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Lessons from Grenfell Tower accident

The Grenfell Tower, a building in which public flats in West London, had been hit by a fire on June 14, 2017, in which 71 people were killed and more than 70 were injured, the fire was extinguished only after 60 hours of intense shutdown

Grenfell Tower is a 24-storey (67.3 m) housing project located in North Kensington, London, UK. It was designed by Clifford Wearden and Associates in 1967, and erected by 1974. The building consists of 120 flats located on 20 residential floors, six flats per floor. The main structural system consists of RC slabs, transferring loads to inner RC core and outer RC columns, Figure 1.

Renovation

In 2016, the building was refurbished, which included installation of exterior cladding. A vertical cross section of the installed cladding is shown in Figure 2.

Fire

The initial fire started on the 4th floor due to malfunctioning of a freezer refrigerator. The fire brigade was called in and

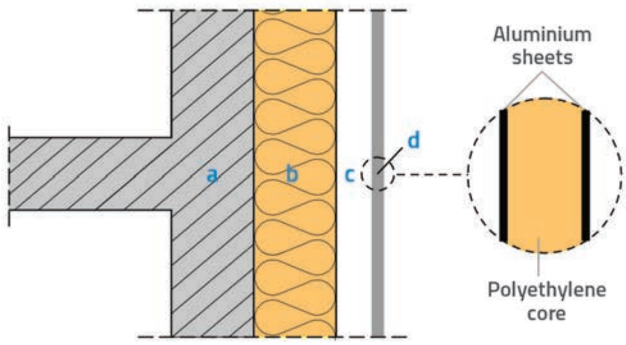

Figure 2. Exterior cladding installed in 2016: a) existing reinforced concrete structure, b) Celotex FR5000 insulation material – 150 mm, c) 50 mm air gap, d) Cladding – 3 mm

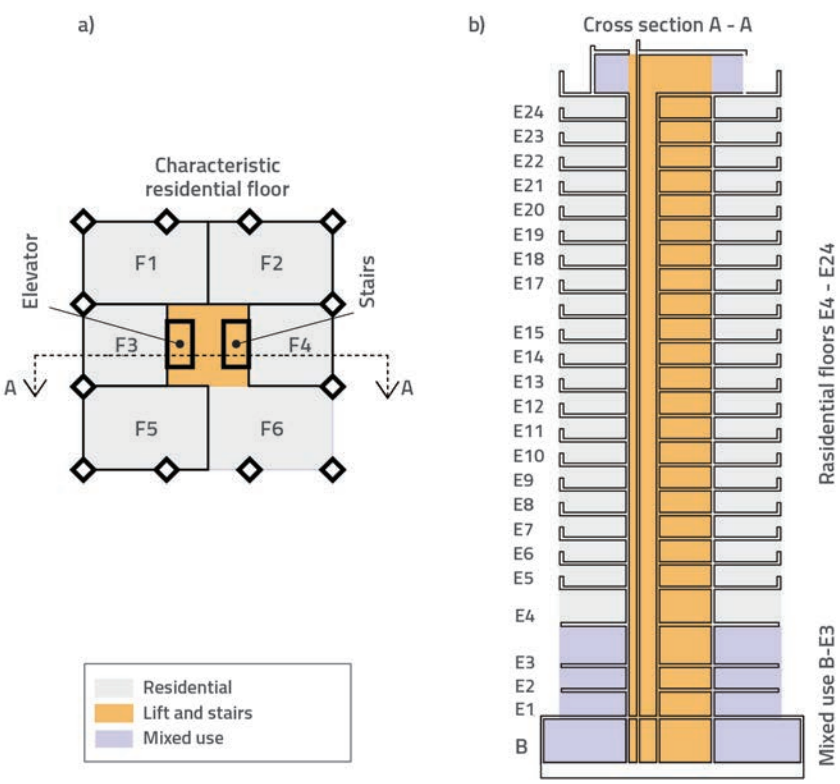

Figure 1. a) Residential floor layout; b) vertical cross section showing lifts and stairs

they managed to extinguish the fire inside the flat. As a result, no evacuation of residents was ordered. Then, suddenly, the fire rapidly spread in such a way that it engulfed more or less the entire building above the 4th floor within a very short period of time. The results were fatal for the residents trapped in the flats.

Fire processes

One is tempted to blame the contractor who installed the cladding, or the manufacturer of the cladding, or the building regulations. In the authors opinion, a better approach is to try to learn from the disaster and apply the knowledge to future renovation and design projects.
First of all, the installed cladding material is insignificant in terms of its volume and energy content, as shown in Figure 2. From this point of view, a conventional analysis using either design codes or "state of the art" software shows that the fire resistance of the building is not significantly

affected by the cladding: in fact, this is implicitly acknowledged by the fact that the cladding has been widely used in the construction industry. However, if fire propagation as a function of time is studied more closely, Figure 3, it can only be concluded that the fire spread from the 4th floor to the rest of the building in a sudden burst.

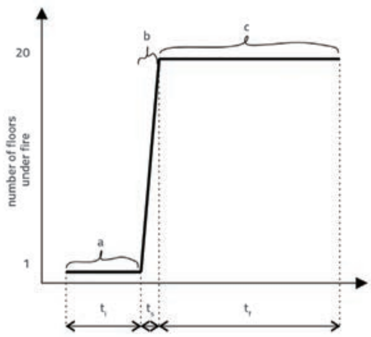

Figure 3. Fire extent as a function of time

In Figure 4, the extent of fire as a function of time is shown in terms of real photographs. The initial stage of fire propagation, t_i is relatively long and is limited to the 4th floor. The final stage of fire, t_f is even longer and it involves simultaneous fire on all twenty floors. The transition from initial to final stage occurred extremely fast, with the transition time, t_t, lasting less than few minutes, and the most violent part of the transition literally lasted few seconds only.

Discussion

It could be argued that the organic cladding material, although insignificant in terms of volume and energy content, was able to produce flammable gas when heated. This gas penetrated the 5cm continuous cavity enveloping the entire building. Inside the cavity, a relatively small amount of flammable gas mixed with air created a flammable mixture. Once ignited, the entire cavity was on fire in a matter of seconds. Thus, the cladding did not jeopardise the fire safety of the building in terms of design norms, but it acted as an ignition mechanism, facilitating the spreading of fire. This process is rather new, and has not been anticipated by any design codes either in the USA, Japan, EU or the UK. The disaster could have been prevented only if either real or virtual experiments had been conducted, which could have indicated the presence of a trigger like mechanism for a catastrophic and rapid fire propagation.

It could also be argued that a similar situation, albeit of a different nature, occurred in the case of Twin Towers, which were in fact designed to survive an impact of an aircraft. However, no one envisioned that this impact would create a trigger like mechanism resulting in structural weaknesses and progressive collapse. It was not the energy of the impacting aircraft that destroyed the towers – it was the potential energy of the towers themselves that destabilised the towers, thus causing a progressive collapse. The impact of an aircraft was just a starting mechanism for the progressive collapse process. The design codes available at that time failed to address this potential hazard.

In a similar way, the cladding served as an accidental, but clever initiation mechanism for subsequent fire propagation process, something that had not been envisioned by design codes.

There are many cases in civil engineering where new failure phenomena were discovered only after major accidents (structural instability, progressive collapse, resonance, etc.). One should not fail to recognise that the Grenfell Tower accident resulted in the discovery of yet another failure phenomenon called rapid spontaneous fire propagation, which would certainly be worth considering in future renovations or new projects.

This topic also stirs some philosophical implications on how to educate a new generation of civil engineers: should one teach the students to blindly follow the design codes or, rather, should they be taught to be creative and innovative in design methods, in order to be able to detect or envision possible catastrophic mechanisms through sophisticated visual experimental design tools [1-4].

References

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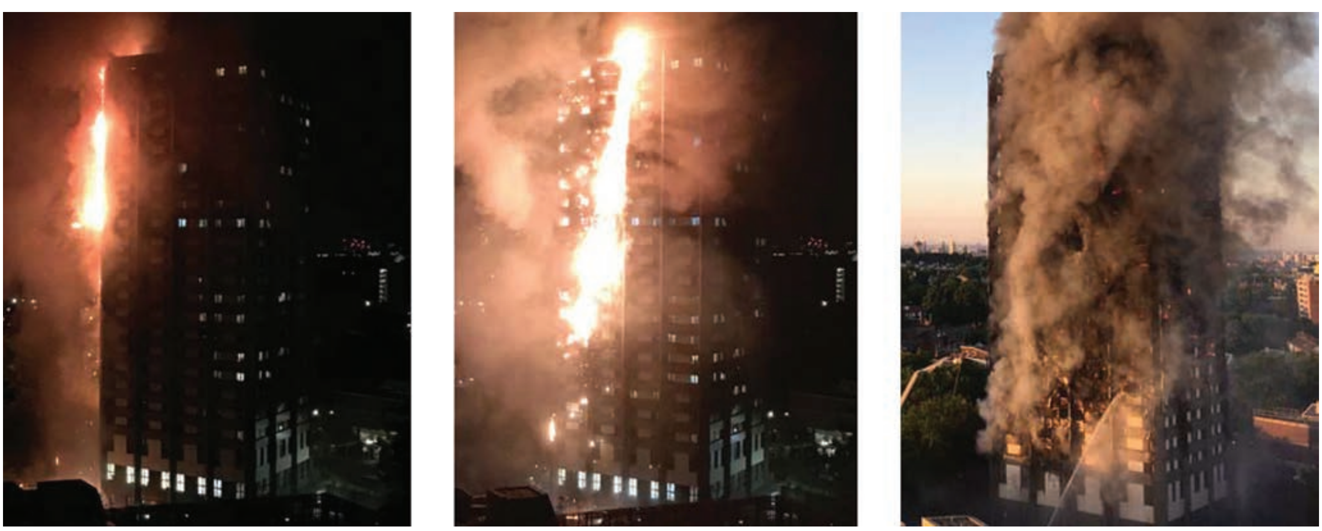

Figure 4. Visual and graphic representation of fire extent as a function of time