general, building regulations for fire safety require fire compartmentation. If a fire occurs in one part of a building, it should be contained within the compartment of fire origin and not spread to other parts of the building. For high-rise residential buildings in Hong Kong, the applicable Codes of Practice require the walls and doors of a flat to achieve a specified Fire Resistance Rating (**FRR**) to isolate the flat from the common areas and from other flats on the same floor in the event of fire.

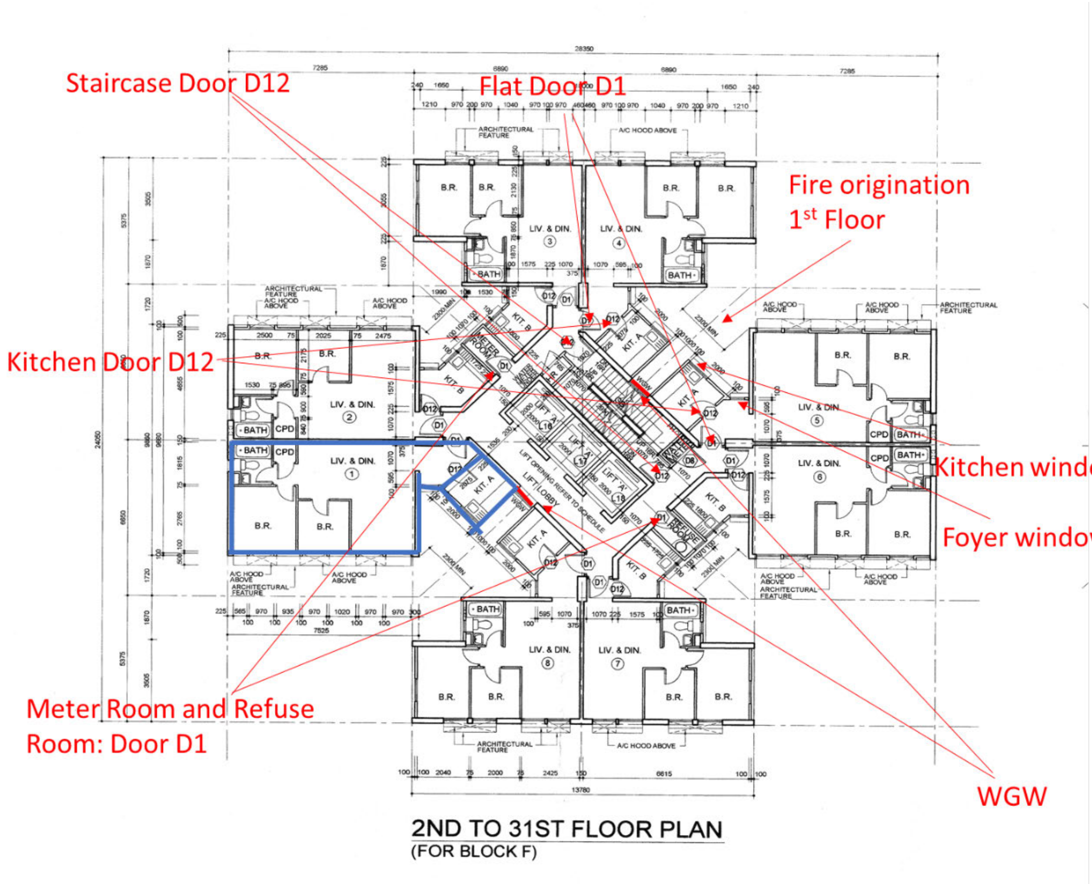


Figure 4.1. Wang Cheong House Floor Plan, as-built drawing

4.1.4. Fig. 4.1 shows as-built drawing of Wang Cheong House (Block F) with marked information of fire separation. The main entrance door to each flat is required to be a fire-rated assembly. On the submitted building plan (as-built drawing), it is identified as "D1" and specified as a "Single Leaf 50 mm Thick Solid Core Flush Door (Self Closing)." This description aligns with a standard fire-rated door; a 50 mm solid core timber door of this type typically provides a Fire Resistance Rating (i.e. FRR) > 1.0 hour. The applicable Code of Practice before 1980s requires an FRR of the flat entrance door not less than ½ hours.

4.1.5. The staircase door is marked as "D12" and described as a "Single Leaf Solid Core Flush Door with View Panel (Self Closing)". The inclusion of "Self-Closing" indicates this door is also intended to be fire-rated. The door's thickness is not specified, and its specific fire resistance period is therefore unknown. The Code of Practice on Provision of Means of Escape in Case of Fire and Allied Requirements (1976) (**CoP 1976**) requires a self-closing door having an FRR not less than ½ hour.

4.1.6. CoP 1976 requires a lobby with FRR door to access the staircase from internal corridor. The lobby does not exist in the design as shown in Fig. 4.1.

4.1.7. Further review of the as-built drawings indicates that the scissor staircase includes a wired glass window (i.e. WGW) intended for natural lighting. It is important to note that wired glass is generally not considered a fire-resistive element.

4.1.8. The kitchen door is also identified as "D12" and is specified to provide a ½-hour fire resistance rating (i.e. FRR). CoP 1976 did not specify an FRR requirement for kitchen doors. However, Clause 11 (1) states "Every flat or tenement floor which is provided with a single exit door shall be so arranged that the entrance to the kitchen is not adjacent to the exit route, within the flat or tenement, to such exit door. Provided that the kitchen door may be adjacent to the exit route if: (a) such door is self-closing, and (b) the capacity of the flat or tenement floor does not exceed ten persons". Therefore, the kitchen door specification shown in Fig. 4.1 exceeds the requirements of the CoP 1976 or at least complies the code requirements.

4.1.9. Based on this information, a fire in the kitchen should not affect the living room for at least 30 minutes, and a fire in the flat should not affect the common corridor for at least 30 minutes.

4.1.10. In addition, a wired glass window (i.e. WGW) is installed on the external wall of the lift lobby facing the re-entrant space.

4.1.11. In typical scenarios, the WGW would not pose a problem if a fire occurs within a flat. However, it represents a potential point of failure if a fire develops on the façade adjacent to the staircase and the lift lobby, as breakage of the window may compromise the integrity of the protected escape route.

4.1.12. The fire at Wang Fuk Court was a rapidly developing fire within the re-entrant. Under this condition, these WGWs would have been likely to fail at some point. Further exacerbating this situation is the fact that some of the WGWs had already been removed and left open with access openings for workers to access the external scaffolding. This would allow smoke to quickly fill the scissor staircases and common corridors, compromising the only means of escape and preventing occupants on the upper floors from evacuating.

<u>*4.1(b) Plausible routes of lateral fire/smoke spread into buildings*</u>

4.1.13. Based on a review of the as-built drawings (Fig. 4.1), four potential paths for lateral fire spread from the façade to the flats have been identified in the Wang Fuk Court fire:

(a) Path 1 (Kitchen): Fire in the re-entrant breaks the kitchen window, igniting combustibles within the kitchen. The fire then breaches the kitchen door and spreads into the living room and bedrooms. As noted earlier, the original kitchen door had a 30 minute FRR, so a fire should have been contained within the kitchen for at least 30 minutes before affecting the living room. However, in many flats the original kitchen door was removed and/or replaced during refurbishment (Fig. 4.2). The FRR of the replacement doors is unknown but is very likely to have been non–fire-rated, particularly where self-closing devices were removed or the doors were left open.

Figure 4.2. Self-closing kitchen doors replaced by non-fire rated doors

(b) Path 2 (Living/Bedrooms): Fire on the main façade breaks the living room and/or bedroom windows, allowing fire to spread directly into and throughout the flat. The IFITF Final Report identified that these windows were covered with polystyrene foam. When the bamboo scaffolding and safety net ignited, flame contact and radiative heat could have ignited the foam and caused window failure. As mentioned earlier, the main flat entrance doors had an FRR > 1.0 hour; in principle, fire should have been contained within the flat for over an hour before door failure. However, due to the large fuel load within the flats, fires burned for a prolonged period, and many entrance doors were burned through, as documented in the IFITF Final Report. When a fire develops within a flat, the living room and bedroom windows are highly likely to fail under flashover conditions.

This facilitates the "leap-frog" effect, enabling the fire to spread vertically to the window of the flat immediately above (Section 2.3 above).

(c) Path 3 (Staircase): Fire in the re-entrant breaks the wired glass window (WGW) on the staircase wall. Hot smoke and flames then pass through the open staircase door into the common corridor.

(d) Path 4 (Lift Hall): Fire in the re-entrant breaks the WGW on the lift-hall wall, allowing hot smoke and flames to enter the common corridor.

4.1.14. Based on the analysis in Section 3.4 above, the available photographic and video evidence indicates that Paths 1 and 2 are the most likely to have occurred. Fire spread into flats via Paths 3 and 4 is considered less likely, due to the fire-rated performance of the flat entrance doors and staircase doors, and the separation distance between the WGW and the flat entrance doors.

4.1.15. However, lateral spread of smoke via Path 3 and Path 4 is critical, as briefly addressed in Section 3.9(a) above by reference to the video evidence. Toxic hot smoke spreads into the staircases and common corridor from the open / broken WGW windows on staircases and lift lobby at an early stage of the fire. The egress routes become untenable. This is likely to have caused large number of fatalities in the common corridors and staircases in Wang Cheong House and Wang Tai House.

4.1(c) Impact of foam boards on fire spread into buildings

4.1.16. Section 10.5 of the IFITF Final Report stated that polystyrene window covers (i.e. foam boards), which were installed as a protective measure against debris on unit and common corridor windows, obstructed residents' view of the external environment. This obstruction potentially prevented occupants from realizing the severity of the fire in neighbouring units as well as their own, thereby lowering situational awareness and delaying evacuation. We agree with this assessment.

4.1.17. We also agree with the conclusion in Key Observation (12) of the IFITF Final Report and the Yuen Final Report (Section 2.11.9), which pointed out the physical fire hazards of these polystyrene window covers. It noted that although the total heat release from the polystyrene window covers was minimal due to their small mass, they significantly promoted fire spread to other combustibles and accelerated fire development due to their ease of ignition and tendency to produce burning droplets. Additionally, these covers released highly toxic smoke, further compounding the hazard.

4.1.18. This conclusion contrasts with the initial views of Professor Richard Yuen, expressed in Section 4.20 of Appendix A-27(A) of the IFITF Final Report (i.e. the Yuen Initial Report): "For fire scenarios involving the use of foam (i.e., Test Nos. 5 and 6), it can be observed that the presence of foam has little impact on the speed and spread of the fire. This is because, as compared to the major combustible materials (i.e., bamboo scaffolding, wooden planks and toe boards inside the re-entrant), foam boards had relatively much lower mass and therefore contributed less to the total fire load."

4.1.19. To evaluate this assertion in the Yuen Interim Report, the temperature measurements from the full-scale fire tests in the Yuen Interim Report were examined. The primary measurement locations of interest (Location A) are inside the kitchen, as shown in Fig. 4.3 (reproduced from Fig. 2.9 of the Yuen Initial Report at Appendix A-27(A) of the IFITF Final Report).

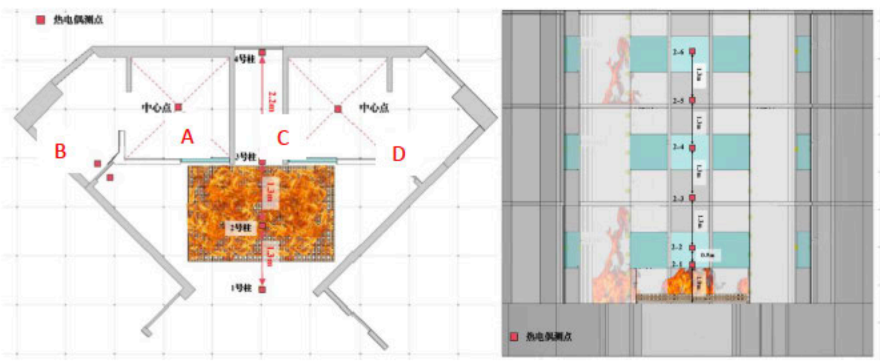


Figure 4.3. Location of thermocouple trees (from the Yuen Interim Report)

4.1.20. The Yuen Final Report detailed the results of 13 full-scale fire tests. Tests 3 to 6 are highly relevant for isolating the impact of polystyrene window covers on fire spread via glass windows. The setup parameters for these tests are summarized in Table 4.1.

Table 4.1 - Information full-scale fire tests (Tests 3 – 6, from Section 2.2.2 of the Yuen Final Report)

Test	Fire Size (MW)	Safety Net	Polystyrene Covers	Canvas
3	2.5	Sample 1 (Uncertified)	No	No

4	2.5	Sample 2 (FR)	No	No
5	2.5	Sample 1 (Uncertified)	Yes	No
6	2.5	Sample 2 (FR)	Yes	No

4.1.21. Table 4.2 compiles the maximum temperature readings recorded at Window A. The label "W1-1 in" refers to the thermocouple located inside the kitchen, as illustrated in Fig. 4.3. These maximum values and the times to reach them were extracted from the temperature-time curves in the Yuen Interim Report (e.g., the 50°C reading for Test 3 was extracted from "Fig. 2.36 Temperature at A of Floor I and II"). The temperature-time curves of 4 tests are reproduced in Fig. 4.4.

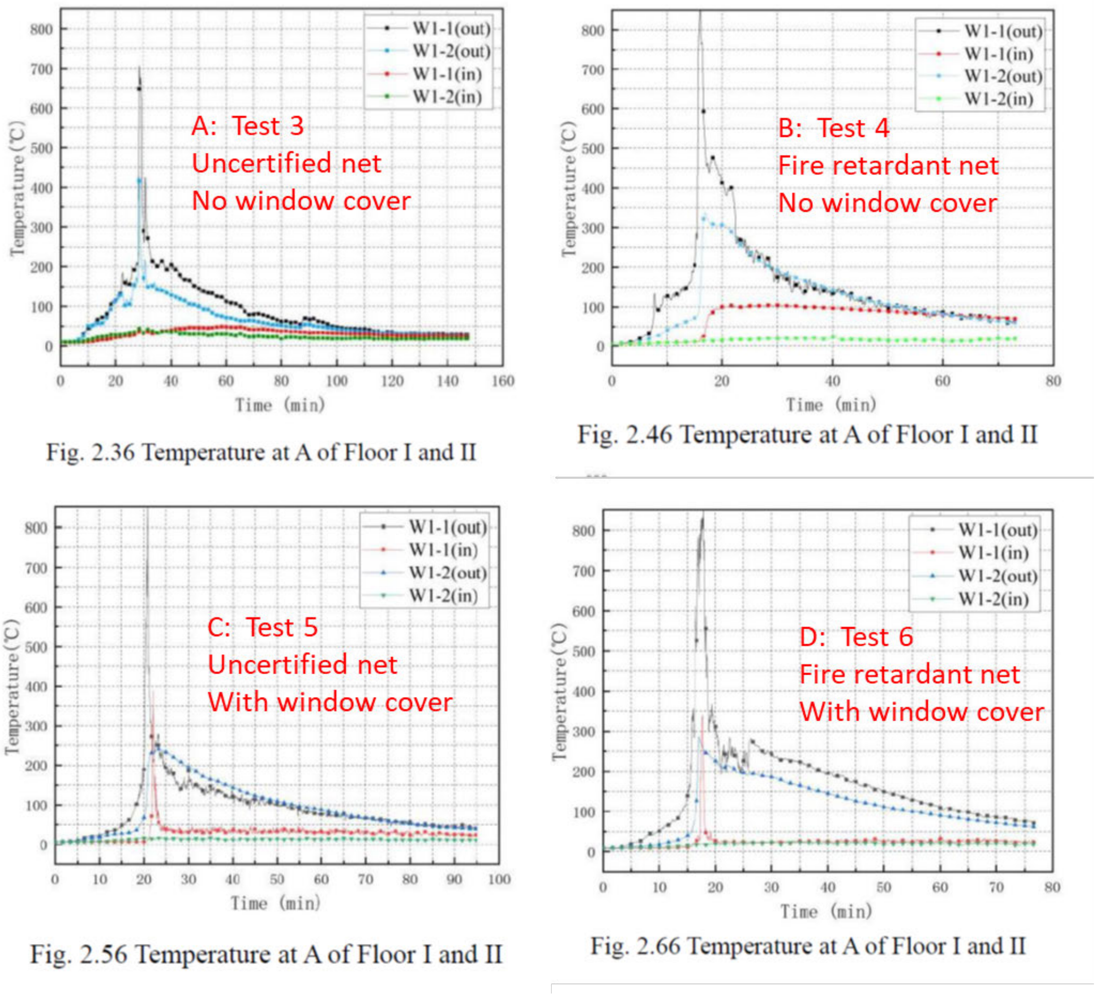


Figure 4.4. Measured temperatures at Window A (outside and inside the kitchen window, reproduced from the Yuen Interim Report)

Table 4.2 - Maximum temperatures in and out of kitchen

Test No.	Window cover/Safety net	Source (App A-27)	Measurement location (Window A, Fig. 2.9)	Max temperature (°C)	Time to Max temperature at W1-1 in (min)	Remarks
3	No / Uncertified	Fig. 2.36	W1-1 out	700	30	W1-1 out: Window, 1st floor, outside of the window. W1-2 out: Window, 2nd floor, outside of the window. W1-1 in: Window, 1st floor, inside of the window. W1-2 in: Window, 2nd floor, inside of the window.
			W1-2 out	410		
			W1-1 in	50		
			W1-2 in	50		
4	No / FR	Fig. 2.46	W1-1 out	850	20	
			W1-2 out	320		
			W1-1 in	100		
			W1-2 in	15		
5	Yes / Uncertified	Fig. 2.56	W1-1 out	850	21	
			W1-2 out	280		
			W1-1 in	370		
			W1-2 in	15		
6	Yes / FR	Fig. 2.66	W1-1 out	850	16	
			W1-2 out	280		
			W1-1 in	340		
			W1-2 in	15		

4.1.22. The following is our analysis of the test results:

(a) Tests 3 and 4 (without foam board covers): The kitchen windows were not covered with polystyrene foam. The maximum interior temperatures ("W1-1 in") remained at or below 100°C, indicating that the glass windows likely remained intact and successfully barred fire penetration throughout the tests.

(b) Tests 5 and 6 (with foam covers): The kitchen windows were covered with polystyrene foam. In Test 5, the interior temperature ("W1-1 in") raised to 370°C at 21 minutes. In Test 6, it reached 340°C at 16 minutes. These rapid, severe temperature rise clearly indicate the exact moment of window breakage, which allowed hot gases and smoke to breach the kitchen.

4.1.23. Direct comparison of these tests reveals that the presence of the polystyrene foam board covers directly caused—or accelerated—the thermal shock and subsequent breakage of the window glass. This failure mechanism enabled lateral fire and smoke spread into the building's interior.

4.1.24. Furthermore, this hazard is expected to be even more pronounced for living room and bedroom windows, where there is typically less combustible material nearby than in the re-entrant area. In the absence of foam window covers, radiation from an external safety net fire may not be intense enough to break living room and bedroom glazing. However, when covered with highly ignitable polystyrene foam boards, these windows are highly susceptible to early failure, creating direct pathways for internal fire spread.

4.2. Locations of fatalities and correlation with damage of flats

4.2.1. Section 5 of the IFITF Final Report reported the damage of all 7 blocks during Wang Fuk Court fire. The details are available in Appendix A-17 and Appendix A-26 of the IFITF Final Report. The extent of interior fire damage has been categorised into four principal levels:

(a) Extremely severe damage (**esd**),
(b) Severe damage (**sd**),
(c) Minor damage (**md**),
(d) Unaffected (**u**).

4.2.2. As to the details of the fatalities and injuries, these are addressed in Section 9 and Section 10 of the IFITF Final Report. The details are summarised in Appendix A-22A and Appendix A-22B.

4.2.3. Tables 4.3 and 4.4 of this Report summarise the fatalities in Wang Cheong House (Block F) and Wang Tai House (Block E), together with the damage conditions of the flats in which the victims were located. The information is drawn from Appendices A-17 and A-22A of the IFITF Final Report, but overlap the casualties and the fire damage conditions of the flat. The purpose is to map the locations of fatalities, relate them to the extent of fire damage in the corresponding flats, and analyse the impact of lateral fire and smoke spread on tenability in common areas and in individual flats.

4.2.4. A significant proportion of fatalities occurred in common corridors and staircases. In Wang Cheong House (Block F), 24 of 81 victims died in common corridors and staircases and in Wang Tai House (Block E), 38 of 82 died in these areas. As there is essentially no combustible fuel in these areas, it is reasonable to assume that flame or severe radiant heat would not have been present there. The likely cause of death in these locations is smoke inhalation.

4.2.5. In Wang Cheong House (Block F) (Table 4.3), 15 fatalities occurred in 9 flats where at least one room in each flat was unaffected by flame. It is reasonable to infer that these occupants were initially able to move away from the flames and high heat into unaffected areas before losing consciousness. The cause of death in these flats is therefore most likely to be smoke inhalation. Notably, Flat 2602 and Flat 1202 were completely unaffected by flame, yet one and four occupants, respectively, still died in these flats.

4.2.6. Similarly, in Wang Tai House (Block E) (Table 4.4), 17 people died in 9 flats in which at least one room remained unaffected by flame and 2 flats completely unaffected.

Table 4.3 - Fatality table: Wang Cheong House (Data from IFITF Final Report)

Floor No	Unit No								C/C	SC	Remarks
	1	2	3	4	5	6	7	8			
31									1 esd/sd		
30	1 esd	2 md/u						2 md/u			Numbers represent number of fatalities
29									6 esd/md		
27	2 esd	1 esd						4 esd			
26		1 u						5 sd/md	1 sd/md		C/C: Common Corridor
25							1 md/u				
24							2				SC: Staircase
23		1 md/u				4 esd				1 esd	
22	1 esd										CC faces re-entrant between Units 1 and 8
										1 esd	
21	2 esd						1 esd		1 esd/md		
19		2 md/u						1 esd			SC faces re-entrant between Units 4 and 5
18	1 esd										
17	1 esd					1 esd					
16							1 esd				
15									1 esd/sd		esd: Extremely Severe Damage
12		4 u							1 sd/md		
11									2 md		sd: Severe Damage
10							1 esd/sd/md/u	1 esd/sd		1 md	
9							2 esd		1 esd/sd/md		md: Minor Damage
8		1 md/u						1 esd/sd/md			
7								3 esd/sd/md	1 esd		u: Unaffected
6				1 esd/sd							
5		2 sd/md						1 esd			
4					2 esd						
3									1 sd/md		
										1 esd/sd	
2					2 esd				1 esd/sd		
G										3 sd/md	
									Fatalities in C/C and SC: 24		**Total: 81**

Table 4.4 - Fatality table: Wang Tai House (Data from IFITF Final Report)

Floor No	Unit No 1	2	3	4	5	6	7	8	C/C	SC	Remarks
R/F						2 store room					
31		1 esd				1 md/u			3 sd	2 sd	
										2 esd/md	
30											Numbers represent number of fatalities
29							2 md/u				
28							1 md/u				
26					1 esd						C/C: Common Corridor
25											
23								2 esd	1 sd/md		SC: Staircase
22	1 esd										
21					1 esd		1 u		1 esd		CC faces re-entrant between Units 1 and 8
20		1 esd/u			1 esd						
19				2 sd/md/u			4 sd/md/u	2 esd			SC faces re-entrant between Units 4 and 5
18											
										2 md	
17	1esd								1 sd		
16				2 esd/sd/md						4 md	esd: Extremely Severe Damage
										3 md	
15											
14										2 md	sd: Severe Damage
12	1 esd									2 md	
11				4 esd/sd/md/u						1 sd/md	md: Minor damage
10								1 esd		1 esd	
9								1 esd/sd/md	2 esd/md		u: Unaffected
8			2 sd/sd/md								
7		1 esd								1 md	
6				2 esd					1 esd/md		
5		2 esd									
4			1 esd							2 esd	
3						1 u				3 sd/md	
										2 esd	
2											
1					1 esd					1 esd	
G/F									1 sd		
G	1 outside (fireman)								**Fatalities in C/C and SC: 38**		**Total: 82**

4.2.7. Section 9.3 of the IFITF Final Report summarised the cause of death as below (Table 4.5):

Table 4.5 - Cause of Death

Cause of death	Number of fatalities
Adverse effect of fire	65
Inhalation of fire fumes	91
Inhalation of fire fumes and burns	4
Inhalation of fire fumes extensive burns	4
Multiple causes	4

4.2.8. These statistics are consistent with the findings above that fire deaths are predominantly due to smoke inhalation, and that victims are often found outside the room of fire origin.

4.2.9. A key focus of this Report will therefore be to analyse how smoke spread from the re-entrant to the staircases, common corridors, and flats, with particular attention to the fatalities that occurred in flats unaffected by direct flame impingement.

4.3. Impact of smoke spread on fatalities

4.3(a) Staircases and common corridors

4.3.1. As summarized in Tables 4.3 and 4.4 above, 24 occupants of Wang Cheong House and 38 occupants of Wang Tai House died in staircases and common corridors (including lift lobbies).

4.3.2. Fig. 4.5 and 4.6 show that the staircases and common corridors were clear and free of combustible materials prior to the fire incident. It is therefore reasonable to conclude that no localized fires developed in these areas, including the lift lobbies. Fig. 4.7 shows the wired glass windows (i.e. WGW) in the staircase and the lift lobby. The upper part of each WGW was open. This configuration was code-compliant and intended to provide natural lighting and ventilation. As illustrated in Fig. 4.7, both windows were located within the re-entrant, where smoke from a re-entrant fire could readily enter the staircase and lift lobby (common corridor). Smoke inhalation was therefore likely the major contributor to the fatalities that occurred in these areas.

Figure 4.5. Conditions of staircases before fire

Figure 4.6. Conditions of common corridors before fire

Figure 4.7. Wired glass window (WGW) in (a) staircase; (b) lift lobby

4.3.3. A series of CFD simulations were carried out assuming a fire of 20 MW located at the bottom of the re-entrant, with the upper parts of some WGWs open. This assumption is based on: (i) photographs taken by contractors before the incident showing the windows open, and (ii) the assumption that, even if closed, the windows may fail under the thermal exposure of a fully developed re-entrant fire. In the simulation, staircase windows (or access doors) on every fifth floor were assumed to be fully open, consistent with observations that some wooden doors for worker access openings were wide open or had gaps and in any event were burnt through during the incident.

4.3.4. The simulation assumed that fire initiated at ground level at the bottom of the re-entrant. Due to the chimney effect, flames and smoke rapidly entered the re-entrant. The open windows/doors every five floors created a pressure differential, drawing smoke from the re-entrant into the staircase. Smoke gradually filled the staircase from the lower to the upper levels, eventually compromising the entire staircase from the ground floor to the roof.

4.3.5. The simulation results indicate a very rapid vertical spread of fire gases in the re-entrant, with smoke entering the staircases and lift lobbies on all floors. Fig. 4.8 shows the simulation results of smoke spread from the re-entrant into the staircase.

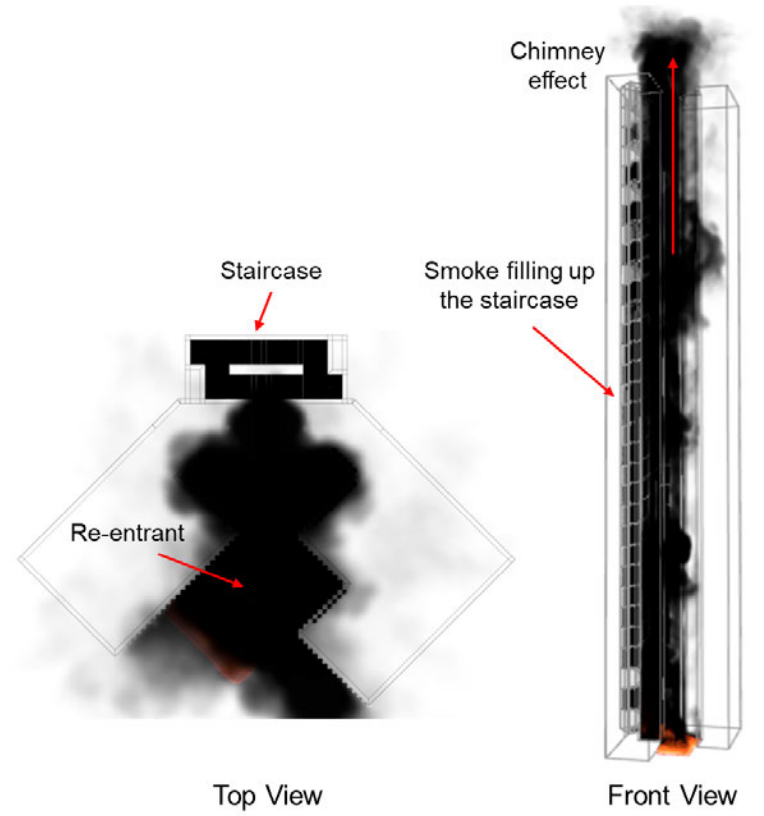


Figure 4.8. Simulation results of smoke spread from the re-entrant into the staircase

4.3.6. As shown in Fig. 4.9, smoke spread rapidly upward through the re-entrant due to the chimney effect. Because the internal pressure in the lift lobbies was lower than in the re-entrant, smoke flowed inward through the open ventilation windows, gradually filling the lift lobbies and adjacent corridors with smoke and toxic gases (Fig. 4.10).

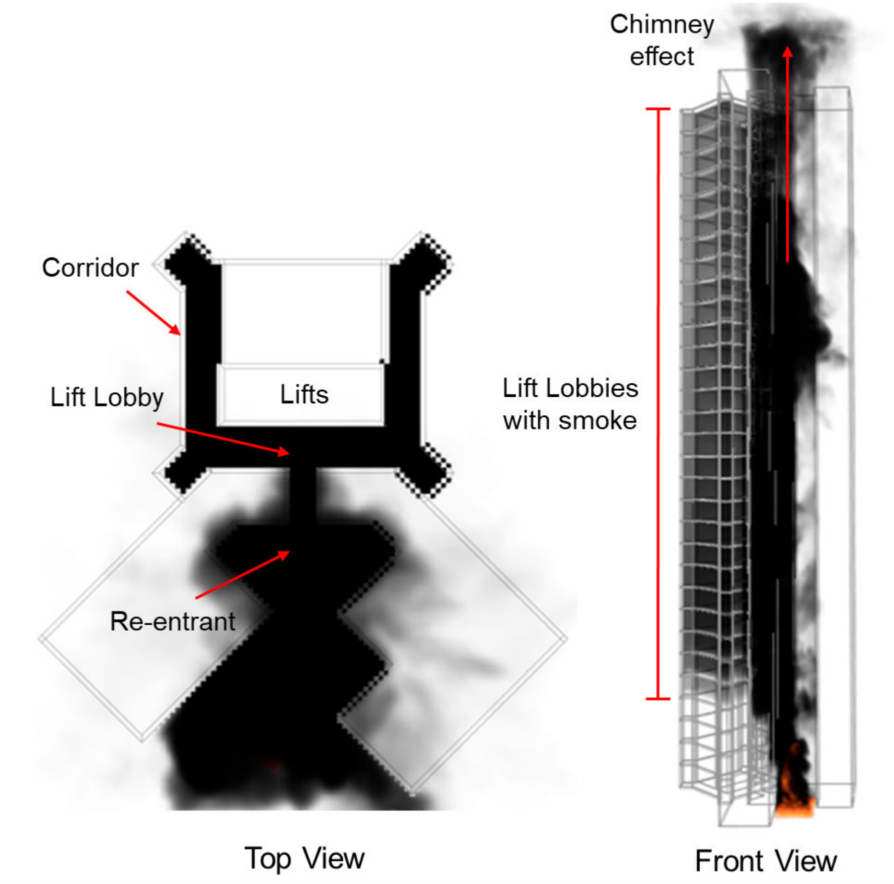


Figure 4.9. Simulation results of smoke spread from the re-entrant into lift lobbies.

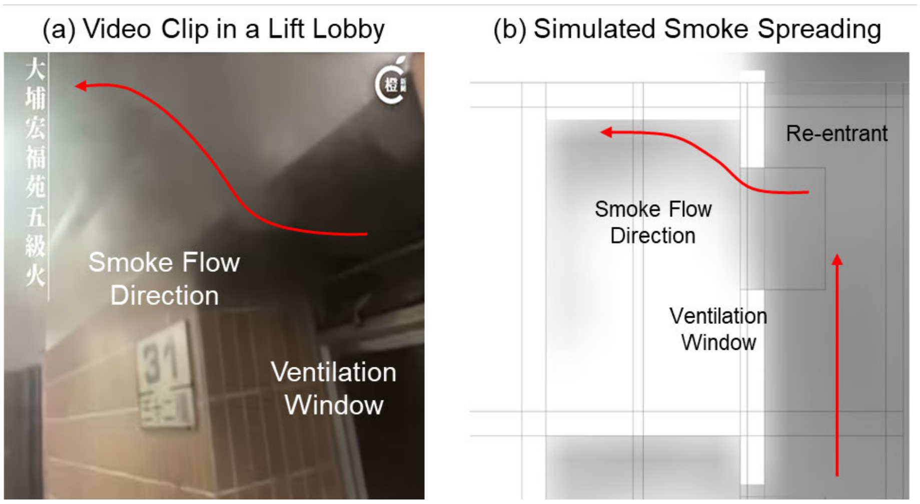


Figure 4.10. Smoke spreading conditions in the lift lobby: (a) video, and (b) simulation result

4.3.7. Carbon monoxide and smoke concentrations increased rapidly over time. The deactivated fire alarm system, combined with polystyrene window covers that blocked the occupants' view of the developing fire, likely delayed occupant awareness and evacuation. Consequently, both staircases—which formed the primary means of escape—became heavily smoke-logged. According to the CFD-predicted visibility, temperature, and gas concentrations, visibility in the common corridors of the lower floors dropped below 10 m in less than one minute, breaching the threshold of tenable conditions for safe evacuation. The detailed simulation results are available in Appendix A.

4.3(b) How smoke entered into the flats

4.3.8. During the short-period vertical fire at re-entrant region (especially the first re-entrant fire at Wang Cheong House, F1), the glass panels of kitchen windows and the side windows between kitchen doors and living rooms were very likely to be broken by the direct heating of intense re-entrant fire. These windows would become the openings to allow smoke spread into the room units. Meanwhile, a large amount of smoke was seen after the decay stage of re-entrant fire, which may be caused by the piled scaffolding materials that fell off during the re-entrant fire. These scaffolding materials underwent insufficient combustion due to limit of air supply, generating smoke filling the re-entrant.

4.3.9. To take Unit [redacted]03 of Wang Cheong House (Block F) as an example, the post-fire investigation suggested very limited damage, except smoke marks in the rooms. According to the webcam video evidence, smoke was found at 14:59 and accumulated at 15:00, which was corresponding to the first re-entrant fire. Considering that Unit [redacted]03 was not exposed to fire directly, the smoke should come from the corridor. The webcam video also suggested that heavy smoke was outside the door when the residents opened it. The corridor smoke was likely from Unit [redacted]04 as this unit was fully ignited. The smoke entering the room and the ignition of combustibles in Unit [redacted]04 would generate considerable amount of smoke and enter the corridor.

Figure 4.11. Conditions in Unit [redacted]03 of Wang Cheong House

4.3(c) *Fatalities in flats unaffected by fire*

4.3.10. To illustrate the impact of smoke in flats that were not directly affected by fire, we have analysed Wang Cheong House (Block F) Units [redacted]02 and [redacted]02. These flats were not directly affected by flaming combustion, yet one and four occupants, respectively, still died in these flats. In Unit [redacted]02, two victims (D54 and D56) originated from Unit [redacted]04.

Fatalities in Unit [redacted]02

4.3.11. Inspection of the post-fire damage on [redacted]/F shows that Units [redacted]04 and [redacted]05, which share the re-entrant with the fire origin, were completely destroyed. In Unit [redacted]04, the kitchen was fully burned out and no remains of the kitchen door were found, indicating that it was either removed prior to the incident or completely consumed by fire. Units [redacted]06, [redacted]07 and [redacted]08 were also seriously damaged.

4.3.12. Unit [redacted]01 was totally consumed, and its entrance door was burnt through (Fig. 4.12a). The entrance door of Unit [redacted]01 is immediately adjacent to the entrance door of Unit [redacted]02. The post-fire photograph of the Unit [redacted]02 entrance door (Fig. 4.12b) shows significant charring on the upper portion of the leaf and heavy soot deposition on the ceiling of the entrance foyer inside of Unit [redacted]02. This indicates that hot smoke penetrated into Unit [redacted]02 through the door gaps while other flats on the same floor were burning for an extended period.

(a) (b)

Figure 4.12. Entrance door of (a) Unit [redacted]01 and (b) Unit [redacted]02, Wang Cheong House

4.3.13. The following sequence of events is considered the most probable explanation for the four fatalities in Unit [redacted]02:

(a) The fire initiated on the 1st floor roof of Wang Cheong House (Block F) and developed fully within the re-entrant between Units 4 and Flat 5 at approximately 14:59 (Section 3 above, timeline analysis location "F1"). At this time, two occupants (D44 and D45[15]) were inside Flat [redacted]02.

(b) Around 15:00, the re-entrant fire likely caused failure of the kitchen window of Unit [redacted]04, allowing flames and hot gases to enter and ignite combustibles in the kitchen. Post-fire photographs show complete destruction of the kitchen, with the kitchen door frame burnt down and no remains of the door leaf, indicating full involvement of the kitchen and loss of compartmentation (the kitchen door may have been removed prior to the fire or completely consumed during the fire).

[15] D45 resided in Unit 1407, 14/F, Wang Cheong House.

(c) Smoke from the kitchen spread rapidly into the living room of Unit [redacted]04. It is likely that the two occupants of Unit [redacted]04 (D54 and 56) exited into the common corridor. By this time, according to witness evidence (4th Witness Statement of Yiu Men-yeung, paras. 21–22 and A-24 of the IFITF Final Report) and the CFD simulations, the staircase and lift lobby were already heavily smoke logged, preventing safe escape to the ground.

(d) D54 and D56 then knocked on the door of Unit [redacted]02 and entered. Together with the two original occupants of Unit [redacted]02 (D44 and D45), four people remained in Unit [redacted]02 shortly after 15:00. Since there is no evidence of direct flaming in Unit [redacted]02, conditions inside the flat would have remained tenable for a period, until fire developed in Unit [redacted]01 and burnt down the entrance door.

(e) By approximately 15:09, the re-entrant between Unit [redacted]01 and [redacted]08 was fully involved with fire (Section 3 above, timeline analysis location "F3"). It is probable that the kitchen window of Unit [redacted]01 failed around this time, allowing the fire to develop within Unit [redacted]01.

(f) Post fire photographs show that all furniture in Unit [redacted]01 was completely consumed. No remains of the kitchen door were found, indicating that it was either removed or fully burned. The main entrance door of Unit [redacted]01 was a fire-rated single leaf 50 mm solid-core flush door with self-closing device, with a required fire resistance rating (i.e. FRR) of ½ hour. Such a door can typically resist standard fire exposure for at least 30 minutes, and often longer under real fire conditions. In general, the door could resist a fire for at least 60 minutes.

(g) It is therefore plausible that the fire in Unit [redacted]01 broke through the entrance door between 15:30 and 16:00. Given the direct adjacency of the entrance doors of Units [redacted]01 and [redacted]02, hot smoke and possibly flames from Unit [redacted]01 would have impinged directly on the entrance door of Unit [redacted]02. The [redacted]/F common corridor would have been filled with hot smoke, which then leaked into Unit [redacted]02 through door gaps.

(h) The entrance door of Unit [redacted]02 appears to have retained its structural integrity, suggesting that it resisted direct flame attack for at least 30–60 minutes. However, smoke infiltration through leakage paths (door gaps) was sufficient to cause lethal conditions inside Unit [redacted]02, ultimately overcoming all four occupants.

Fatality (D87) in Unit [redacted] 02

4.3.14. On [redacted] /F, Units [redacted] 04 and [redacted] 06 were totally consumed, and the entrance door of Flat [redacted] 04 was burnt through. Both flats are remote from Unit [redacted] 02. Unit [redacted] 01, which is adjacent to Unit [redacted] 02, was seriously damaged internally; however, its entrance door remained intact and showed no sign of burn-through.

4.3.15. The post-fire photograph of Unit [redacted] 02's entrance door shows only light soot deposition on the upper portion facing the corridor, indicating that fires in other flats on this floor had limited impact on conditions inside Unit [redacted] 02 via the corridor.

4.3.16. Within Unit [redacted] 02, most windows were found open in the post-fire photographs, particularly the living room window. It is therefore envisaged that smoke penetrated into Unit [redacted] 02 from the exterior. The re-entrant between Units [redacted] 02 and [redacted] 03 did not catch fire; the likely source of exterior smoke was fire along the building façade involving the safety netting, bamboo scaffolding and other combustible materials. Smoke from these façade fires would have readily entered Unit [redacted] 02 through the open windows, resulting in the fatality of occupant D87.

Summary of assessment of fatalities in Units [redacted] 02 and [redacted] 02

4.3.17. The fatalities in Units [redacted] 02 and [redacted] 02 illustrate two distinct lateral fire/smoke spread mechanisms:

(a) Unit [redacted] 02: Fatalities were mainly caused by smoke from internal flat fires on the same floor. Fire spread from the re-entrant into Unit [redacted] 04 and other flats, fully involving those compartments and eventually breaching the fire-rated entrance door of Unit [redacted] 01. Subsequent hot smoke and flame impingement on the entrance door of Unit [redacted] 02 led to significant smoke leakage into Unit [redacted] 02 via door gaps, resulting in lethal conditions for the four occupants sheltering inside.

(b) Unit [redacted] 02: The fatality was predominantly due to smoke from external façade fires involving safety nets, bamboo scaffolding and other combustibles. With windows (especially the living room window) open, smoke from the façade entered Unit [redacted] 02 directly from outside, despite minimal impact from corridor fires on that floor.

Estimation of fire duration in Unit [redacted] 01

4.3.18. In reviewing the impact of the fire in Unit [redacted] 01 on the victims in Unit [redacted] 02, it is essential to estimate the intensity and duration of the fire in Unit [redacted] 01.

4.3.19. A fire load survey in Hong Kong[16] concluded that the fire load density of high-rise residential flats can be as high as 1400 MJ/m^2. The Code of Practice for Minimum Fire Service Installations and Equipment and Inspection, Testing and Maintenance of Installations and Equipment (Fire Services Department) specifies the upper limit of fire load density as 1135 MJ/m^2.

4.3.20. For the Wang Fuk Court fire, it is assumed that the fire load density is 1135 MJ/m^2. The total usable area of Unit [redacted] 01 of Wang Cheong House (Block F), including the kitchen, is approximately 36 m^2. The total fire load (heat energy) in the flat is therefore:

$$1135 \text{ MJ/m}^2 \times 36 \text{ m}^2 = 40{,}860 \text{ MJ}$$

4.3.21. When the fire is fully developed in the flat, it is assumed to become ventilation-controlled. Under such conditions, the maximum fire size, or heat release rate (i.e. HRR), is governed by the available oxygen (air) supplied through the ventilation openings. An empirical correlation widely used to estimate the maximum HRR (kW) is:

$$Q_{max} = 750\ A_v\sqrt{H_v}$$

where A_v is the area of the ventilation opening (m^2), and H_v the height of the ventilation opening (m).

4.3.22. Assuming that all windows of the living room and bedrooms were dislodged during the fire, and based on approximate dimensions from photographs and as-built drawings, the sum of these window widths is taken as 2.4 m and the height as 1.5 m. The maximum HRR is estimated as:

$$Q_{max} = 750\ (2.4{\times}1.5)\sqrt{1.5} \approx 3.3\ MW$$

The fire in Flat 1201 could last for:

[16] J. Liu, W.K. Chow, Determination of Fire Load and Heat Release Rate for High-rise Residential Buildings, Procedia Engineering, Volume 84, 2014, Pages 491-497, ISSN 1877-7058, https://doi.org/10.1016/j.proeng.2014.10.460.

40,860 ÷ 3.3 = 12,381 seconds = 3.44 hours

4.3.23. Considering the development of flashover, incomplete combustion, and the fact that the HRR will vary over time and may not remain at the peak ventilation-controlled value throughout, it is reasonable to conclude that the fire in Unit [redacted]01 could have persisted for over 2 hours.

4.3.24. The results indicate that the fire in Unit [redacted]01 of Wang Cheong House (Block F) was severe enough to breach its entrance door, whereas the entrance door of Unit [redacted]02 retained its structural integrity.

4.4. Timeline analysis for fire evacuation (ASET/RSET)

4.4.1. This Section analyses the inability of occupants to evacuate and escape from the effects of fire and smoke during the Wang Fuk Court fire. Section G "Guidelines on Fire Engineering" of the Code of Practice for Fire Safety in Buildings (**FS Code 2011**) introduced a fire safety design concept, namely, timeline analysis.

4.4.2. Timeline analysis is an essential tool in fire safety analysis, offering a structured, quantitative framework for reconstructing and understanding the sequence of events during a fire and the subsequent evacuation.

4.4.3. Fundamentally, life safety is a race against time. The level of fire safety within a building is evaluated by comparing the time required for occupants to safely evacuate against the progression of the fire and the onset of hazardous, life-threatening conditions. Life safety is assessed through a quantitative timeline analysis, which primarily involves determining the Available Safe Egress Time (**ASET**)—the period before conditions within the fire environment or evacuation pathways become untenable—and comparing it with the Required Safe Egress Time (**RSET**).

4.4.4. To guarantee occupant safety, the following condition must be satisfied:

$$\text{RSET} + \text{Safety Margin} < \text{ASET}$$

4.4.5. In other words, for any given fire scenario, occupant safety is achieved only if the total time required for evacuation—including detection, decision-making, and physical movement—is less than the time available before untenable conditions develop, with an added safety margin to account for uncertainties in assumptions, human behaviour, and physical calculations.

4.4.6. As illustrated in Fig. 4.13, a comprehensive timeline assessment consists of the following components:

(a) Evacuation Assessment (i.e. RSET): Comprising detection time, pre-movement time, and physical travel time to a place of relative safety.

(b) Fire Development Calculations: Determining the rate of heat release (i.e. HRR) and toxic gas production for a fire within the designated compartment.

(c) Smoke Development Calculations: Predicting smoke layer descent, visibility reduction, temperature rise, and toxicity levels within the evacuation routes.

(d) Safety Factor or Margin of Safety: The comparative gap enforced between the two timelines to account for real-world variances.

4.4.7. In analysis, RSET represents the total evacuation or escape time t_{esc}, which can be expressed with the following equation:

$$t_{esc} = t_{alarm} + t_{pre} + t_{flow}$$

Where:

- t_{alarm} is the time elapsed from ignition to alarm activation/occupant notification.
- t_{pre} is the pre-movement time (encompassing recognition, decision-making, and coping/preparation time).
- t_{flow} is the physical travel time required for occupants to traverse the discharge paths to reach a place of safety.

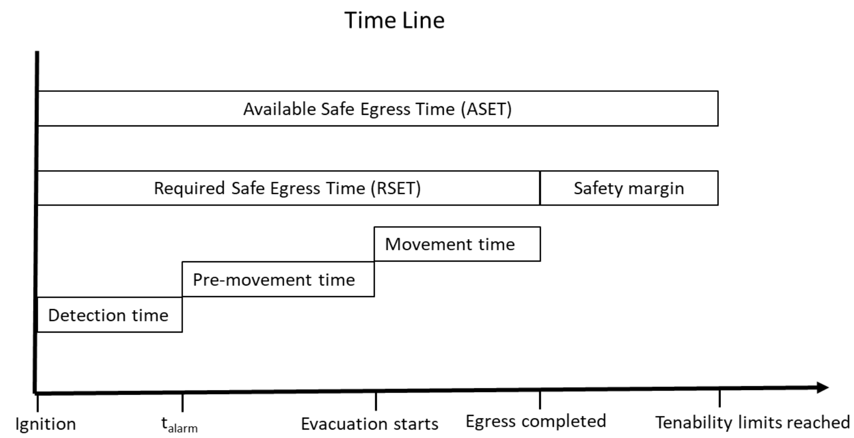


Figure 4.13. Graphical Representation of a Timeline Assessment

4.4.8. A safety margin is essential to ensure that there is sufficient time for occupants to evacuate before conditions become untenable. This margin is typically determined to incorporate a level of conservatism into the calculations.

4.4.9. Alternatively, a Safety Factor may be applied. Globally, and specifically within dense jurisdictions (e.g., FS Code 2011), this factor is typically set at 1.5 to 2.0. This dictates that the time to reach untenable conditions (i.e. ASET) must be at least 1.5 to 2.0 times the calculated evacuation time (i.e. RSET):

$$ASET >= (1.5 - 2.0)\ RSET$$

4.4.10. In timeline analysis for high-rise buildings, the Required Safe Egress Time (i.e. RSET) represents the total evacuation or escape time, t_{esc}. Because a structurally protected staircase is designated as a place of relative safety, t_{esc} is defined as the cumulative time required for occupants to successfully reach and enter the protected staircase on their respective floor, at which point floor-level evacuation is deemed complete.

4.4.11. In the Wang Fuk Court fire, the physical layout of the building—specifically the narrow re-entrant spaces—coupled with the critical thermal failure of the Wired Glass Windows (i.e. WGWs) on the external wall of the staircase, caused rapid smoke infiltration into the staircases at a very early stage of the incident.

4.4.12. For Wang Cheong House (Block F), the timeline analysis detailed in Section 3 above indicates that the first vertical fire spread (designated as "F1") initiated from a localized fire at the re-entrant platform of Wang Cheong House (situated between Units 4 and 5), which was first recorded at 14:50. The fully developed stage of fire scenario "F1" was reached at approximately 14:59.

4.4.13. Crucially, the witness statement of construction worker Mr. LI Ka-ching (李家程, as detailed in Appendix A-24 of the IFITF Final Report) revealed that the staircase on the 14th Floor was already heavily filled with thick black smoke between 14:56 and 14:57.

4.4.14. At this precise stage (14:56), the designated protected staircase of Wang Cheong House (Block F) had ceased to function as a place of safety. Conversely, the vast majority of the building’s occupants had not yet recognized that a fire had occurred due to a lack of alarm activation and blockage of the windows with polystyrene foam cover.

4.4.15. Consequently, the Available Safe Egress Time (i.e. ASET) within the primary escape route was reduced to zero before the occupant evacuation process (i.e. RSET) could even be initiated. This absolute overlap of untenability and lack of occupant notification renders the ASET/RSET timeline analysis inapplicable for this case, as safe egress was physically impossible for occupants on all floors from the outset of the vertical fire spread.

5. ASSESSMENT OF FIRE SAFETY REGULATION COMPLIANCE

5.1. Fire safety requirements for buildings

5.1.1. The legislative requirements for the provision of fire safety measures in buildings are laid down in various Ordinances, Subsidiary Legislation, and Codes of Practice published by the Government of the Hong Kong SAR. Generally, fire safety provisions are categorized into four main areas:

- Fire Service Installations (**FSI**);
- Means of Escape (**MOE**);
- Means of Access (**MOA**) for firefighting and rescue; and
- Fire Resisting Construction (**FRC**).

5.1.2. Codes of practice for fire safety requirements are divided into two main categories: Active Fire Safety Provisions and Passive Fire Safety Provisions.

5.1.3. The former refers to Fire Service Installations (i.e. FSI). The first edition of the FSI Code was issued in 1964, entitled "Code of Practice for Minimum Fire Service Installations and Equipment". Administered by the Hong Kong Fire Services Department (**FSD**), this Code is continuously updated to align with technological advancements. The latest version was published in 2022 under the title "Code of Practice for Minimum Fire Service Installations and Equipment and Inspection, Testing and Maintenance of Installations and Equipment".

5.1.4. Passive Fire Safety Provisions cover MOE, MOA and FRC. The Codes of Practice governing these three areas are administered by the Buildings Department (**BD**).

5.1.5. In September 2011, the BD issued the Code of Practice for Fire Safety in Buildings (i.e. FS Code 2011). The FS Code 2011 is a performance-based code that consolidates the previously separate MOE, MOA, and FRC codes, while incorporating additional requirements for the fire properties of building elements and fire safety management. Furthermore, a section entitled "Guidelines on Fire Engineering" was introduced to facilitate performance-based designs, which includes timeline analysis (ASET/RSET). The latest amended version of the FS Code 2011 was issued in 2024.

5.1.6. As a result of several big fires in existing buildings (Garley Building fire in 1996 and Prat Avenue Karaoke fire in 1997) with multiple fatalities and injuries, the Fire Safety (Commercial Premises) Ordinance (Cap. 502) was legislated, and came into force on 2 May 1997.

5.1.7. As stated in the Ordinance, its purpose is to provide better protection from the risk of fire for occupants and users of, and visitors to, certain kinds of commercial premises and commercial buildings. The target buildings of this Ordinance are those buildings where fire safety provisions were provided to the older standards. Fire safety upgrade of these buildings is to be achieved by provision of or improvement on fire service installations and equipment, and/or means of escape/access constructions.

5.1.8. The Fire Safety (Buildings) Ordinance (Cap. 572) was subsequently enacted and came into force on 1 July 2007 to provide better protection from the risk of fire to occupants in certain kinds of existing composite buildings and domestic buildings, by provision of or improvement on fire service installations and equipment, and/or means of escape/access constructions. The Director of Fire Services and the Director of Buildings are the enforcement authorities for the provision of fire service installations and; the provisions of fire safety measures in the planning, design and construction, respectively.

5.1.9. The Fire Safety (Buildings) Ordinance covers composite buildings (partly for domestic purpose and partly for non-domestic purpose) and domestic buildings. The scope of this Ordinance includes buildings, which plans of building works were first submitted to the Building Authority for approval on or before 1 March 1987; or which was constructed on or before 1 March 1987 where no plans of building works were submitted to the Building Authority for approval on or before that date.

5.1.10. Under this Ordinance, the enforcement authorities have the right to issue improvement order to certain kind of buildings' owners to improve their existing fire safety standards.

5.1.11. The objectives of these fire safety upgrade legislations are to reduce the fire risks of the old building, to protect lives of the occupants and the properties, to maintain business continuity etc. Both the Fire Safety (Commercial Premises) Ordinance (Cap. 502) and the Fire Safety (Buildings) Ordinance (Cap. 572) call the requirements from FSI Code (1994) and BD Code of

Practice (1996). Specifically, for residential buildings, the Fire Safety (Buildings) Ordinance (Cap. 572) details the requirements as follows:

(a) Provision of fire service installation or equipment:

a) a requirement to provide or improve a fire hydrant and hose reel system as a source of water supply for fire fighting;
b) a requirement to provide or improve a manual fire alarm system to alert occupants of the building in the event of fire; and
c) a requirement to provide or improve emergency lighting within the common parts so as to facilitate the evacuation of occupants of the building in the event of a power failure.

The detailed specifications and requirements of the installation or equipment under paragraphs (a) to (c) are set out in the Code of Practice for Minimum Fire Service Installations and Equipment 1994, as published by the Director of Fire Services.

(b) Fire safety construction:

a) the protection of staircases with separating walls of fire resisting construction;
b) the improvement of exit arrangements in terms of exit from the parts used for domestic purposes to the street;
c) the provision of fire doors.

The detailed requirements on the design, construction or installation in relation to construction requirements in paragraphs (a) to (c) are set out in the following Codes of Practice published by the Director of Buildings:

- the Code of Practice for the Provision of Means of Escape in Case of Fire 1996;
- the Code of Practice for Fire Resisting Construction 1996; and
- the Code of Practice for Means of Access for Firefighting and Rescue 1995.

5.2. Fire safety requirements for façade

<u>5.2(a) General Performance and Fire Resistance Ratings (FRR)</u>

5.2.1. According to the General Enclosure Requirement in Clause C5.1 of FS Code 2011 (2024 edition), every building must be suitably enclosed by external walls and a roof with an adequate Fire Resistance Rating (**FRR**) to protect against the spread of fire to adjoining buildings or neighbouring sites.

5.2.2. FRR Exposure and Criteria (Table C2 - Item 5):

(a) External walls must be designed to withstand fire exposure from each side separately.

(b) Loadbearing external walls must satisfy Stability, Integrity, and Insulation (X/Y/Z) criteria. For residential building, FRR is 60/60/60.

(c) Non-loadbearing external walls must satisfy Integrity and Insulation (Y/Z) criteria. For residential building, FRR is 00/60/60.

(d) Curtain Wall Glazing Exception (Table C2): Subject to Clause C9.7 (staircase protection) and Subsection C5 (boundary separation), standard curtain wall glazing itself does not generally require an FRR. For staircase window of residential building, FRR is 00/60/60.

<u>5.2(b) Prevention of Vertical Fire Spread (Spandrels and Curtain Walls)</u>

5.2.3. According to the Spandrel and Horizontal Projections in Clause C11.1 / Diagram C7 of FS Code 2011 (2024 edition), to prevent fire jumping vertically from floor to floor along the exterior facade, the external wall at any floor must be separated from the floor next below by:

(a) A vertical spandrel of at least 900 mm in height, constructed with an FRR of not less than that of the intervening floor slab (00/60/60 for residential building); or

(b) A horizontal projection of at least 500 mm, with an equivalent FRR (00/60/60 for residential building).

5.2.4. As to Spandrel Penetrations (Clause C11.2): For residential buildings (Use Classification 1), pipe penetrations (plumbing/drainage) through fire-rated spandrels at kitchens and bathrooms are restricted to a maximum diameter of 110 mm and must be fire-stopped.

5.2.5. As to Curtain Wall Voids (Clause C10.2): Curtain walls extending beyond one storey must be constructed entirely of non-combustible materials (except sealants/gaskets). Any void formed between the curtain wall and the floor slab perimeter must be sealed with an effective smoke and fire barrier having:

(a) An FRR of not less than that of the floor slab; and

(b) A certified D-stability duration (smoke leakage limit of ≤25 m3/h/m2 at 25 Pa at ambient temperature when tested in accordance with BS EN 12101-1).

5.3. Status of compliance of Wang Fuk Court with fire safety regulations

5.3.1. Wang Fuk Court is a residential development by the Hong Kong Housing Authority (**HA**). The development was sold to eligible households at discounted prices under the Home Ownership Scheme (**HOS**).

5.3.2. Under the Housing Ordinance (Cap. 283) (**HO**), buildings of the Housing Authority – including new construction sites and existing public rental housing (**PRH**) estates that have not been sold or otherwise disposed of by the HA – are exempt from the provisions of the Buildings Ordinance (Cap. 123) (**BO**). Accordingly, the design of Wang Fuk Court was exempt from the BO. Nevertheless, the HA developed the project with reference to the prevailing statutory provisions, as well as the relevant codes of practice and guidelines issued by the then Building Authority.

5.3.3. As stated above, in Hong Kong, fire safety requirements are divided into two categories: Active Fire Safety Provisions and Passive Fire Safety Provisions. The former comprises requirements for fire service installations (**FSI**), which are detailed in Section 4.2 of the IFITF Final Report.

5.3.4. This Section reviews the fire safety code requirements of the passive provisions at the time Wang Fuk Court was designed. This information helps us understand the fire resistance of the building elements, which relates to lateral fire spread inside a flat and fire/smoke spread from one flat to another on the same floor. For active fire safety provisions, the fire safety installations are listed in Section 4.2 of the IFITF Final Report.

5.3.5. The layout plans of the Wang Fuk Court blocks released from the IFITF Final Report, the basic information is listed below:

- Usable area of each floor: 271.35 m^2.
- Occupant capacity: 60 persons/floor (271.35/4.5).
- Total occupant capacity: 1875 persons/block (8,439/4.5).
- Maximum travel distance from flat to the staircase door: <16 m.
- Staircase width: 2 x 1,070 mm.
- Fire rated door: D1 for all flat entrance doors, meter room, and refuse room. D12 for staircase doors and kitchen doors.
- Wired glass window (i.e. WGW): wired glass window as borrowed light on external wall of staircase and lift lobby.

5.3.6. For ease of reference, the following table summarizes the key code requirements relating mainly to means of escape and the fire-resisting construction of the egress route.

Table 5.1 - Compliance of Wang Fuk Court Blocks

<table>
<tr><th>Item</th><th>Description</th><th>Code requirement*</th><th>Wang Fuk Court Design</th><th>Remark</th></tr>
<tr><td>1</td><td>Travel distance (Corridor + flat)</td><td><24+12 m</td><td>< 6+10 m</td><td>Roughly measured from drawing</td></tr>
<tr><td>2</td><td>Number/width of staircases</td><td>2 nos / 1,050 mm</td><td>2 nos / 1,070 mm</td><td></td></tr>
<tr><td>3</td><td>Staircase discharge capacity</td><td>2,335 persons</td><td>1,875 persons</td><td>The discharge capacity > the number of total occupants</td></tr>
<tr><td>4</td><td>Flat entrance door</td><td>½ hours fire rating</td><td rowspan="2">D1: Single Leaf 50 mm Thick Solid Core Flush Door (Self-Closing).</td><td rowspan="2">50 mm solid core timber door typically has FRR > 1.0 hour</td></tr>
<tr><td>5</td><td>Meter room door and Refuse room door</td><td>½ hours fire rating</td></tr>
<tr><td>6</td><td>Staircase door</td><td>½ hours fire rating</td><td rowspan="2">D12: Single Leaf Solid Core Flush Door with View Panel (Self Closing)</td><td rowspan="2">Code specifies ½ hours FRR for staircase door but self-closing only for kitchen door. Many kitchen doors have been replaced by non-FRR doors or left open during fire.</td></tr>
<tr><td>7</td><td>Kitchen door</td><td>Self-Closing (adjacent to flat exit door)</td></tr>
<tr><td>8</td><td>Staircase door lobby</td><td>Building height > 30 m, require a lobby between internal corridor and staircase</td><td>No lobby provided for Wang Fuk Court</td><td>The purpose of lobby is to prevent smoke spreading from corridor to staircase when an occupant opens the lobby doors for</td></tr>
</table>

				evacuation. For the fire at Wang Fuk Court, smoke entered into the staircase from external windows or worker access openings. Accordingly, the lobby would not help in this circumstance.
9	Wired Glass Windows (WGW) on external wall of lift lobby and staircase	½ hours fire rating if WGW is located in a light-well. A light-well is 4-side enclosed space.	Wang Fuk Court blocks' re-entrants are open on one side. WGW does not require FRR.	

- Codes of Practice on Provision of Means of Escape in Case of Fire and Allied Requirements (i.e. CoP 1976)

5.3.7. Based on Table 5.1, the following points are worth noting:

(a) At the time Wang Fuk Court was designed, a protected lobby with fire rated doors was required between the internal corridor and the staircase (i.e. there should have been two doors between the internal corridor and the staircase). However, at Wang Fuk Court there was only a single door with a ½-hour FRR between the internal corridor (i.e. lift lobby) and the staircase.

(b) At the time of design, a ½-hour FRR for wired glass window (i.e. WGW) was required for staircases and lift lobbies connecting to a lightwell for natural light. However, this requirement was exempted for re-entrant spaces with one open side.

5.3.8. Table 5.1 above summarizes the status of code compliance for the Wang Fuk Court blocks. Based on the as-built layout drawings, the design was largely compliant with the regulatory requirements in force at the time of construction.

5.3.9. To understand the status of the Wang Fuk Court buildings in current fire regulation system, the latest fire safety requirements are included for comparison with the design and the old Code of Practice in Table 5.2.

Table 5.2. Comparison of Wang Fuk Court building design with FS Code 2011 (2024 edition)

Item	Description	Original Code Requirement* (CoP 1976)	Wang Fuk Court Design	FS Code 2011 (2024 Edition) Requirement	Comparison & Compliance Review
1	Travel distance *(Corridor + flat)*	<24+12 m	<6+10 m *(Roughly measured)*	Max. 24 m inside flat to flat exit door, plus Max. 15 m from flat exit door to staircase/point of choice *(Clause B11.2(a))*	Compliant under FS Code 2011 (2024 edition)
2	Number / width of staircases	2 nos / 1,050 mm	2 nos / 1,070 mm	Min. 2 nos / Min. 1,050 mm *(Table B2)*	Compliant under FS Code 2011 (2024 edition)
3	Staircase discharge capacity	2,335 persons	1,875 persons	Based on Table B3, Discharge Value of 2 Staircase (Non-Sprinklered): 1,170x2=2,340 persons.	Compliant under FS Code 2011 (2024 edition)
4	Flat entrance door	½ hour fire rating	D1: Single Leaf 50 mm Solid Core Flush Door (Self-Closing)	FRR -/60/60 (with smoke seals) *(Clause C6.1 & Clause C9.3)*	Partially compliant with FS Code 2011 (2024 edition). The 50 mm solid timber core door has excellent fire resistance integrity, but modern codes mandate a certified smoke seal *(Clause C6.1(c))*, which was likely absent in original 1980s construction.
5	Meter room & Refuse room door	½ hour fire rating		FRR -/120/120 if opening directly into a protected exit route. *(Clause C13.1 for special hazards)*	Non-compliant with FS Code 2011 (2024 edition). FS Code 2011 classify meter rooms as "areas of special hazard," requiring a minimum of 2 hours (120 min) fire resistance rating (FRR) if adjacent to exit routes.
6	Staircase door	½ hour fire rating	D12: Single Leaf Solid Core Flush Door with View Panel (Self-Closing).	FRR equal to the staircase wall enclosure (minimum -/60/60 + Smoke Seals + Upper transparent view panel *(Clause C9.3 & C16.5)*	Non-compliant with FS Code 2011 (2024 edition). Doors must match the FRR of the staircase enclosure (which is at least 1 hour for high-rise residential blocks) and feature smoke seals to stop toxic smoke bypass.
7	Kitchen door	Self-Closing *(adjacent to flat exit door)*		FRR -/30/30 and Self-Closing (if adjacent to exit door). Alternatively, Open Kitchen design requires dynamic smoke detectors,	Non-compliant with FS Code 2011 (2024 edition). In typical tragic fires, many kitchen doors were either removed by occupants or failed. Under current codes, any kitchen adjacent to a single flat exit must have a certified 30-minute FRR door and partition, or be fully protected as an open kitchen.

Item	Description	Original Code Requirement* (CoP 1976)	Wang Fuk Court Design	FS Code 2011 (2024 Edition) Requirement	Comparison & Compliance Review
				sprinklers, and a 600 mm FRR wall *(Clause C13.3 & C13.4)*.	
8	Staircase door lobby	Required if building height >30 m	No lobby provided	Required for buildings where the highest floor is >20 m above ground level *(Clause B10.4(b))*	Non-compliant with FS Code 2011 (2024 edition). The FS Code 2011 strictly mandates a protected lobby between the internal corridor and the required staircase for buildings over 20 m high to prevent smoke migration during evacuation.
9	Wired Glass Windows (WGW) on external wall	½ hour fire rating if in a 4-side enclosed light-well.	Open on one side (re-entrant), WGW does not require FRR.	Must be imperforate with FRR ≥ staircase wall (e.g., -/120/120) if located within 6 meters of opposite unprotected openings *(Clause C9.7)*	Non-compliant with FS Code 2011 (2024 edition). The FS Code 2011 applies a 6-meter separation rule *(Clause C9.7)*. If the external windows of the lift lobby/flats are within 6 m of the staircase window (even in an open re-entrant), those staircase windows must be fire-rated and fixed closed to prevent external fire spread into the stairwell.

**Note: "Code requirement" refers to the older applicable Code of Practice on Provision of Means of Escape in Case of Fire (i.e. CoP 1976).*

6. SUMMARY OF VIEWS ON FIRE SPREAD AND RESULTING CASUALTIES

6.1. Overview

6.1.1. Based on the detailed analysis of fire spread mechanisms, building code compliance, fatality patterns, and experimental test data above, this Section summarises the key findings on the spread of fire and casualties in the Wang Fuk Court fire incident.

6.1.2. The findings may be limited by the current depth of analysis presented in the above sections, and supplementary report(s) will be prepared while additional analyses are conducted and concluded.

6.2. The re-entrant geometry created an uncontrolled chimney effect

6.2.1. The trapezoidal re-entrant spaces, open on only one narrow side, functioned as vertical chimneys. Computational fluid dynamics (i.e. CFD) simulations demonstrated that such geometries dramatically enhance flame height compared to open-wall or L-shaped configurations. As detailed in Appendix A, for a 50 MW fire at the base, flames exceeded 100 m in height—reaching the rooftop—within seconds, whereas a single flat wall produced flames of only 33 m under identical conditions. This geometry transformed a localised fire into a building-enveloping conflagration.

6.3. Combustible materials in the re-entrant (including non-FR materials) provided the fuel for rapid vertical spread

6.3.1. Large quantities of bamboo scaffolding, non-FR safety nets, canvases, toe boards, and polystyrene foam window covers were present within the re-entrant. These materials significantly increased the fuel load per unit volume. In particular, non-FR safety nets acted as continuous vertical wicks, enabling flame propagation across all 31 storeys within minutes (Section 3.6 to 3.8 above).

6.3.2. According to our experimental tests and the available evidence, bamboo members are likely to be ignited after the fire droplets of non-FR safety nets built up a sufficiently large fire through igniting combustible items on the ground (e.g. cardboard, wood panels). Therefore, the non-FR safety nets may have played an important role in initiating a fire to unlock the energy contained in bamboo sticks which would not otherwise have been ignited.

6.3.3. We agree with Professor Richard Yuen that if the safety nets and canvases at Wang Fuk Court were fire retardant, the initial fire may have self-extinguished and not caused the combustible materials inside the re-entrant to catch fire so the fire might not develop and the fire spread would have been much more minimal in Wang Fuk Court and less buildings would have been on fire (Section 2.13.4 and Section 4.2.15 of the Final Yuen Report).

6.4. Polystyrene foam window covers directly caused window failure and lateral fire spread

6.4.1. Full-scale fire tests (Tests 5 and 6, Appendix A-27(A) to the IFITF Final Report) demonstrated that polystyrene foam board covers caused kitchen window failure and the kitchen interior temperatures rise to 340–370°C. In contrast, tests without foam covers (Tests 3 and 4) showed interior temperatures remaining at or below 100°C, with windows remaining intact. The foam covers might have facilitated window breakage, allowing fire and hot gases to enter flats laterally.

6.4.2. Although our experimental tests showed that polystyrene foam board covers would quickly melt and drop off from the glass panels when subjected to heating (Section 3.6(a) above), based on the IFITF's large scale fire tests, we find that the presence of foam covers have caused or accelerated the thermal shock and subsequent breakage of window glass, enabling lateral fire and smoke spread into the interior (Section 4.1(c) above). We agree with Professor Richard Yuen's Key Observation (12) that although the total heat release from foam boards was minimal due to their small mass in re-entrant fires, they significantly promoted fire spread to other combustibles due to their ease of ignition and production of burning droplets, and additionally released toxic smoke, further increasing fire hazards (Section 2.11.9 of the Yuen Final Report).

6.5. Smoke infiltration into staircases and lift lobbies was the primary cause of fatalities

6.5.1. Wired glass windows (i.e. WGWs) on staircase and lift lobby external walls, which were not required to be fire-rated due to the re-entrant being classified as "open on one side," likely failed under the thermal exposure of the re-entrant fire. In our CFD simulations, staircase windows (or access doors) on every fifth floor were assumed to be fully open, consistent with observations that some wooden doors for worker access openings were wide open or had gaps and in any event were burnt through during the incident. These CFD simulations (Section 4.3(a) above) showed that smoke entered these protected escape routes within minutes of fire development. Within less than one minute, visibility in common corridors on lower floors dropped below 10 m, exceeding tenability thresholds.

6.5.2. Of the 81 fatalities in Wang Cheong House, 24 occurred in common corridors and staircases; in Wang Tai House, 38 of 82 died in these areas. These locations contained no significant combustible materials, confirming that smoke inhalation—not flame contact—was the likely cause of death. Furthermore, in flats such as Units [redacted]02 and [redacted]02, occupants died from smoke infiltration despite their flats sustaining no direct flame damage (Section 4.3(c) above).

6.5.3. We agree with Key Observations (5) and (13) of the Yuen Final Report, i.e. fire and smoke could infiltrate the staircase through the gaps and holes in the movable boards for worker access openings, even before they were completely burned out, and that the IFITF's test results indicate that both the wooden board and aluminium composite panel are unsuitable for protecting the staircase openings.

6.6. The ASET/RSET timeline analysis confirms that safe evacuation was impossible

6.6.1. Timeline analysis (Section 4.4 above) shows that the staircase in Wang Cheong House (Block F) was already heavily smoke-logged by 14:56–14:57, yet the vast majority of occupants had not been alerted due to a deactivated fire alarm system and polystyrene covers blocking their view of the external fire. The Available Safe Egress Time (i.e. ASET) for the primary escape routes effectively reached zero before the Required Safe Egress Time (i.e. RSET) could even begin.

6.7. The building design complied with CoP 1976

6.7.1. Table 5.2 above provides a direct comparison between the original CoP 1976, the as-built design of Wang Fuk Court (which was largely compliant with the CoP 1976, save for the absence of protected lobbies between the corridors and staircases), and the current FS Code 2011 (2024 edition). Key noncompliances under current standards under FS Code 2011 (which are not legally applicable to Wang Fuk Court) include:

(a) No staircase protected lobby (required for buildings >20 m high under FS Code 2011);

(b) Staircase doors lacking smoke seals and with FRR potentially less than the required 60 minutes;

(c) Meter room and refuse room doors with only ½-hour FRR, whereas FS Code 2011 requires 120 minutes if opening onto a protected exit route; and

(d) Wired glass windows in staircases and lift lobbies not fire-rated (contravening Clause C9.7 of FS Code 2011).

7. RECOMMENDATIONS ON PREVENTING FUTURE URBAN FIRE DISASTERS

7.1. Context of how temporary works in buildings are regulated

7.1.1. Most building regulations are primarily focused on fires originating inside building compartments. External fires in Hong Kong buildings are not considered likely as regulations expressly prohibit the use of combustible materials on building exterior facades (FS Code 2011 requires non-combustible materials on external façades).

7.1.2. Firefighting strategies and training are also focused on internal fires and these indeed form the vast majority of the fire emergencies in Hong Kong and the FSD has an exemplary track record of providing timely and effective response to such fires saving lives and protecting property, despite Hong Kong building fire loads being among the highest in the world (~1400 MJ/m^2) since it is one of the most densely populated urban environments in the world. There are heavily regulated high-rises with "subdivided flats" offering as little as 2–5 m^2 of living space per person.

7.1.3. Despite the requirement for non-combustible materials on building façades, combustible materials are allowed for temporary works as it is not considered a part of the building façade, leading to frequent fires in buildings under renovation and/or repair. What is even more notable is that the regulatory system allows occupants to continue inhabiting the buildings despite the entire building being enveloped in combustible materials, as happened in the case of Wang Fuk Court. The risk of the event that ultimately happened was severely exacerbated by multiple adjacent buildings being clad in the same envelope simultaneously for a prolonged period of time (well over one year), challenging the use of the term “temporary” in the temporary works involved.

7.1.4. This is a systemic failure and must be reviewed at the level of public policy and appropriate changes must be made in how temporary works are regulated. More detailed recommendations are provided below, however making changes at this level will require significant detailed studies and research in order to develop new regulations suitable for local conditions, without being excessively restrictive or cumbersome that they inhibit timely renovation and repair while also being sufficiently robust to prevent the recurrence of life threatening situations in the event of external fires related to temporary works.

7.2. Key observations and lessons from the Wang Fuk Court fire

7.2.1. Notwithstanding any changes in temporary work regulations that would simply not permit the simultaneous cladding of adjacent buildings in combustible materials for prolonged periods of time, there are more immediate actions that can be undertaken based on a proper understanding the events that led to the catastrophic consequences at Wang Fuk Court in Tai Po. These actions suggest themselves when one distils down to the most important critical events leading to an unbroken chain of events resulting in the catastrophe that ultimately materialized.

7.2.2. The order by which the following refers to links in the chain that led to the disaster do not necessarily reflect their comparative importance, as each factor would have played an important contributing role.

7.2.3. Collection of combustible materials and debris including foam boards and non-FR safety nets in all the re-entrants, which gave rise to an enveloping combustible cladding of temporary works, was clearly the reason for a strong enough secondary ignition source to be present that started the original re-entrant fire. The use of non-FR safety nets and canvases enabled a small initial fire to propagate and ignite the rest of the combustible materials which stored much more heat energy, such as bamboo members. This was the first link chain that led to the disaster.

7.2.4. The re-entrant geometry was the second link in the chain. Once the fire took hold and ignited the combustible lining of the re-entrant (consisting of plastics, including the safety nets, canvas, foam boards covering the windows and toe boards; and cellulosics, including bamboo scaffolding and wooden walking boards), the geometry of the re-entrant governed the fire development and extremely rapid upward spread which is unprecedented in the history of major building fires (up to a very high rate of 10 m/s, as evidenced from re-entrant fire videos) to beyond the top of a building almost like a volcano of very high velocity hot gases generating exceptionally intense radiative and enhanced convective heat fluxes to the interior surfaces of reentrant and also to the areas adjacent to the re-entrant.

7.2.5. The third link in the chain was the direct connection of the re-entrant space to the public areas including the fire escape staircases resulting in windows being broken during the reentrant fire (some of which were open or replaced by wooden boards by the workers for access) and ingress of smoke and hot gases blocking evacuation paths. As a result, many people were found dead in staircases, and other people had no choice but to stay inside the building and many died there both in public areas and apartment units.

7.2.6. The fourth link in the chain of disaster was the breaking of windows with single panes of glass located inside of the re-entrant facade in less than a minute (because of the extremely high incident heat fluxes) and spreading the fires directly into the apartment units. It is noteworthy that the effect of this in the interior of the reentrant façade did not cause the greatest damage as the windows broken as a result opened into the kitchen and into the entrance hallways which in most cases (except a few) did not allow the fire to spread to the rest of the unit because of a lack of combustibles in these areas.

7.2.7. The fifth link in the chain was the breakage of the living room windows. These were adjacent to the re-entrant but not inside it. Videos show flames spilling out of the reentrant opening engulfing these windows. These flames ignited the combustible temporary works lining in front of these windows producing high enough a heat flux to break them within the duration of the re-entrant fire. This enabled fires to find another route to enter the apartment units directly and, in many cases, caused the burnout of the high fuel loads in many of the units. It also contributed to secondary fire spread internally from unit to unit, both vertically and laterally.

7.2.8. The final link in the chain of disaster was the spreading of the fire from the first re-entrant fire to other re-entrants in the same building and then on to re-entrants in neighboring buildings because of fire induced fountains of embers ejected at high velocity above the buildings which then turned into firebrands (burning embers big enough but light enough to travel long distances driven by the high winds without getting extinguished and spreading the fire to distant locations). All of the combustibles (including the non-FR safety nets) are likely to have contributed to the firebrand production. These firebrands were the key to spreading the fire to other re-entrants igniting them at multiple locations including igniting any collected debris at the base of the re-entrants. This cycle repeated a dozen times (half of the 24 re-entrants in total) primarily driven by the reentrant geometry that ultimately engulfed the entire estate. The re-entrant fires acted as an engine that drove a cascading disaster, like a series of explosives in a chain.

7.2.9. Extraneous factors like the weather with unusually low humidity and high winds further exacerbated and facilitated this chain of events. Alarms in 6 of the 8 buildings were not functioning and the foam boards covering the windows blocked vision and sound, which prevented safe evacuation and contributed to an extremely high casualty count.

7.3. Recommendations that can be implemented with immediate effect

7.3.1. Based on the findings in this Report, the following recommendations are made for immediate action when building maintenance and renovation works are carried out:

(a) **Stricter oversight to be maintained over temporary works materials**: There should be stricter oversight to ensure that all the materials used in temporary works, such as protective and safety nets, foam boards and toe boards have been adequately treated with fire retardant compounds with proper certification and source identification. Cellulosic materials such as bamboo scaffolding and timber walking boards must also be treated with fire retardant materials and used with care in areas where they can contribute to or exacerbate the fire hazard.

(b) **Prohibition of combustible materials in re-entrant spaces:** During any building maintenance and renovation works, no combustible materials (including bamboo scaffolding, wooden toe boards, polystyrene foam, or unprotected plastic sheeting) shall be used, stored or installed within re-entrant spaces. Metal scaffolding with fire-retardant decking shall be used as an alternative in re-entrants.

(c) **Prohibition of non-FR safety nets and other external temporary materials, including polystyrene foam window covers:** Safety nets, canvases and other required temporary protective materials in the scaffolding must be strictly fire resistant. The use of polystyrene foam or any similarly combustible material as window coverings on external façades shall be prohibited. Alternative protective measures (e.g. removable fire-retardant canvas or mesh) shall be required to meet a minimum Class B fire classification.

(d) **Prohibition of combustible materials in façades and ground level exits of occupied renovated buildings:** Where it is unavoidable that occupants must be present in buildings during maintenance and renovation works:

- No combustibles should be allowed on any part of the building façade that could enable heat and smoke to enter the building and block evacuation routes.

- No combustibles should be present above the ground level exits that could allow materials from the temporary works to fall and block exits. So, for instance, no bamboo scaffolding should be allowed immediately above the exits, and non-combustible metal scaffolding should be used (ideally with metallic netting as well) near these exits.

(e) **Ban on multiple-building simultaneous cladding:** Do not permit simultaneous cladding of high-rise buildings with combustible temporary works that are adjacent or in the vicinity of each other. Repair and renovation works can be arranged in a coordinated manner by the local authorities. This will prevent the compounding of any disaster through spreading beyond the origin of fire.

(f) **Stricter approvals for renovation works involving re-entrants:** In addition to the duration of the project, other considerations in the approval of the building maintenance and renovation works and corresponding fire safety measures should include any special features of the building, such as its geometry, distribution and locations of windows and openings and any exits and entrances, provision of refuge floors etc.

- Any architectural features like re-entrants which could create conditions for hazardous heat fluxes on any portion of the building façade containing openings or windows that could provide a route for the fire and smoke to enter the building and block evacuation routes should be considered. The building usage and the age and vulnerability profile of the occupants could also be considered in the approval process.

- Relatedly, architectural features such as the re-entrants in Wang Fuk Court should be considered as a special kind of vertical shaft in a building, and any renovation or repair of such areas must follow the fire regulations mandated for vertical shafts inside buildings (in the aftermath of the Garley Building lift shaft fire, which bears some similarity to this event).

(g) **Caution against the occupation of renovated buildings and supply additional FSI protection:** Residents may be cautioned against occupying high-rise buildings under maintenance and renovation, and the regulatory bar should be raised where this is considered unavoidable by providing fool-proof safety procedures for ensuring occupant safety in the event of a fire. This may require installing redundant FSI systems before the commencement of the building maintenance and renovation work as part of temporary works undertaken. The requirement of redundant safety measures must be modulated based on the projected duration of the works, with additional measures mandated for longer duration projects. For projects lasting longer than an acceptable duration, the provision of alternative accommodation for all or the most vulnerable occupants (based on ability and the height of the floor they occupy and distance from the exits) should be considered.

(h) **Fire-rated glazing for staircase and lift lobby windows:** All external windows of staircases and lift lobbies that face into re-entrant spaces or are within 6 metres of any unprotected opening shall be retrofitted with fixed, fire-rated glazing achieving integrity and insulation of not less than 60/60 minutes, in accordance with Clause C9.7 of FS Code 2011.

(i) **Improved monitoring of renovation works:** Once the building maintenance and renovation work starts, continuous monitoring of the site should be undertaken using currently available manpower and automated monitoring systems based on computer vision (as a component of the redundant FSI systems) with independent detection and potentially (where feasible) suppression systems. The monitoring system should also be able to identify debris accumulation and any other fire hazards that could present a secondary ignition source.

(j) **Strengthened training of workers:** Site workers must receive regular training to maintain a high level of awareness of fire hazards and maintain vigilance to reduce the probability of fire initiation on site. They could also be trained to take preventive actions and immediately report any anomalies to the site supervisors.

(k) **Fire drills and enhanced communication with occupants and workers**: An intensive induction of occupants and workers must be conducted before the commencement of the building maintenance and renovation works, followed by routine fire drills to ensure that all occupants and workers remain prepared and ready to act when an emergency presents itself.

(l) **Coordination with building management on fire safety:** The building management structure (through property management companies and owners' corporations) and their coordination with the Mandatory Building Inspection Scheme regime should be reviewed to ensure that fire safety remains a paramount consideration when any major building maintenance and renovation works are undertaken.

7.4. Recommendations that require further study and research

7.4.1. A well thought out and well-designed risk-based methodology must be developed for approval of building maintenance and renovation works for all buildings in Hong Kong, enabling a bespoke building specific temporary works solution to be implemented with appropriate safety measures including redundant FSI.

7.4.2. There should be development of new, less combustible, light-weight protective materials that could be used in temporary works.

7.4.3. There should also be development of bespoke redundant FSI systems especially for temporary works (such as temporary sprinkler systems).

7.4.4. Dedicated software (e.g. "apps") for each building could be developed to provide personal information, reporting and alarm portals to each resident, including live video feeds. The more eyes on potential fire risks, the more the likelihood of early fire detection.

7.4.5. In the longer term SureFire based technologies (Section 8 below) could enable real time monitoring of high-risk sites using digital twins and identifying the most serious potential hazards and disaster scenarios in advance through artificial intelligence (**AI**) based simulations and AI based automated building safety management.

7.5. Recommendations for policy level research and consultation

7.5.1. Building regulations, codes of practice, building codes and standards etc. provide essential guidance to engineers and practitioners and compliance with them ensures a certain level of assurance of safety against severe demands during the life of a building. The flip side of this is that often compliance with regulations and codes is seen as adequate by highly cost-conscious clients and the construction industry promoting a tick-box culture of ensuring safety against expected hazards that a building may face in its lifetime.

7.5.2. As a society we must address this culture and promote more rigorous engineering analyses and judgement to be exercised, especially when making decisions that could have a bearing upon the life safety implications of an engineering design. Since every building project is different and may have features that may throw up unforeseen challenges to occupant safety, a certain level of rigour and engineering judgement should be mandated through the approval process, whether it is for new projects or for building repair, rehabilitation or renovation projects.

7.5.3. Without the risk of 'throwing the baby out with the bathwater', it is recommended that a committee is formed to review Hong Kong building regulations and codes of practice to ensure that some level of responsibility is borne by the owners, designers, operators and managers of buildings when things go wrong and compliance with regulations should not become a shield for them.

8. RECOMMENDATIONS ON FIRE FIGHTING

8.1. Observations from the incident

8.1.1. In addition to revisiting building regulations in the context of temporary works, it will also be very important to reevaluate the prevailing strategies for firefighting and emergency response in the events of future catastrophic events on the scale of Wang Fuk Court. In the long run there would naturally be gradual progress towards technology driven firefighting and emergency response (as envisaged in the recently concluded SureFire project, explained below), exploiting AI, sensing, robotics, unmanned aerial vehicles (**UAV**) and other such emerging technologies.

8.1.2. According to the IFITF Interim Report, the Fire Services Communications Centre (**FSCC**) received the first building fire call at 1451. The Senior Station Officer (**SStno**) arrived on site at 1456, indicating a five-minute response time and demonstrating that frontline firefighting response was both effective and efficient.

8.1.3. During firefighting operations, the Pre-determined Attendance (**PDA**) alarm level was escalated as follows:

- No. 1 Alarm at 1451;
- Upgraded to No. 3 Alarm at 1502;
- Upgraded to No. 4 Alarm at 1534; and
- Upgraded to No. 5 Alarm at 1822.

8.1.4. Resource deployment increased significantly in line with (and ultimately beyond) the PDA levels. The level of resource committed to the incident exceeded the standard PDA requirements. Even though there was a significant delay in upgrading No. 4 Alarm to No. 5 Alarm, the PDA deployed at No. 4 Alarm had already exceeded No. 5 Alarm requirements. It could be argued that the 32-minute delay in raising No. 4 Alarm was perhaps too much. However, it is difficult to determine if this had any significant effect on worsening an already disastrous situation.

8.1.5. Since the incident was unprecedented in both scale and circumstances, therefore, within such an extreme context, in practical terms very limited additional action that the FSD could have taken on site to materially alter the outcome. Accordingly, the recommendations in this section concern future general building fires and are not intended as criticism of the FSD's performance in this specific incident.

8.2. SureFire: Smart Urban Resilience and Firefighting

8.2.1. Since 2000, PolyU has conducted a comprehensive research programme titled "Smart Urban Resilience and Firefighting" (SureFire). The aim is to integrate:

- Smart building technologies
- State-of-the-art fire simulation
- An event-library forecasting database (big data)
- Artificial Intelligence (AI)

to provide real-time forecasts of critical fire events and to support decision-making by firefighters and incident commanders.

8.2.2. A high-level framework divides SureFire into three main work packages, centred around a Digital Twin that coordinates Building Information Modelling (**BIM**) and Internet-of-Things (**IoT**) technologies. The system continuously monitors a building or infrastructure facility and, in the event of a fire, activates an AI subsystem that:

- Generates forecasts of fire and structural behaviour;
- Relays decision-support information to fire crews; and
- Highlights probable critical events, including expected time and location.

SureFire focuses particularly on:

- Networking (data acquisition and communication); and
- Forecasting (AI-driven incident evolution and impact analysis),

as these pose the most significant research challenges and underpin the desired capabilities.

8.2(a) SureFire key system components and functions

8.2.3. The main components of the SureFire system and their roles are:

(a) Digital Twin:

- Uses BIM to create a digital twin of target buildings, incorporating the sensor network.
- Establishes an IoT framework for continuous updating of the digital twin in real time.
- Develops efficient methods to construct a geometric model for existing buildings where no BIM model is available.

(b) Networks for Data Collection:

- Collects real-time data from sensors at the emergency location.
- Relays data to the central command and control (**C&C**) system for processing and decision support.

(c) Data Analysis, Incident Simulation and Forecasting:

- Develops and deploys the Event Library Forecasting (**ELF**) concept.
- Uses a large ELF database, big-data analytics, and AI/machine learning to train models for practical implementation.
- Employs sensor-steered, AI-based simulation tools to:
  - Forecast fire evolution;
  - Assess structural impact; and
  - Analyse response options and evacuation strategies.
- All computations are designed to run faster than the real-time progression of the fire.

(d) Feedback to Incident Venue:

- Continuously sends updated forecasts to actuators, C&C, and the Incident Commander (**IC**).
- Presents information in formats easily understood and quickly actionable by users.

(e) Smart Emergency Response

- Enhances coordination between C&C, IC, and frontline firefighters.
- Provides clear, unambiguous execution support to minimise delays and reduce operational errors.

8.2(b) Enhancing communication resilience: wireless sensor networks and self-healing

8.2.4. Research on networks for data collection has implemented indoor Wireless Sensor Networks (**WSN**) in smoky environments, where it is challenging to visualise conditions or localise deployed sensors. The research work included the use of UAVs to:

(a) Deploy ad hoc wireless sensors to obtain live data for real-time prediction; and

(b) Drop replacement wireless sensor nodes to achieve "self-healing" of the network when parts of it are damaged by fire.

8.2.5. The self-healing mechanism is intended to restore and maintain communication pathways even when the original network is disrupted. This is directly relevant to firefighter safety: frontline personnel often operate in highly dangerous conditions and may lose communication with the Incident Commander (i.e. IC), which has contributed to fatalities, including the firefighter who tragically died in the Wang Fuk Court fire.

8.3. Recommendations

8.3.1. In addition to the existing communication system, it is recommended to develop and adopt wireless sensor–based, self-healing communication networks to provide multiple, redundant communication channels between frontline firefighters and the IC. This would:

(a) Improve the reliability of voice and data links in compromised environments;

(b) Reduce the likelihood of losing contact with firefighters operating in hazardous zones; and

(c) Enhance situational awareness and decision-making for both IC and crews on the ground.

8.4. Fire statistics

8.4.1. The level of fire safety of a community is directly related to the quality of services of the FSD. The risks associated with fires are commonly assessed based on the number of incidents in different types of buildings, as well as the resulting fatalities and injuries. In terms of the overall level of fire safety in Hong Kong, when compared with the overseas countries reviewed, Hong Kong has historically demonstrated a strong record based on the benchmark of fire deaths per million population per year, as shown in the table below.

Country or Region	Statistical results
Hong Kong	3.5 deaths per million population (Hong Kong Monthly Digest of Statistics, 2002 and Hong Kong Year Book, 2000)
Australia	10.0 deaths per million population (Narayanan and Whiting, 1996)
Sweden	15.4 deaths per million population (Narayanan and Whiting, 1996)
Japan	16.0 deaths per million population (Narayanan and Whiting, 1996)
UK	18.1 deaths per million population (Narayanan and Whiting, 1996)
USA	26.3 deaths per million population (National Fire Data Centre, 2002)

8.4.2. The International Association of Fire and Rescue Services (**CTIF**) regularly issues reports on global fire statistics. From 1993 to 2023, the report has compiled data from 27 to 57 countries / regions worldwide, representing populations ranging from 0.9 to 3.8 billion people. In 1993, the 39 countries / regions surveyed accounted for approximately 40% of the world's population. In 2008, the 31 countries / regions included in the survey represented more than 50% of the global population.

8.4.3. The number of countries / regions included in the survey varies from year to year, depending on data availability and reporting practices. On average, the report covers about 40 countries and regions, with a combined population of over 2.3 billion. The statistical data provide insight into several key trends, including the number of fires per 1,000 inhabitants, the number of fire deaths per 100,000 inhabitants, and the number of fire deaths per 100 fires. These indicators help to assess the level of fire risk faced by the general public in the surveyed areas.

8.4.4. The main findings from the 31-year survey are as follows:

(a) The average number of fires per 1,000 inhabitants: 1.6

(b) The average number of fire deaths per 100,000 inhabitants: 1.6

(c) The average number of fire deaths per 100 fires: 1.0

8.4.5. The Hong Kong FSD publishes statistical information annually. The results of statistics for Hong Kong from 2005 to 2024 are given below:

(a) The average number of fires per 1,000 inhabitants: 1.07

(b) The average number of fire deaths per 100,000 inhabitants: 0.26

(c) The average number of fire deaths per 100 fires: 0.31

8.4.6. These results show that fire fatalities in Hong Kong were significantly lower than the global average fire fatalities. Unfortunately, the tragic fire at Wang Fuk Court has re-written the fire safety history of Hong Kong. The Wang Fuk Court fire itself contributed to 2.24 deaths per 100,000 inhabitants, which is significantly higher than the previous statistical average in Hong Kong and illustrates the unprecedented nature of the incident. It suggests that collaborative efforts from various Government departments and the whole society are required to ensure public fire safety.

8.4.7. In particular, the Wang Fuk Court incident illustrates that:

(a) Strong firefighting performance and fast response from the FSD cannot fully compensate for weaknesses in building design, maintenance, management or user behaviour.

(b) Effective fire risk reduction requires coordinated action by multiple Government departments, such as housing, buildings, planning, and education, so that fire safety is considered in policies on building control, public housing, and care for vulnerable groups.

(c) Building owners, owners' corporations, property management companies and professionals (e.g. engineers, fire service contractors) must take shared responsibility for proper design, installation, inspection and maintenance of fire service installations and equipment, as well as for safe management of common areas, escape routes and fire loads.

(d) Residents and the general public need to be continuously educated and engaged on fire prevention, safe use of combustible materials, proper use of escape routes, and appropriate responses during an emergency.

(e) Continuous review and enhancement of legislation, codes of practice, enforcement strategies, data collection, and post-incident learning are needed so that experience from serious fires, including the Wang Fuk Court fire, can be translated into practical improvements.

(f) Develop future firefighting solutions such as UAV based fire sensing and forecasting, UAV and robot based firefighting for high-rise building fires.

8.4.8. Only through this kind of integrated, system-wide and collaborative approach – involving the FSD, other Government departments, professionals, building owners and managers, and the public at large – can Hong Kong maintain and further improve its favourable fire statistics, and reduce the likelihood and consequences of future catastrophic fire events.

9. EXPERT DECLARATIONS

(a) I declare and confirm that I have read the Code of Conduct for expert witnesses as set out in Appendix D to the Rules of the High Court (Cap. 4A) and agree to be bound by it. I understand that my duty in providing this written report and giving evidence is to assist the Committee. I confirm that I have complied and will continue to comply with my duty.

(b) I know of no conflict of interest of any kind, other than any which I have disclosed in my report.

(c) I do not consider that any interest which I have disclosed affects my suitability as an expert witness on any issues on which I have given evidence.

(d) I will advise the Committee if, between the date of my report and the hearing of the Committee, there is any change in circumstances which affect my opinion above.

(e) I have been shown the sources of all information I have used.

(f) I have exercised reasonable care and skill in order to be accurate and complete in preparing this report.

(g) I have endeavoured to include in my report those matters, of which I have knowledge or of which I have been made aware, that might adversely affect the validity of my opinion. I have clearly stated any qualifications to my opinion.

(h) I have not, without forming an independent view, included or excluded anything which has been suggested to me by others, including my instructing lawyers.

(i) I will notify those instructing me immediately and confirm in writing if, for any reason, my existing report requires any correction or qualification.

(j) I understand that:

- My report will form the evidence to be given by me;

- Questions may be put to me in writing for the purposes of clarifying my report and that my answers shall be treated as part of my report and covered by my statement of truth;

- The Committee may at any stage direct a discussion to take place between the experts for the purpose of identifying and discussing the expert issues in the inquiry, where possible reaching an agreed opinion on those issues and identifying what action, if any, may be taken to resolve any of the outstanding issues between the parties;

- The Committee may direct that following a discussion between the experts that a statement should be prepared showing those issues which are agreed, and those issues which are not agreed, together with a summary of the reasons for disagreeing;

- I may be required to attend the hearing of the Committee to be cross-examined on my report by Counsel of other party/parties;

- I am likely to be the subject of public adverse criticism if the Committee concludes that I have not taken reasonable care in trying to meet the standards set out above.

Statement of Truth

I believe that the facts stated in this expert report are true and the opinion expressed in it is honestly held.

Dated this 15th day of June 2026

___[redacted]____ ___[redacted]____

Professor Asif Sohail Usmani Professor Jiang Liming

APPENDIX A -
RESULTS OF CFD SIMULATION

1. Re-entrant Chimney Effect

1.1. Background

1.1.1. High-rise residential buildings at Wang Fuk Court in Tai Po incorporate re-entrant spaces, also known as re-entrance bays or light wells (Figure 1). These semi-enclosed vertical shafts, formed by adjacent apartments, are designed to provide natural ventilation and daylight under normal operations.

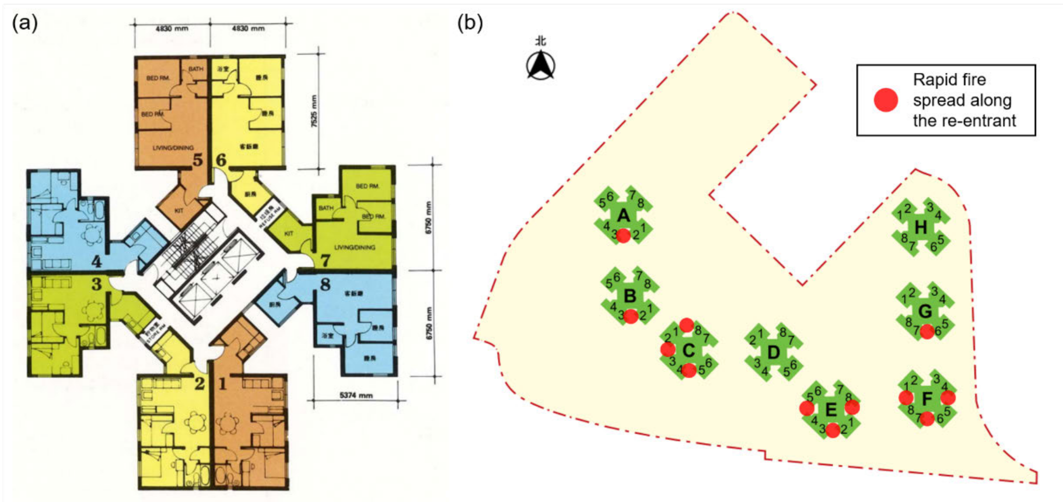


Figure 1. (a) Typical floor plan (Wang Cheong House) of Wang Fuk Court buildings, and (b) re-entrant fire locations where the chimney effect occurred.

1.1.2. However, the fire at Wang Fuk Court on 26 November 2025 demonstrated how these re-entrants, when combined with external renovation materials, including bamboo scaffolding, non-fire-retardant mesh netting, and polystyrene window protection foam boards, significantly amplified vertical fire spread. The incident resulted in rapid upward propagation across multiple 31-storey blocks (Figure 1b), with flames climbing through a combination of re-entrant geometry and external scaffolding. The re-entrants functioned as vertical conduits, which drew fresh air in at lower levels and expelled hot combustion gases and products at the top (Figure 2). Most compartments adjacent to the affected re-entrants suffered severe damage, indicating that vertical fire spread also facilitated horizontal spread into the compartments.

Therefore, the re-entrant design was key factor, accelerating vertical fire spread during the incident.

Figure 2. Chimney effect observed at (a) Wang Cheong House west re-entrant and (b) Wang Yan House south re-entrant, and (c) combustible scaffolding burning along the re-entrant (credit to RTHK and HK01).

1.1.3. This appendix examines the chimney effect in re-entrant configurations using computational fluid dynamics (i.e. CFD) modeling, with a focus on how re-entrant open area and design influence flame behavior and critical heat release rates (i.e. HRRs) for the flame reaching the building rooftop.

1.2. Chimney effect phenomena

1.2.1. The chimney effect, also known as the stack effect, refers to buoyancy-driven vertical airflow in an enclosed or semi-enclosed space caused by temperature-induced density differences [1–3]. Hot combustion gases rise within the vertical shaft, creating negative pressure at the base that induces inflow of ambient air. This enhanced oxygen supply accelerates combustion, increases the HRR, and promotes upward flame spread [4].

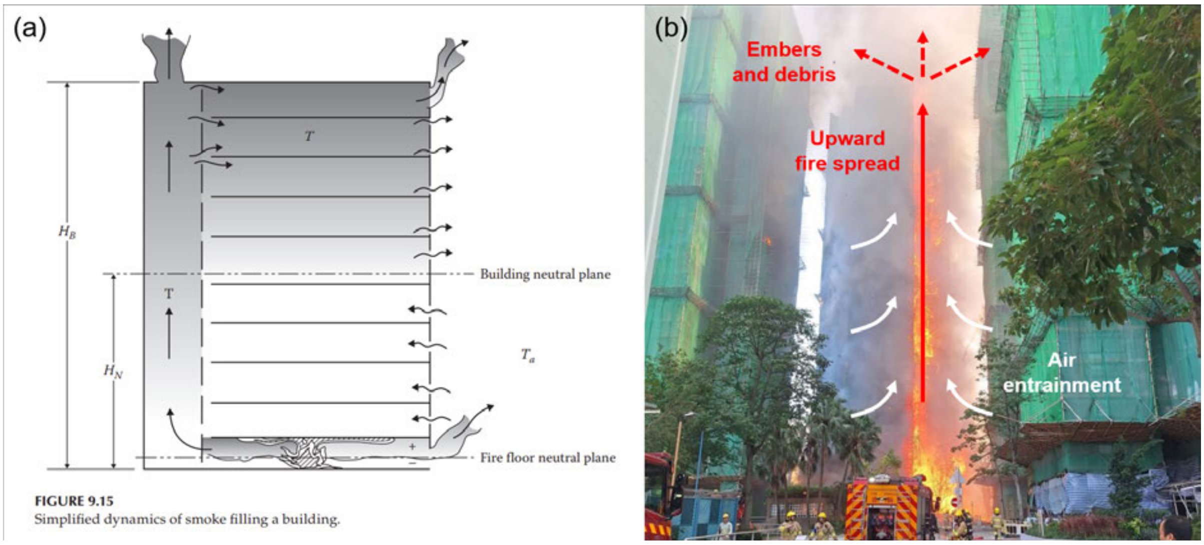


Figure 3. (a) Fire spread mechanics driven by chimney effect [5] and (b) chimney effect at Wang Cheong House west re-entrant.

1.2.2. In re-entrant spaces, the geometry acts as a partial chimney, which allows rapid vertical propagation of flames and smoke. The enclosed walls restrict lateral entrainment, while the open face allows air entrainment (Figure 3). The pressure differential ΔP is quantified by the stack effect equation:

$$\Delta P = cah(\frac{1}{T_o} - \frac{1}{T_i}) \quad (1)$$

where c equals to 0.0342 K/m, a is atmospheric pressure, h is height, and T_o and T_i are outside and inside absolute temperatures. For a 100 m tall re-entrant with a 200 to 400 °C fire smoke plume, ΔP can exceed 400 to 650 Pa, generating significant draft velocities. The chimney effect draft flow rate Q can be determined by using Eqn. 2. The resulting flow rate could further intensify the fire.

$$Q = CA\sqrt{2gh\frac{T_i - T_o}{T_i}} \quad (2)$$

where C is discharge coefficient (ranging from 0.65 to 0.7), A is flow area, and g is gravitational acceleration.

1.2.3. In the Wang Fuk Court incident, renovation materials (e.g. bamboo, non-fire-retardant safety nets) added substantial fuel load (Figure 2c), which intensified the fire size and temperature, and thereby strengthened the chimney effect.

Flame heights within the re-entrants were observed to be significantly greater than in open-air scenarios. The combination of vertical scaffolding fuel load and the chimney effect enabled the fire to spread vertically from lower to upper levels within minutes. Additionally, an external chimney effect facilitated fire spread between blocks through falling embers and firebrands.

1.3. Numerical model

1.3.1. A CFD model was developed using Fire Dynamics Simulator (**FDS**) to simulate the Wang Fuk Court re-entrant configuration. The building geometry was simplified, with focus on the re-entrants. The model represented a 31-storey re-entrant bay approximately 100 m in height, based on Wang Cheong House. Vertical scaffolding fuel load and wind effect were not considered in the model. Four re-entrant shapes were simulated to represent increasing levels of lateral confinement, including single flat wall (Case 1), L-shaped corner wall (Case 2), semi-enclosed Wang Cheong House south re-entrant (Case 3), and semi-enclosed Wang Cheong House east re-entrant (Case 4), as shown in Figure 4. The detailed simulation parameters are shown in Table 1.

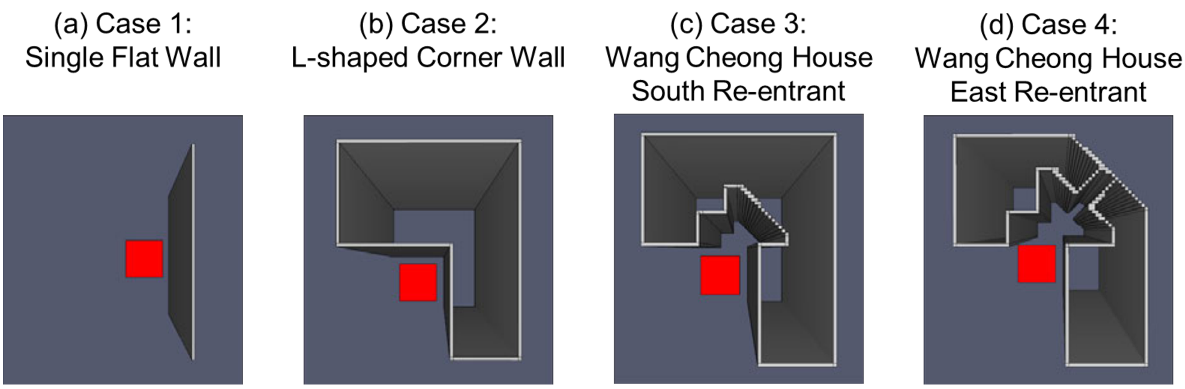


Figure 4. Re-entrant models of (a) Case 1: single flat wall, (b) Case 2: L-shaped corner wall, (c) Case3: Wang Cheong House south re-entrant, and (d) Case 4: Wang Cheong House east re-entrant.

1.3.2. The fire source was positioned 1 m outside the re-entrant to simulate accumulated fallen bamboo forming a large ground-level fire. The burning area is 5 × 5 m^2. Different HRRs were tested to determine the minimum value capable of producing a flame height reaching the roof of the building (100 m). The flame height is defined by the continuous flame area where the HRRPUV is approximately 100 kW/m^3.

Table 1. The computational setting for the numerical simulations for the re-entrants

Parameters	Value	Remark
Total height (m)	100	The building height of Wang Fuk Court blocks is 93 m.
Re-entrant's shape	/	Single flat wall; L-shaped corner wall; Wang Cheong House south and east re-entrant.
Computational domain (m^3)	18 × 18 × 120	Only one re-entrant is considered.
Dimension of fire source (m^2)	5 × 5	Simulating the fallen bamboo accumulating outside the re-entrant.
HRR (MW)	25 – 75	The fuel load of accumulated bamboo is large as observed in the fire.
Soot yield (g/g)	0.015	
Cell size (m)	0.2	

1.4. Flame height affected by re-entrant designs

1.4.1. Flame height and vertical fire spread behavior are strongly influenced by re-entrant design and the resulting chimney effect. Unlike open-air or fully compartmented fires, where the fire size and flame height are limited by fuel load and air supply, re-entrant geometries introduce varying degrees of confinement that could influence fire plume dynamics, air entrainment patterns, and radiation feedback. Simulation results show that flame height increases as the re-entrant transitions from minimal enclosure (single flat wall) to moderate enclosure (L-shaped corner wall) and high enclosure (semi-enclosed re-entrants in Wang Cheong House). These designs enhance buoyancy-driven flows, producing taller flames and accelerating vertical fire spread, even when the fire source is positioned outside the re-entrant.

1.4.2. In a single flat wall re-entrant (Case 1) with only one vertical wall bounds the fire plume. This allows nearly unrestricted air entrainment from three sides (i.e. like open-air fire). For a 50 MW fire at the base of a 100 m height configuration, simulation results show that the flame height is approximately 33 m (Figure 5a). The plume rises vertically with minimal chimney effect, as ambient air mixes from multiple directions (i.e. three sides except the wall), diluting hot gases and reducing buoyancy effect and upward momentum. This design offers the least enhancement to the chimney effect due to limited radiant heat trapping and directional buoyancy forces.

1.4.3. The L-shaped corner-wall re-entrant (Case 2), formed by two perpendicular walls, introduces moderate confinement. The two walls restrict entrainment to roughly half the plume circumference. For the same 50 MW fire, flame height increases to approximately 41 m (Figure 5b), which is higher than that of the single-wall case. Buoyancy-induced draft draws the flame plume toward the corner intersection, even with the ignition source 1 m outside. Cool air rushing in from the open sides creates a preferential flow path into the enclosed space, rapidly migrating external flames into the vertical channel.

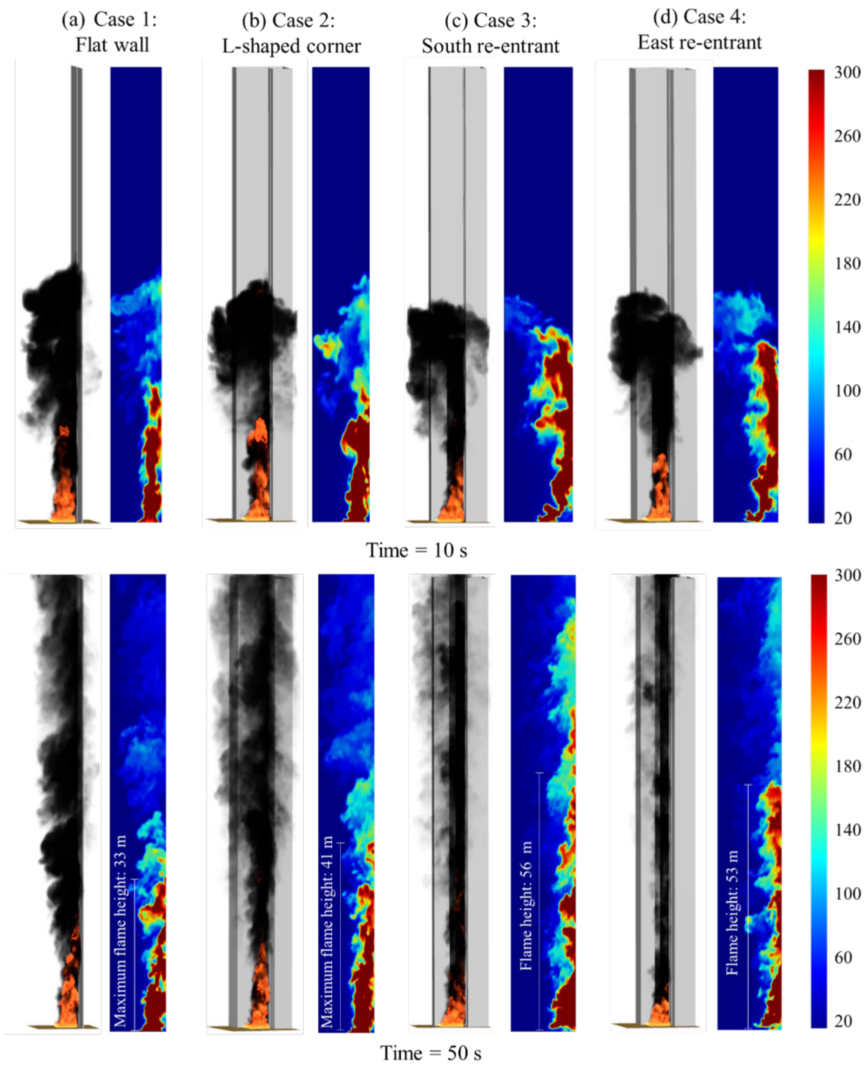


Figure 5. Visualization of fire smoke plumes and temperature contours of a 50 MW fire for (a) Case 1: single flat wall, (b) Case 2: L-shaped corner wall, (c) Case 3: Wang Cheong House south re-entrant, and (d) Case 4: Wang Cheong House east re-entrant.

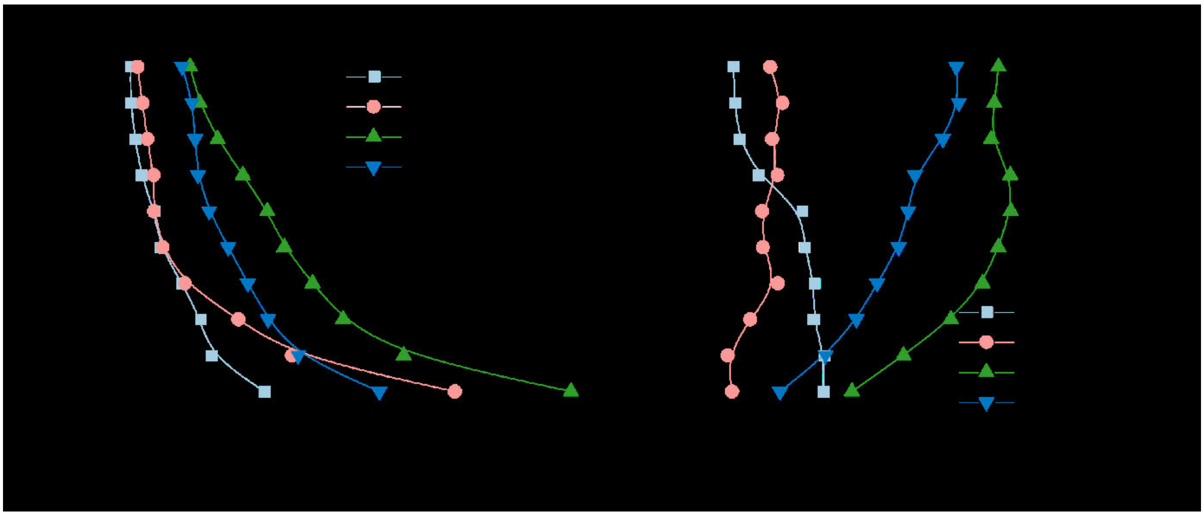


Figure 6. (a) Temperature and (b) velocity profiles for different cases.

1.4.4. The semi-enclosed re-entrants of Wang Cheong House south (Case 3) and east (Case 4) form narrow vertical shafts open on only one face, similar to an enclosed chimney. Simulations with a 50 MW fire show that the flame can instantaneously travel exceeding 100 m in some times (Figure 5c-d). Air entrainment becomes highly directional: fresh oxygen enters through the open face at lower levels, while hot gases exit at the top, establishing a strong stack flow. Even with the fire burning 1 m outside, the geometry pulls the plume inward within the first 10 seconds. The flame anchors against the back wall and extends upward along the full 100 m height. This entrainment-driven attachment occurs because the confined space generates negative pressure that overcomes the natural vertical rise of an open plume. These dynamics help explain the rapid vertical propagation observed across multiple storeys in the Wang Fuk Court fire.

1.4.5. In the more enclosed Case 3 and Case 4 re-entrants, gas temperatures are higher due to radiation feedback from the re-entrant walls. The enclosed surfaces reflect radiant heat back toward the flame and fuel surface (i.e. bamboo and plastic mesh safety nets). Results show that the temperature and velocity reach approximately 200°C and 20 m/s at mid-height in the south re-entrant (Case 3), compared to about 70°C and 8 m/s in the single flat wall case under identical conditions (Figure 6). This also amplifies buoyancy forces and drives faster upward acceleration of the plume. Hotter gases rise rapidly, drawing in more air and generating even taller flames. Therefore, flame height increases as enclosed volume decreases. Smaller re-entrant cross-sections intensify both the chimney effect and radiation feedback while still supplying sufficient oxygen through the open face.

1.4.6. These fire behaviours have implications for the Wang Fuk Court re-entrant chimney effect that was observed. The Wang Fuk Court blocks featured semi-enclosed re-entrants with additional external confinement from bamboo scaffolding and plastic mesh safety netting, effectively reducing the open-face area and mimicking even tighter chimney channels. Simulations replicating reduced open-face areas produced flame heights above 56 m, sufficiently high enough to ignite materials on upper floors. The inward pull of external flames was observed when ignition was simulated on scaffolding outside the re-entrant. Higher wall radiation feedback also explains the rapid involvement of combustible scaffolding materials, which added HRR and sustained the buoyancy loop even under partially under ventilated conditions.

1.5. Critical HRR and flame height

1.5.1. The critical HRR represents the threshold value at which a fire in a re-entrant generates sufficient buoyancy to drive flame height to the full 100 m building height. This HRR enables complete vertical fire spread through the chimney effect. Once the flame reaches the full building height, hot gases and flames can ignite the combustible materials in upper levels and external scaffolding, which lead to rapid vertical propagation across floors and spread to adjacent blocks via embers and debris.

1.5.2. Numerical simulations also focused on identifying the critical HRR for the Wang Cheong House south re-entrant (Case 3). Results indicate that a 50 MW fire is capable of producing a flame height continuously reaching 50 m height in this configuration (Figure 7c-d). The narrow geometry enhances radiation feedback and restricts lateral entrainment, raising gas temperatures and strengthening the chimney effect. This allows flames to reach roof level at a relatively lower HRR compared with more open designs.

1.5.3. Below the critical HRR, flames remain intermittent and confined to the lower 30 to 40 m (Figure 7a-b). Once the critical HRR is exceeded, flame height increases, with continuous external flaming at the roof. As shown in Figure 8a, sustained gas temperatures above approximately 200°C at upper levels could provide sufficient radiant and convective heating, making the materials in the upper floors easier to ignite. Figure 8b further shows that a larger HRR leads to higher gas velocities at elevated floors, which may enhance upward flame spread and accelerate the transport of hot gases and firebrands, thereby increasing the fire risk in upper floors.

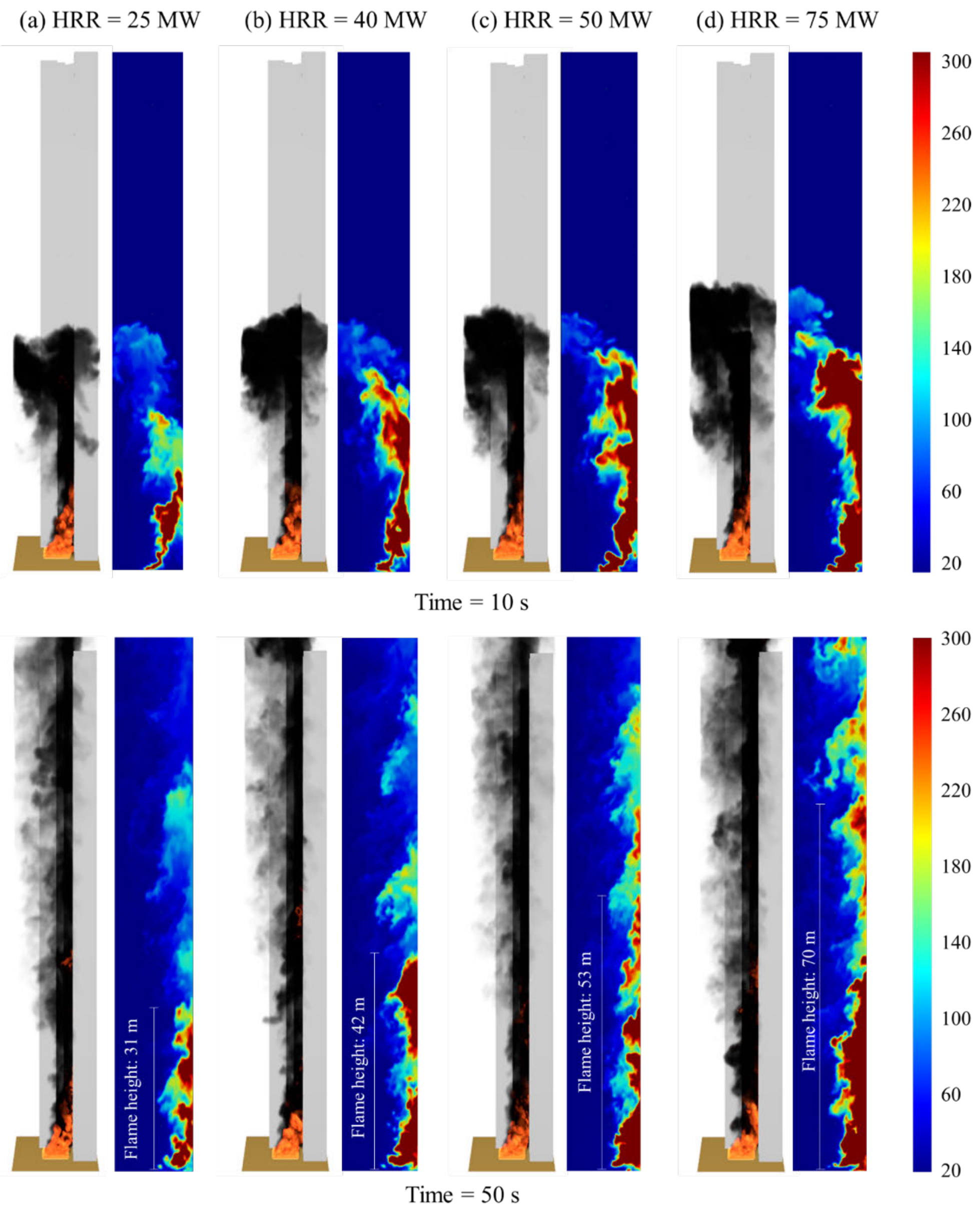


Figure 7. Visualization of flame height and temperature contours in Case 3 (Wang Cheong House south re-entrant) for HRRs of (a) 25 MW, (b) 40 MW, (c) 50 MW, and (d) 75 MW.

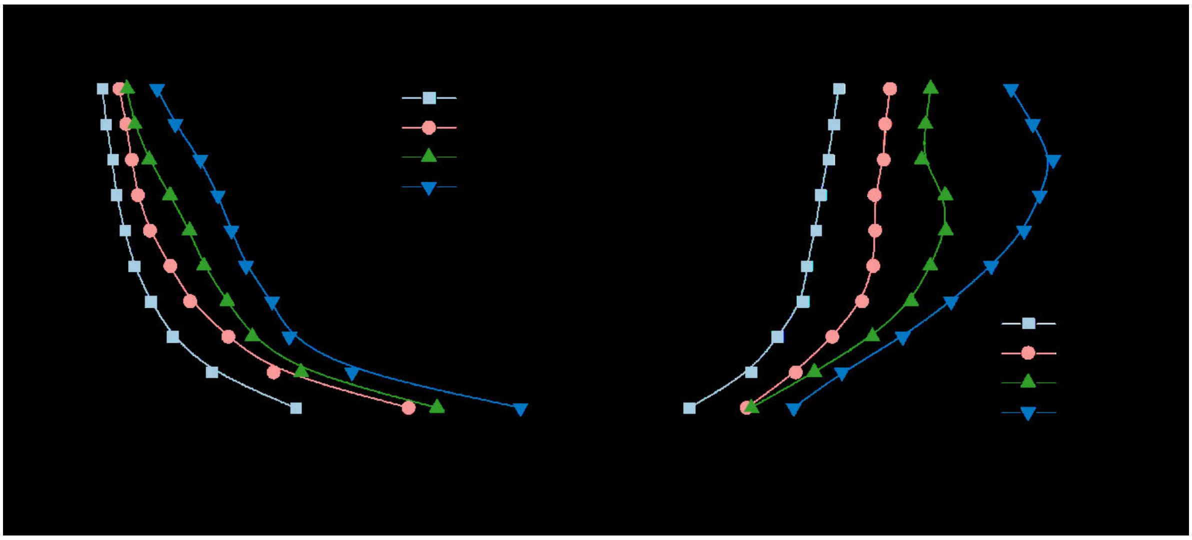


Figure 8. (a) Temperature and (b) velocity profiles for Case 3 (Wang Cheong House south re-entrant) with different HRRs.

1.5.4. In Wang Fuk Court fire, the open-face area was further reduced by scaffolding, plastic mesh netting, and renovation materials, likely lowering the critical HRR even more. Restricted openings concentrate inflow and trap radiant heat, intensifying the draft. Even with the initial fire source outside, induced negative pressure pulled flames inward. Additionally, the fuel loads (i.e. bamboo and combustible renovation materials) were built along the re-entrant and façade, which allow continuous ignition and rapid upward climb. Notably, a relatively small initial fire at the Wang Cheong House east re-entrant reached the roof within minutes, while bamboo members fell and accumulated on the ground, which contributed a large HRR (Figure 2a).

1.5.5. These findings reveal that the combination of semi-enclosed re-entrants and external scaffolding likely reduced the effective open area and lowered the critical HRR. This explains the observed rapid vertical spread across full storeys within minutes. It is important to note that the simulations placed the fire source at ground level to evaluate the chimney effect. However, in the actual incident, distributed combustible scaffolding materials along the height further accelerated propagation by providing a continuous fuel path.

1.6. Conclusion

1.6.1. The re-entrant chimney effect observed at Wang Fuk Court fire on 26 November 2025 reveals a significant fire risk of vertical fire spread in high-rise buildings with external scaffolding. Semi-enclosed re-entrant designs may be intended for natural ventilation and daylight, but it could become vertical fire pathways when combined with combustible renovation materials, including bamboo scaffolding, non-fire-retardant plastic mesh netting, and polystyrene boards.

1.6.2. CFD simulations confirm that flame height and critical HRR are sensitive to re-entrant geometry and open-face area. Single-wall configurations provide the least enhancement to the chimney effect, while L-shaped corner wall and especially semi-enclosed re-entrants significantly increase flame heights through restricted air entrainment, directional plume pull toward the re-entrant (even for external ignition sources), and radiation feedback from surrounding walls. Higher enclosure leads to increased internal temperatures, stronger buoyancy, and enables flames to reach full building height at moderate HRRs (as low as 50 MW in the simulated Wang Cheong House case). Additionally, simulation results illustrate the mechanisms of inward entrainment of external flames and intensified buoyancy from radiation trapping.

1.6.3. In the Wang Fuk Court incident, scaffolding and mesh netting further reduced effective open areas and added fuel load. These factors can lower the critical HRR and enable rapid fire spread to multiple floors within minutes. The combination of restricted openings and continuous combustible materials along the façade created a self-sustaining chimney effect, allowing flames to climb vertically at an accelerated rate. A relatively small initial fire at the base quickly transitioned into full-height involvement. Furthermore, the chimney effect facilitated fire spread to adjacent blocks through falling embers and firebrands.

2. Smoke spread into staircases and lift lobbies from re-entrants

2.1. Numerical method

2.1.1. Same as Section 1, Computational Fluid Dynamics (i.e. CFD) simulations were performed by using Fire Dynamics Simulator (i.e. FDS) to investigate vertical fire spread from the re-entrant into the staircases and lift lobbies of Wang Cheong House (Figure 9a). The building geometry was simplified, focusing on one re-entrant. The model represented a 31-storey building with 83.7 m in height, based on the Wang Cheong House floor plan. Each floor height was assumed as 2.7 m (including floor slab thickness).

2.1.2. Two scenarios were simulated: re-entrant connected to staircase windows (Figure 9b), and re-entrant connected to lift lobby ventilation windows (Figure

9c). Vertical scaffolding fuel loads (e.g. bamboo, plastic net, and renovation materials) and wind effects were not considered in the models. The detailed simulation parameters are listed in Table 2.

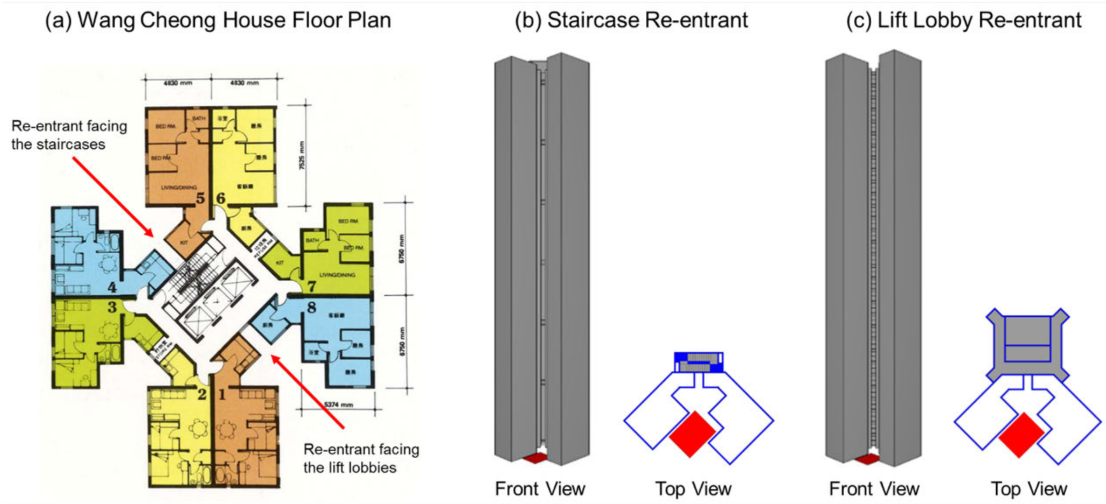


Figure 9. (a) Re-entrant locations in Wang Cheong House and re-entrant models: (b) connected to staircase windows, and (c) connected to the lift lobby windows.

2.1.3. The fire source was placed 3 m outside the re-entrant to simulate a large ground-level fire from accumulated fallen bamboo. The burning area was 5 × 4 m^2 with a steady heat release rate (i.e. HRR) of 20 MW. Soot yield and CO yield were set at 0.075 and 0.038, respectively.

Table 2. Computational settings for re-entrant simulations.

Parameters	Value	Remark
Total height (m)	83.7	The building height of Wang Fuk Court blocks is 93 m.
Re-entrant locations	/	Re-entrants facing staircase and lift lobby windows, see Figure 9a.
Staircase window size (m^2)	1	Opened every 5 floors.
Lift lobby window size (m^2)	1	All ventilation windows assumed open.
Computational domain (m^3)	21 × 23 × 92.8	Only one re-entrant considered.
Dimension of fire source (m^2)	5 × 4	Simulating accumulated bamboo, nets and debris outside the re-entrant.
HRR (MW)	20	Representative of large, accumulated bamboo, nets and debris fuel load.
Soot yield (g/g)	0.075	/
CO yield (g/g)	0.038	/
Cell size (m)	0.2	/

2.2. Smoke spread into staircases

2.2.1. During the renovation of Wang Fuk Court, original staircase windows were removed and replaced with wooden access doors at approximately every 5 floors to allow worker access to the external scaffolding. These doors provided a direct pathway for smoke spreading once an external fire occurred.

2.2.2. In the simulation, staircase windows (or access doors) on every 5 floors were assumed fully open, consistent with observations that some wooden doors were burnt through during the incident. The fire initiated at ground level outside the re-entrant. Due to the chimney effect, flames and smoke rapidly entered the re-entrant. The open windows every five floors created a pressure differential, drawing smoke from the re-entrant into the staircase. Smoke gradually filled the staircase from lower to upper levels, eventually filling the entire staircase from ground floor to roof (Figure 10).

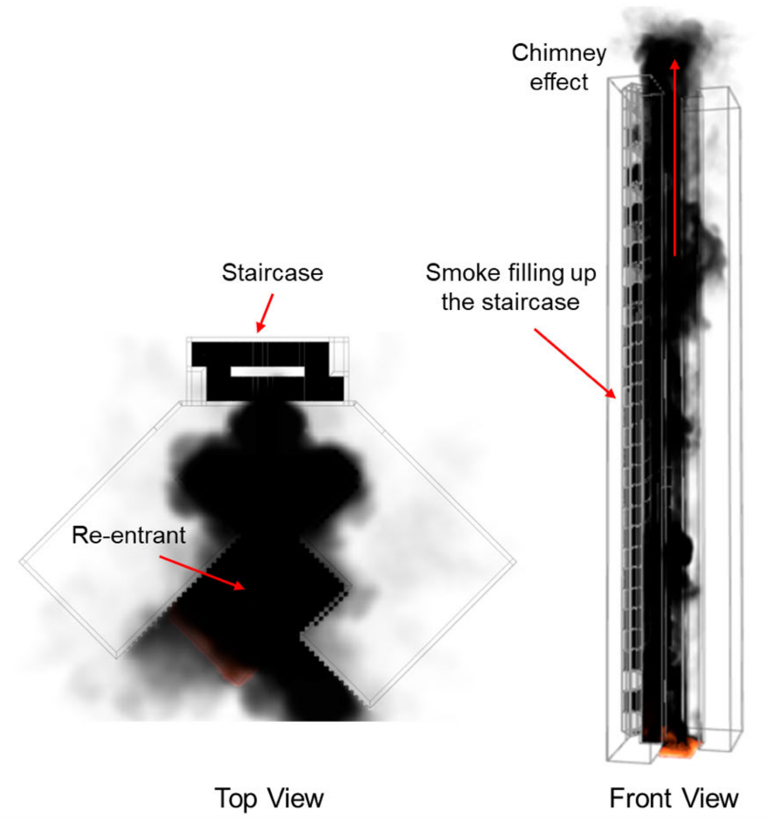


Figure 10. Simulation results of smoke spread from the re-entrant into the staircase.

2.2.3. As smoke accumulated in the staircase, visibility decreased rapidly, followed by increasing CO concentration, temperature, and radiant heat flux (Figure 11). Visibility was the first tenability criterion to be exceeded on all floors. CO concentrations in the staircase reached over 1,000 ppm across multiple floors, with a maximum of approximately 2,500 ppm on the lower floors (Figure 11b). At 1,000 ppm, CO exposure typically causes physical symptoms (e.g., headache, dizziness, nausea) within about 20 minutes and can become fatal within 1 hour. Residents who delayed evacuation were exposed to low visibility, toxic gases, and hot smoke. These could lead to disorientation, prolonged exposure to toxic gases, and even death. This explains the high number of fatalities found in the staircases, despite staircases being designated as protected means of escape.

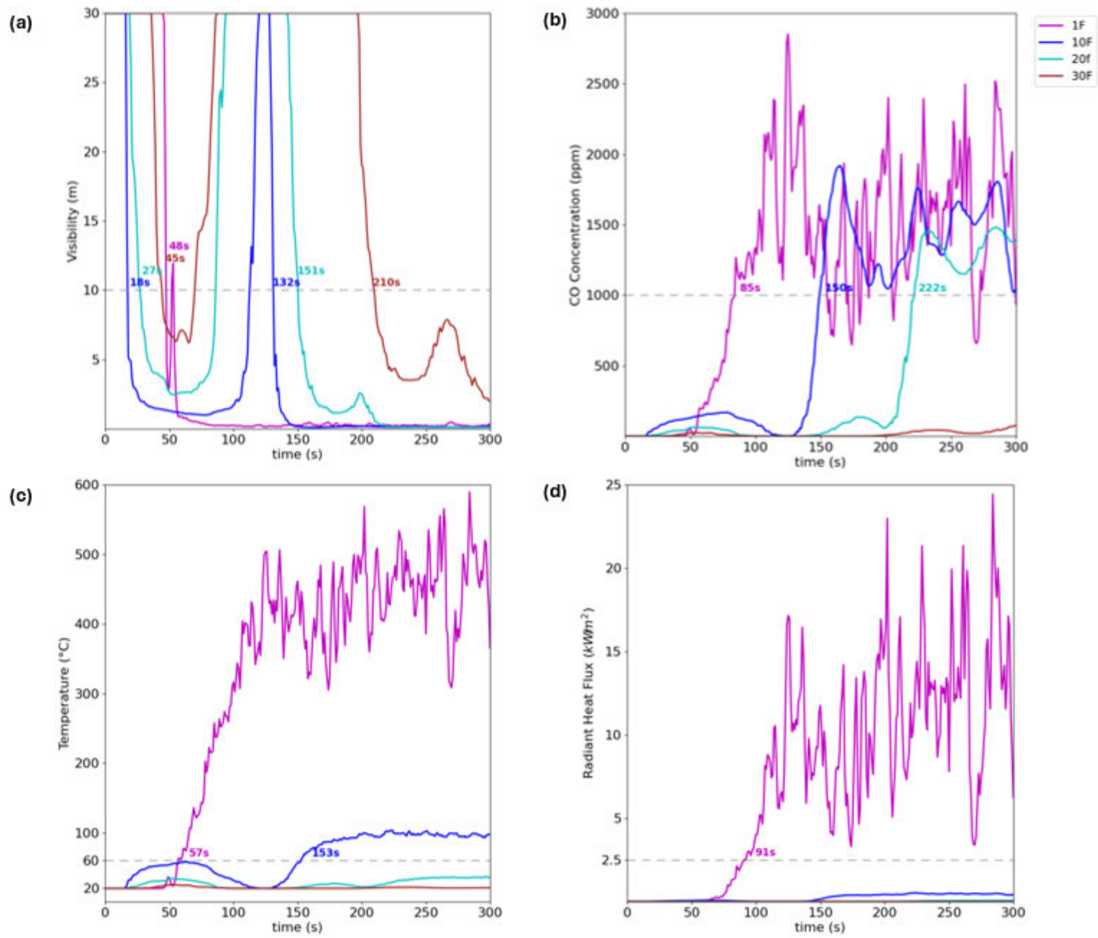


Figure 11. Tenability profiles in the staircases: (a) Visibility, (b) CO concentration, (c) temperature, and (d) radiant heat flux.

2.2.4. It is important to note that these simulation results serve as a reference only, which mainly focuses on investigating the smoke spreading from the re-entrants to the staircases. Actual fire conditions would vary with changes in HRR, soot yield, and CO yield, or the contribution of burning bamboo scaffolding and plastic netting along the re-entrant, which would likely increase temperature, smoke density, and toxicity within the staircase.

2.3. Smoke spread into lift lobbies

2.3.1. Fatalities also occurred in lift lobbies. Some of the ventilation windows in the lift lobbies were opened, allowing smoke ingress. Another simulation was performed to investigate how the smoke spread from the re-entrant into the lift lobbies. Assume that all lift lobby ventilation windows were open.

2.3.2. As shown in Figure 12, smoke spread rapidly upwards through the re-entrant due to the chimney effect. As the internal pressure in the lift lobbies was lower than in the re-entrant, smoke flowed inward through the open ventilation windows, gradually filling the lift lobbies and adjacent corridors with smoke and toxic gases (Figure 13).

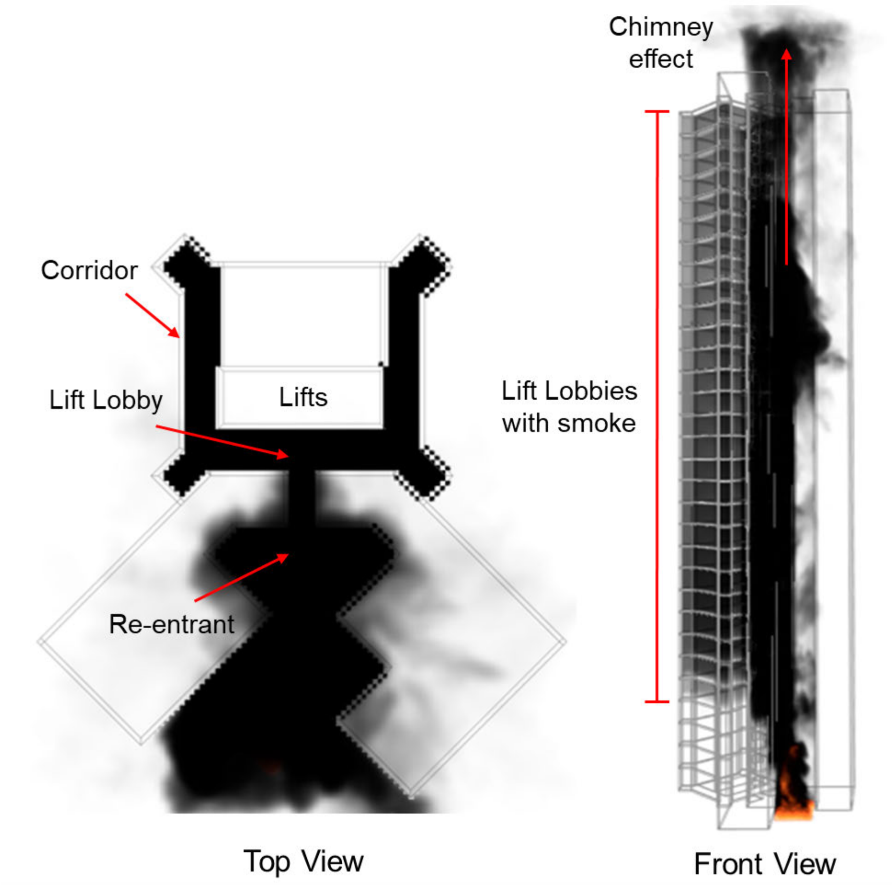


Figure 12. Simulation results of smoke spread from the re-entrant into lift lobbies.

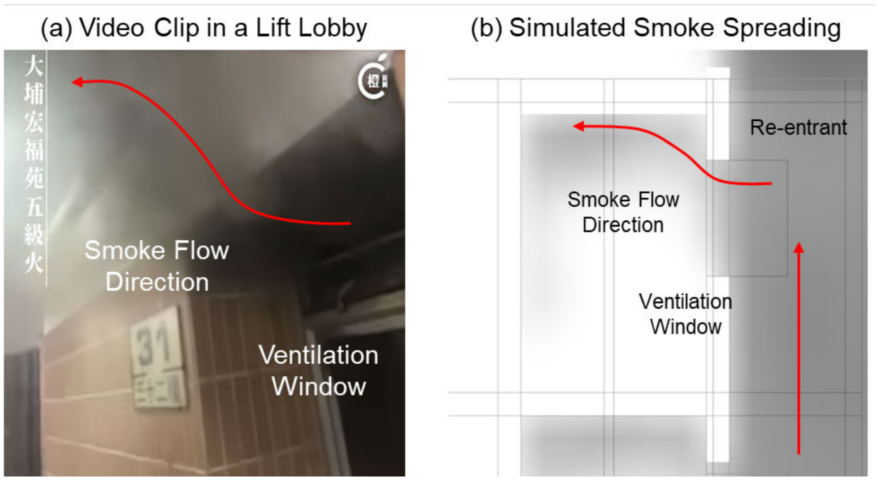


Figure 13. Smoke spreading conditions in the lift lobby: (a) video, and (b) simulation result.

2.3.3. Although tenability limits were not exceeded immediately, CO and smoke concentrations increased over time (Figure 14). The deactivated fire alarm system likely delayed occupant awareness and evacuation. Some residents who found the staircases filled with smoke might have attempted to use the lifts, by which time toxic gas levels had become hazardous.

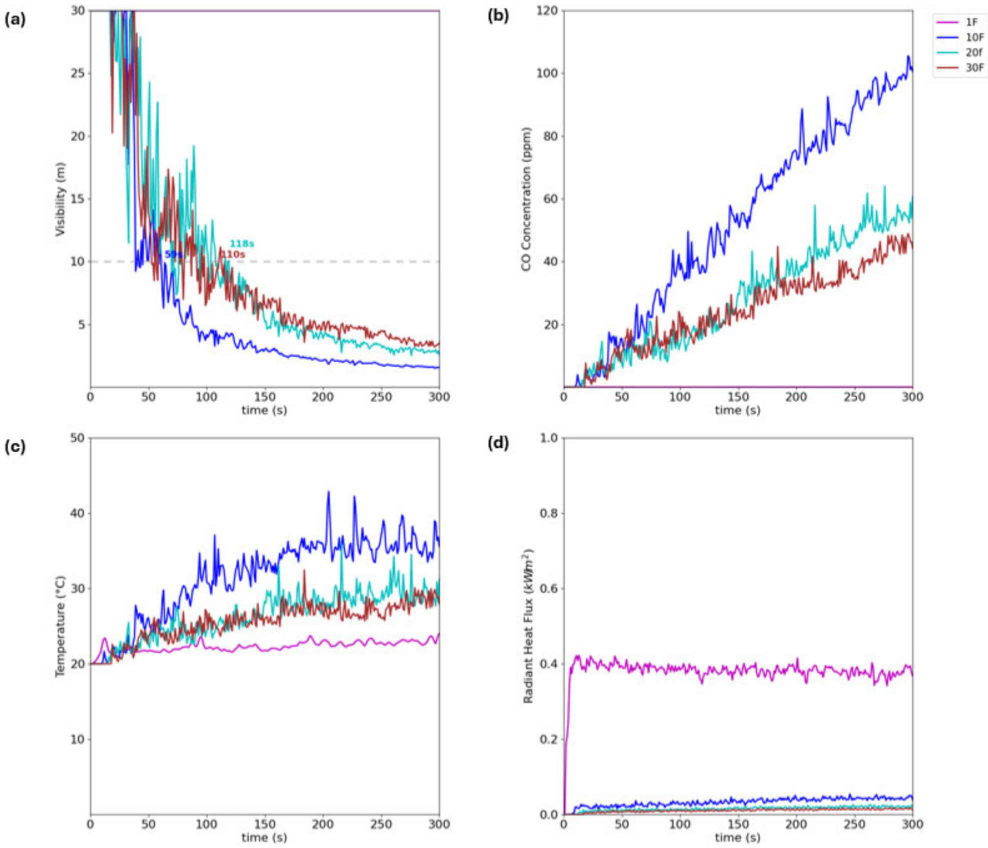


Figure 14. Tenability profiles in the lift lobby on different floors: (a) Visibility, (b) CO concentration, (c) temperature, and (d) radiant heat flux.

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