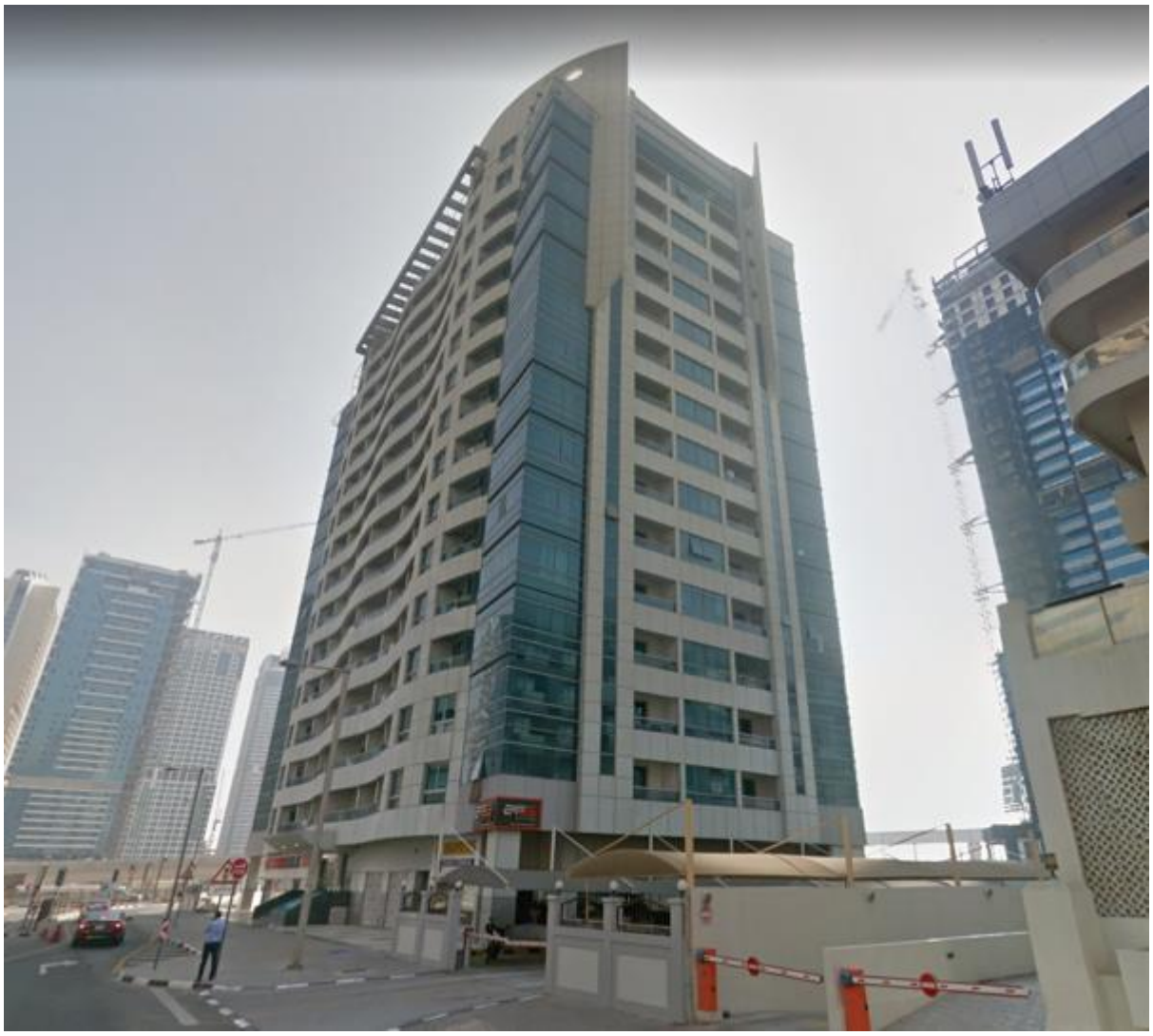
REPORT ON THE FIRE WHICH OCCURRED AT MARINA DIAMOND 2, DUBAI, UAE ON 23 OCTOBER 2021



By Frances Maria Peacock

FCIAT, CBuildE FCABE, IHBC, MIFireE, MSFPE, PG Cert., BSc, Dip. HE

Chartered Architectural Technologist, Chartered Building Engineer and Fire Engineer

November 2021

Introduction

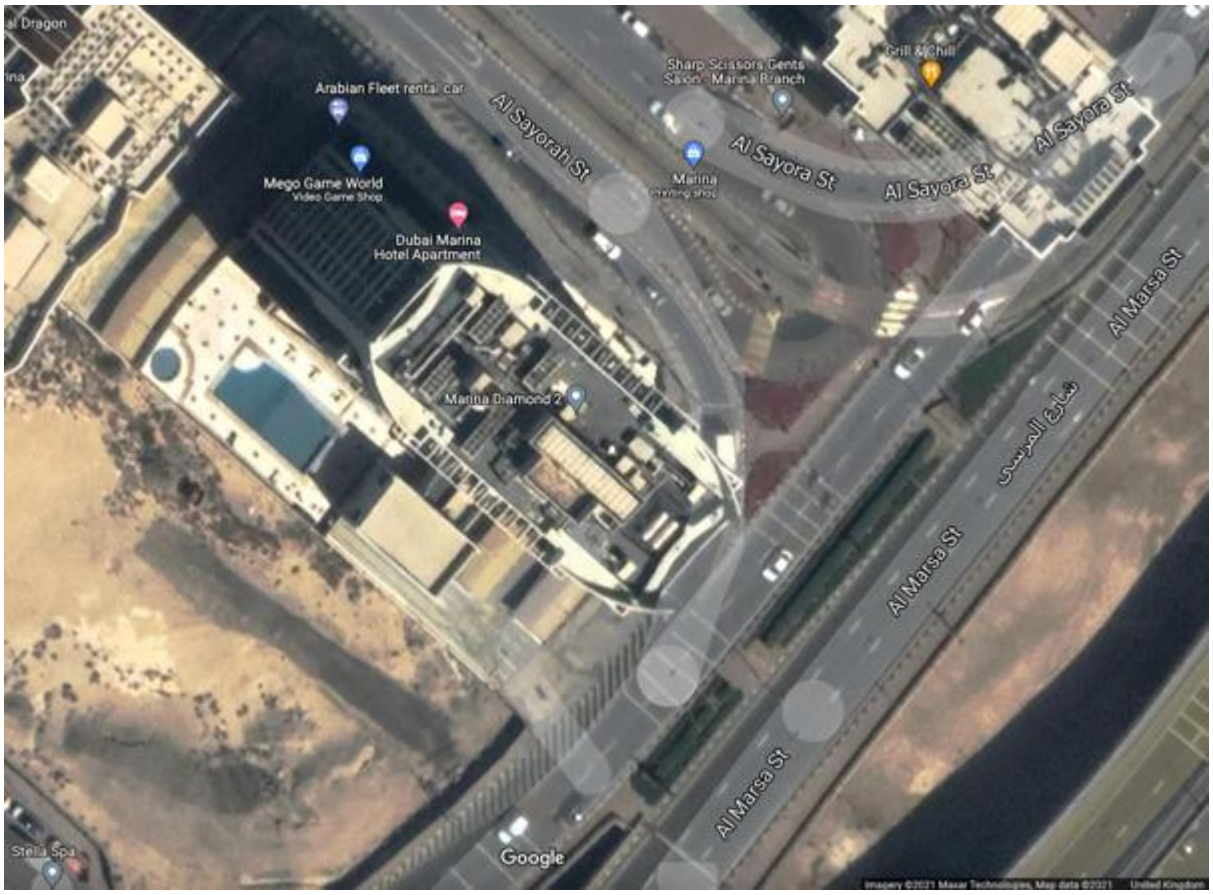
1.1 On 23 October 2021, a fire occurred in a 15-story high rise building in Dubai, United Arab Emirates (UAE), which affected the apartments on the seven uppermost floors on the north-west side of the building. The cause and origin of the fire is still under investigation, but according to the Civil Defence it is thought to have started on the 9th floor, and then spread upwards to the 15th floor. Although the seat of the fire has not been officially confirmed, evidence points to it having started on the balcony, around which there is an abundance of combustible Aluminium Composite Material (ACM) cladding. It has been suggested that the cause could have been an electrical fault, but this has not been confirmed and other causes such as a discarded cigarette cannot be ruled out either.

1.2 This is a preliminary report based on what is known so far and produced with the aim of helping those with an interest in fire safety, building design and engineering understand how the fire was able to spread as it did. The design of the building and its cladding system is complex, and therefore this report sets out to explain this with the aid of photographs and diagrams. This report also draws upon the author's research into the relationship between building design and fire spread, carried out following the Grenfell Tower fire in June 2017, in order to explain how the fire was able to spread so rapidly and behave in the way it did. That research was able to identify specific fire phenomena associated with particular geometric shapes, forms and features, and therefore enable the fire dynamics to be properly explained. Further details about the research can be read in Appendix A.

1.3 Overall, there is much to be learned from this fire, not just in the UAE, but in other countries too, including the UK. It is only by learning the lessons from such incidents that action can be taken to ensure that similar disasters are avoided. Fortunately, there were no injuries or loss of life in this case, although the situation could have been worse if the fire had been able to spread to other parts of the building, and the residents had not been able to evacuate as promptly as they did. It seems that there was no "stay-put" policy in this building and the fire was confined to a limited area of the facade. The fire strategy for the tower, as well as relevant regulations and guidance, will also be considered in this report.

Building Description

2.1 Marina Diamond 2 is situated in Al Sayorah Street at the southern end of Dubai Marina in Dubai, just off Al Masara Street which connects with Sheikh Zayed Road, the main highway through the city (*Figs.1 & 2*). The building is primarily residential and has 15 storeys, although there are several commercial units on the ground floor (including a bank and a travel agent). The residential accommodation, which consists of 266 apartments, occupies all the floors above. The apartments are a mixture of studio flats of varying layouts, as well as those with one or two bedrooms, also with varying layouts. The tower is 61.5m tall and is part of a complex of six buildings constructed as part of the same development, for which building work began in 2005 and was completed in 2010. Construction of the Marina Diamond 2 itself, took place between 2005 and 2007, and therefore it is only fourteen years since the building was completed.



<u>Figure 1</u>: A Google map showing the location of Marina Diamond 2. The building is essentially an oblong shape with curved corners, from which there are four projecting fins (two at each end). ***Photo: Google***

Figure 2: The Marina Diamond 2 within its wider setting in Dubai. The building takes its name from its location (Dubai Marina) and it developer (Diamond Investments LLC). ***Photo: Google***

Figure 3: The south-west side of Marina Diamond 2 showing the curved corners which are covered in combustible cladding. Glazed living areas protrude from these corners at right angles. The rest of the façade has a rippled effect, like waves in the sea. ***Photo: The Author***

Figure 4: The south-east end of the building showing the fins which project beyond the curved corners from the tenth floor upwards. The fire occurred affected the opposite end of the building which is a mirror image of this one (see cover photo). ***Photo: The Author***

2.2 As is the case with many modern high rise buildings, there is an emphasis on aesthetics. The building has been designed with a multitude of forms and features to make the façade look interesting, without any consideration being given to the fact that these could encourage fire spread. However, the neither the dangers of the cladding nor the influence of geometry upon the spread of fire was known at the time.

2.3 The building is orientated north-west to south-east. The fire affected a two-bedroomed flat at the north-east end, the floor plan for which is shown in *Figure 5*. The elevation in its undamaged form can be seen on the cover of this report. The two-bedroomed flats – of

which there are three different configurations - can be found in the corners of each floor. The type shown in Figure 4 is found from the third floor to the thirteenth floor. Smaller one-bedroomed and studio flats are positioned in the middle of the building.

Figure 5: A two-bedroomed corner flat of a type which can be found on floors 3-13. The fire started on the balcony numbered "2" on the plan. The probable point of origin is marked with a red star. ***Image: Bayut***

Design, Geometry and Fire Phenomena

3.1 The design of the façade contains several features which are capable of encouraging the spread of fire. These are listed below, along with the relevant fire phenomena associated with each feature:

- Tall uninterrupted bands of cladding which would cause **Upward Vertical Fire Spread**. This is defined as, "*The rapid spread of fire up tall uninterrupted bands of cladding or some other flammable material on the building façade*."
- The fins are vertically orientated projecting features, and therefore give rise to the potential for **Feature Influenced Upward Fire Spread**. This is defined as, "*The tendency for fire to concentrate itself on vertically orientated projecting features; this will enhance the rate of flame spread*."
- The fins create introverted corners within which fire can become concentrated, therefore making **Corner Influenced Fire Spread** an issue. This is defined as, "*The extension of flame height which occurs when the fire becomes confined to an introverted corner (vertex) on a building face*."
- Due to the continuous vertical bands of cladding, **Downward Vertical Fire Spread** would also occur. This is defined as, "*The downward spread of fire affecting continuous bands of cladding due to the flowing and dripping of molten burning material. This does not involve projecting features*."
- The building also contains many horizontal bands of cladding which would be capable of causing **Standard Horizontal Fire Spread**. This is defined as "*The very slow spread of fire in a lateral direction. It does not necessarily involve a projecting feature, although it may be encouraged by contours on the building face*."
- The horizontal bands of cladding form balcony walls on many parts of the building, and are therefore design features in their own right. They also create ledges upon which molten material can accumulate and help the fire to spread. Therefore, **Feature Enhanced Horizontal Fire Spread** would be an issue. This is defined as fire spread which, "*Occurs when the flames become concentrated on a horizontally orientated projecting architectural feature. The rate of flame spread is much more rapid than for standard horizontal fire spread. If the feature forms a ledge upon which molten material can collect, the fire spread will be further enhanced*."
- There is also the potential for **Cross-radiation** to affect the upper part of the building because the fins are angled inwards towards the vertical bands of cladding on the main building face. This "*occurs when re-entrant corners are present. These have an angle greater than 180° and if there are two inward facing surfaces, cross radiation will occur and the fire will intensify*."

3.2 Below (*Figs.6, 7 & 8*) are some photos of the building in its unburnt form which show the shape, geometric form and features of the building:

Figure 6: A view of the top of the building showing the curvature of the building face with the projecting fins which curve around the ends of the building at this level. These present a significant fire hazard.

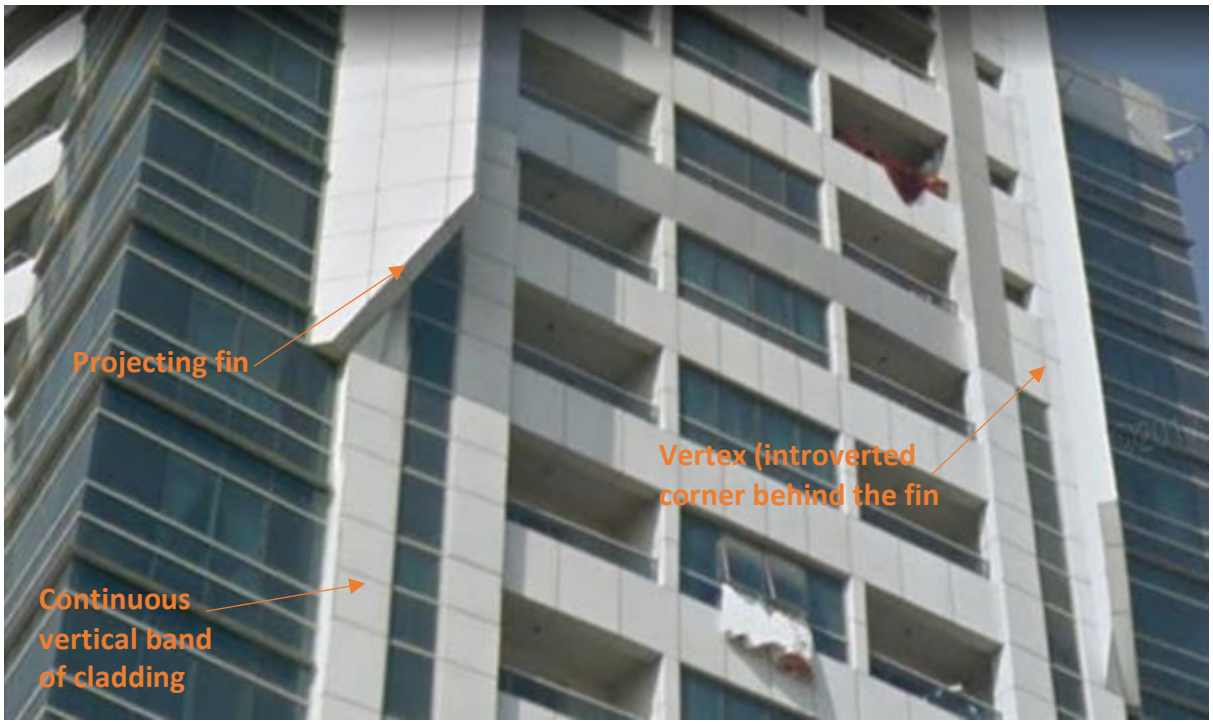


Figure 7: The fins extend from the tenth floor upwards and this photo shows where they connect with the building at their lower ends. A continuous vertical band of cladding extends into the vertex of each fin, thereby creating an opportunity for intense fire spread. ***Photos (Figs.6 & 7): The Author***

Figure 8: This view is taken midway up the building and is taken from a corner so that an end elevation and a side elevation can be seen simultaneously. The vertical bands of cladding which form balcony walls with multiple ledges would be a means of fire spread, as would the projecting roof-top feature. ***Photo: The Author***

3.3 Although all the fire phenomena listed on p.7 actually occurred during this fire, the potential for other phenomena with the possibility of causing greater fire spread and more extensive damage to the building, existed (paragraphs 3.4 – 3.6). Even though these did not occur on this occasion, they are nevertheless worthy of consideration due to their potential appearance in a future fire, or any fires which may affect other buildings with similar geometry.

3.4 As the roof-top feature in *Figure 8* is not a parapet or an architectural crown, and as it is not present on all sides of the building, it would not give rise to **Perimeter (roof-top) Fire Spread** which is defined as, "*essentially Feature Enhanced horizontal fire spread which occurs at roof level, involving a parapet, crown or rim around the perimeter of a building. It may also affect features which sit on top of the roof and is influenced by exposure of the architectural feature*." However, this does *not* mean that it would be incapable of causing fire to spread at roof level.

3.5 The key thing here is that the feature is isolated and does not connect with other faces of the building. At Tamweel Tower (also in Dubai) which suffered a fire in 2012, there was an

elaborate roof-top feature which connected two opposite sides of the building, and even through it did not surround the perimeter of the roof, the fire was nevertheless able to transfer the fire across from one side of the building to the other. The fire then began to affect the opposite side of the building to where it had originally started.

3.6 However, the fact that the feature is not a solid piece and instead consists of a fascia supported by multiple struts, increases the surface area and would allow for a draw of air through the structure. Both of these factors would intensify any fire which was to affect it, and it is therefore fortunate that the fire did not spread to this face of the building or the corresponding one on the other side. In comparison, the architectural crown at Grenfell Tower was a slatted feature and therefore had an increased surface area. It was also affected by a draw of air through the structure.

3.7 The Marina Diamond 2 also has several curved surfaces which would be capable of distorting the fire front and giving rise to "diagonal" fire spread. This is a rare phenomenon which was witnessed at Grenfell, where in that case it was caused by the architectural crown even though there were no curves on the building*. In most cases, the phenomenon is caused by curvature of the building face, which causes a difference in speed between the upper end of the fire front and the lower end of the fire front. It can occur in an upward or downward direction and is capable of causing a large amount of damage to buildings it affects.

3.8 Distortion and inclination of the fire front which gives the diagonal pattern is determined by the following principles:

- *The diagonal inclination is a result of horizontal and vertical fire spread occurring simultaneously, caused by a differentiation in flame speed between the upper and lower levels of the building.*
- *The rate of lateral spread will proportionately slow the rate of vertical spread.*
- *It is the rate of lateral spread in relation to the upward spread which determines the angle of deflection. The greater the amount of horizontal spread in relation to upward spread, the greater the inclination angle will be.*
- *The more pronounced the curve is, the greater the angle of inclination will be.*

* Please refer to my report, *The Relationship between Building Design and Fire Spread: How the Shape, Form & Features of a building can influence the behaviour of fire* for a full explanation.

Cladding System Design and Materials

4.1 The building does not appear to have had a rainscreen cladding system, although – as is quite clear from the observed footage of the fire – the cladding melted flowed and dripped in the way which would be expected if it were to consist of ACM cladding with a polyethylene (PE) core. It is known that Aluminium Composite Material (ACM) was typically used as a standard material for cladding facades in the city prior to it being banned in 2017, so it can be said with virtual certainty that the panels were ACM.

4.2 The charred remains do not reveal any support or fixing rails, which is what would be expected if the ACM panels were used as part of a rainscreen system. Instead it seems that the panels formed part of a bonded system, with insulation behind which was fixed directly to the masonry wall of the building. The insulation is also a combustible material due to the fact that it has been completely consumed by the fire in areas where it was at its most intense. In other places it has sustained severe damage. It is likely that the insulation was polyurethane (PUR) or polyisocyanurate (PIR). The manufacturers of both the insulation and the cladding panels are at the time of writing, unknown.

The Development and Spread of the Fire

5.1 There is some debate as to where the fire started. Some news reports state that it began on the 9th floor and then spread to the 15th floor, whilst others suggest that it began on the 11th floor and spread upwards to the 15th floor, as well as downwards to the 9th floor. Wherever it's origin, the uppermost seven floors at the end of the building where it started, were affected.

5.2 Although my initial thoughts were that the fire started on the 11th or 12th floor, I now believe that it began on the 9th floor, spreading rapidly upwards as the flames concentrated themselves on the narrow bands of vertical cladding, before becoming confined to the vertex behind the fin. There was also downward spread, as is indicated by the burn pattern; this extending as far down as the 8th floor. The video footage clearly shows molten cladding material flowing and dripping downwards, therefore taking the fire with it to lower levels (*Figs.9 & 10*).

Figure 9: The upper floors on one side of the north-west of the Marina Diamond 2 are engulfed in flames, which can be seen spreading downwards as the cores of the cladding panels melt, flow and drip.

5.3 No further information has been released about the fire since it occurred and enquiries I have made in the city have proved fruitless. Therefore, the cause and point of origin may never be known for sure. My conclusions are based solely on my analysis of the video footage and photographs, whilst drawing upon my research into the effects of building geometry and my knowledge of fire spread, fire behaviour and burn patterns.

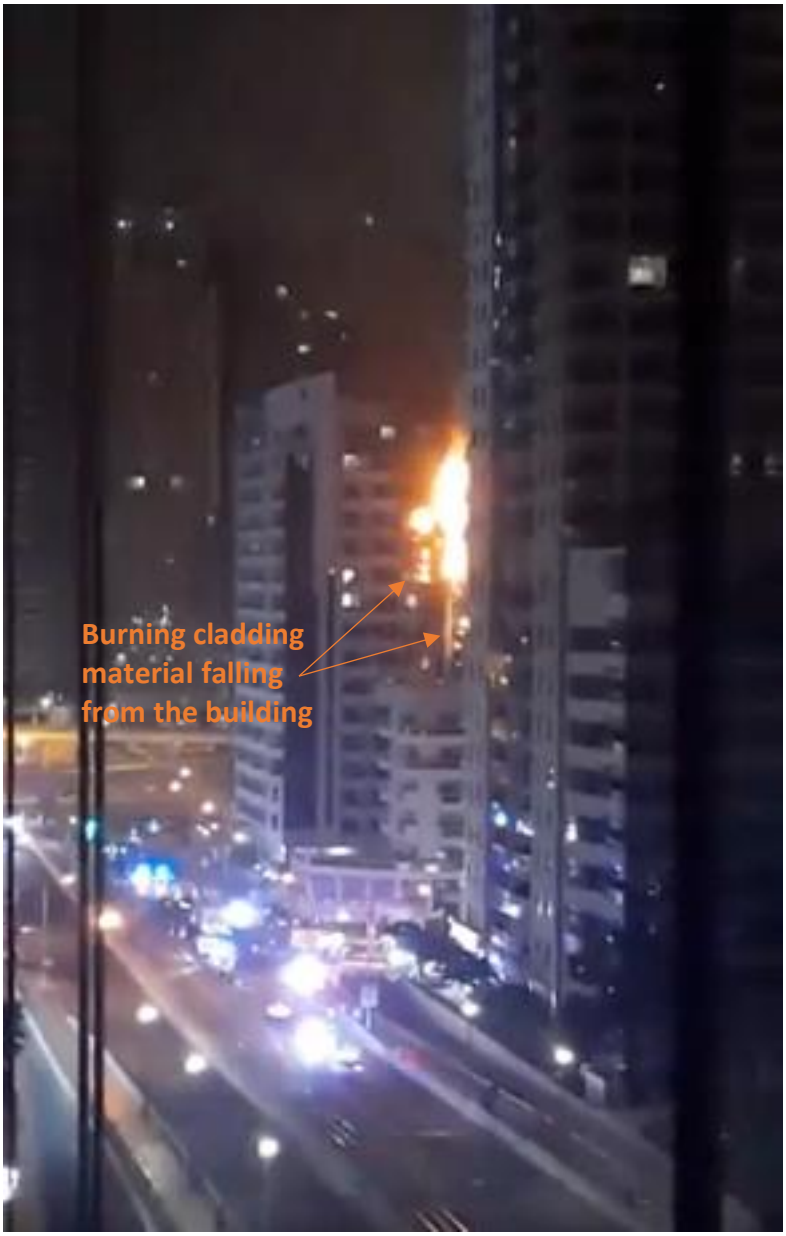


Figure 10: Another view of the fire showing the downward progression and pieces of burning cladding material falling from the building.

5.4 There is evidence to suggest that the fire began on the 9th floor balcony and entered the cladding system on the immediate right of the opening, as you stand facing the building from the outside. The fire then developed and spread to other floors, following the sequence as detailed below. Please also refer to *Figures 11* and *12*.

- The flames spread upwards following a continuous vertical band of cladding. This allowed the flames to concentrate themselves within a narrow area, therefore resulting in *rapid upward vertical fire spread*.

- As the fire approached the 10th floor, it entered an area bounded by the fin. The fin is angled inwards and this allowed the flames and hot gasses to be contained in the area behind it. It was at this point that the fire began to affect the second band of cladding, separated from the one which was originally affected by a row of vertical glazing.
- The fire entered the vertex at the point where the fin connects with the building face, leading to further rapid vertical fire spread in the introverted corner.
- The fire also spreads downwards following the line of the first band of cladding it affected, and reaching the 8th floor. The downward spread affecting the second band ends abruptly at the end of the fin. This is because the containment of the hot gases in the vertex of the fin was so extreme, the cladding burned away before any molten material even had the chance to start flowing downwards.
- The fin itself became directly involved in the fire. As the fin was gradually consumed by the fire, the flames worked their way through the feature towards its outer edge upon which they became concentrated. Hence, there was an "edge effect."
- The blazing fin and the flaming bands of cladding would have resulted in cross-radiation, therefore intensifying the fire further.
- As the heat increased and the panels on the bands of cladding degraded, the fire began to spread horizontally to affect the bands of vertical cladding separating the balconies on each of the levels.
- This was more pronounced at the higher levels, as is evident from the diagonal line which can be drawn across the building from the 9th to the 14th floor. As the temperature increased with height, the fire was able to spread further in a lateral direction with each floor it reached, whilst also continuing its upward progress.
- The result is similar to *upward vertical fire spread with an inclined front* (see *paragraphs 3.7 & 3.8*), but rather than there being a continuous fire front (the top end of which would have travelled faster than the bottom end leading to the diagonal pattern), the fire instead followed the edges of the balcony walls; hence *feature enhanced horizontal fire spread*.
- The edges of the balcony walls represent a narrow area within which the flames can become concentrated, therefore enabling increased heating of the fuel ahead of the burning zone and faster fire spread. The higher temperatures at the upper levels increased this effect.

Figure 11 (above, p.15 and below): **Two comparable photos showing the building during the fire and the damage which was visible once the fire had been extinguished. Such was the intensity of the fire, especially behind the fin, that the cladding has been completely consumed to expose the masonry behind. Some of the cladding also detached and fell from the building as it burned.** ***Photos: Dubai Civil Defence***

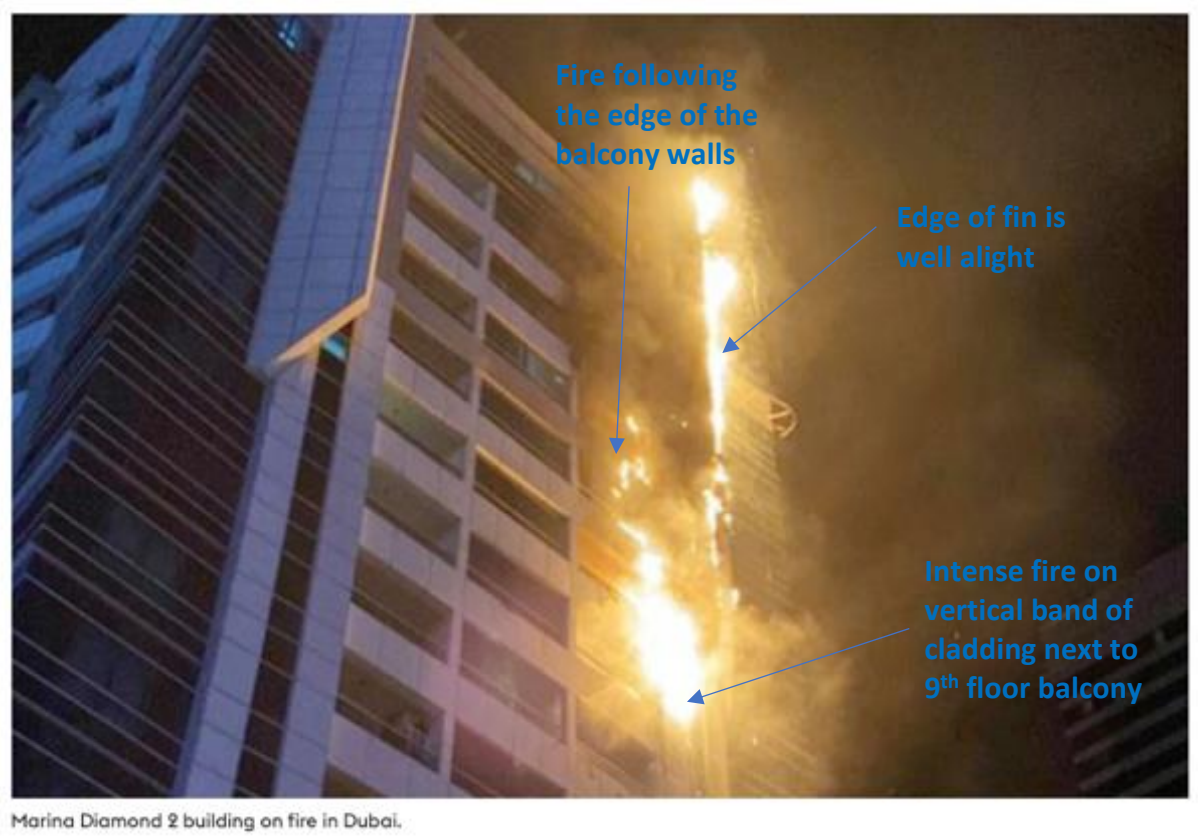


Figure 12: The fire is at its most intense on the band of cladding next to the 9th floor balcony and is spreading upwards to affect other floors. The fin is also well alight.

Timeline for the Fire

03.30 – Fire first discovered by residents

03.58 – First call to fire service (Civil Defence)

04.01 – First fire crews arrive

05.24 – Fire under control

07.15 – Building secured and handed over to investigators

08.00 – Residents on the lower floors are allowed back to their apartments

5.5 The above information has been obtained from Civil Defence and Dubai media reports.

5.6 There are several interesting and notable observations to be made here. Firstly, nearly half an hour elapsed between the fire being discovered and the first call being received by the Civil Defence, which is a considerable period of time, especially when it is considered how rapidly cladding fires develop and take hold on the façade. This delay would have allowed the fire to spread beyond the floor of origin before the Civil Defence was even able to take action. Nevertheless, it would seem that the fire was brought under control after only an hour and a half, therefore limiting the amount of damage to the building.

5.7 It can only be speculated as to why there was such a delay between the fire being discovered and the Civil Defence being alerted. From the available evidence it would seem that the first reaction was for the person discovering the fire to alert their neighbours, who then in turn alerted others. As the fire began to spread to other floors, residents began alerting each other in these areas too. Exactly who discovered the fire and called the Civil Defence has not been confirmed, but it can assumed that the occupants of the flat of origin discovered the fire, and then only called the Civil Defence once they had alerted all the residents in the flats on the 9th floor. The other residents probably fled in panic, particularly when the building began to fill with smoke, and were therefore focussed on egress; no doubt assuming that somebody else had already called the Civil Defence.

5.8 There are conflicting reports as to whether or not a fire alarm sounded. This will be discussed as part of the fire strategy later in the report.

Fire Development on the Balconies

5.9 In order to establish the arrangement of cladding on the balconies and how it relates to their design, I have obtained photos from estate agents' property sales/rental details. This has allowed a comparison to be made with the observed fire spread and burn patterns, and it provides an indication as to how the flames would spread around a balcony if it became involved in the fire.

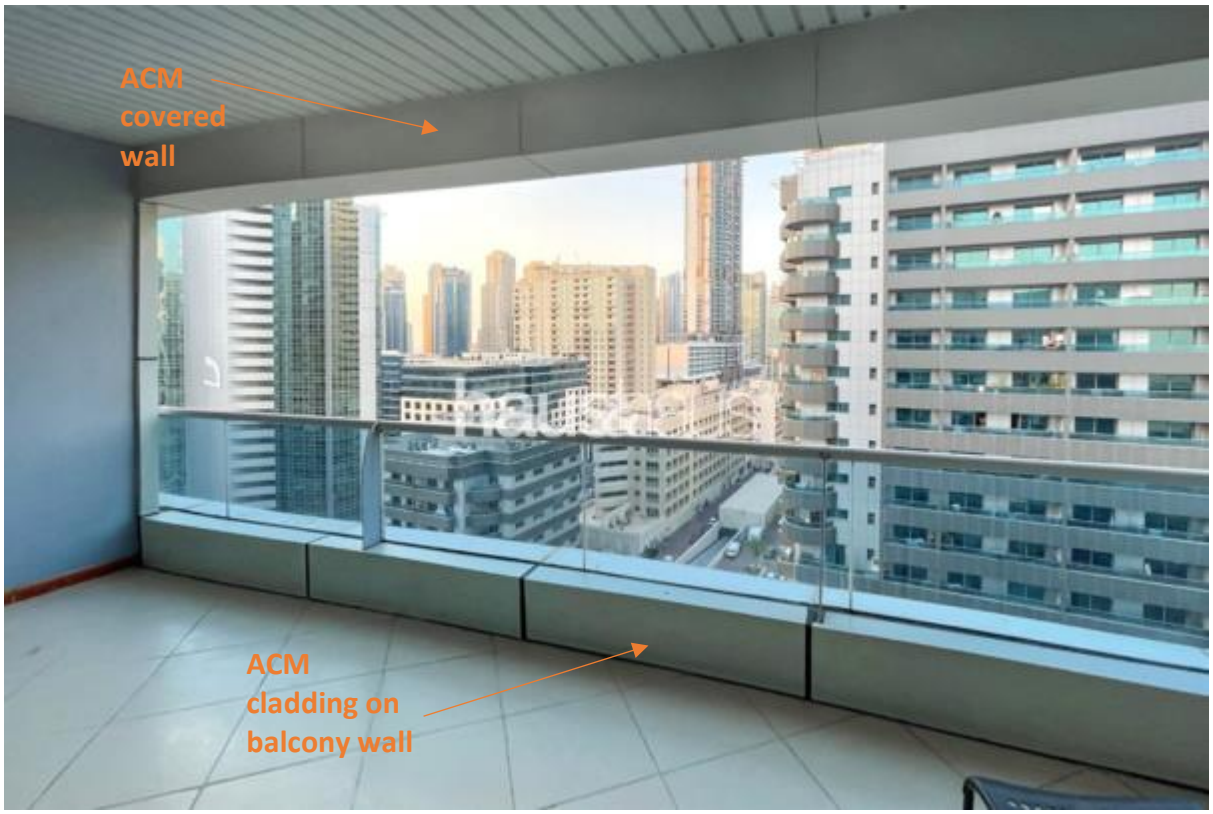


Figure 13: A balcony at the Marina Diamond 2 showing combustible materials around the opening and on the ceiling. The example shown in this photograph is for a one-bedroomed flat on the north-east side of the building. *Photo:* www.bayut.com

5.9 The balconies have ceramic tiled floors which are not combustible and the side walls appear to be plastered (*Figs.13 & 14*). However, the balcony wall consists of combustible cladding with glass balustrading above. The framework for the glazing is metal, and therefore is not combustible (*Fig.14*). At ceiling level, there is an abundance of combustible material, mainly in the form of synthetic boarding, but also on the short section of wall which extends down into the opening. Like the wall below the balustrading, this too is covered in combustible cladding.

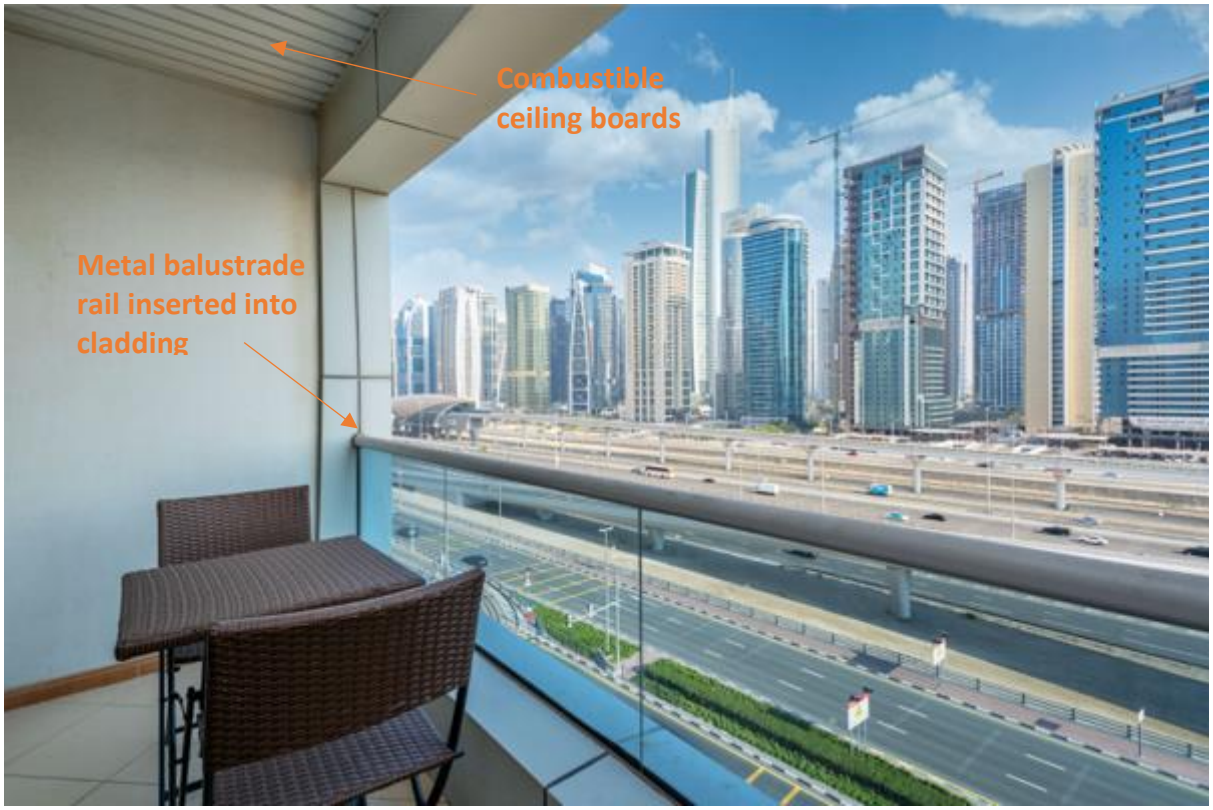


Figure 14: The impressive view from a balcony of a two-bedroomed apartment at the south-east end of the building. This elevation is identical to the one where the fire occurred at the north-west end of the building.

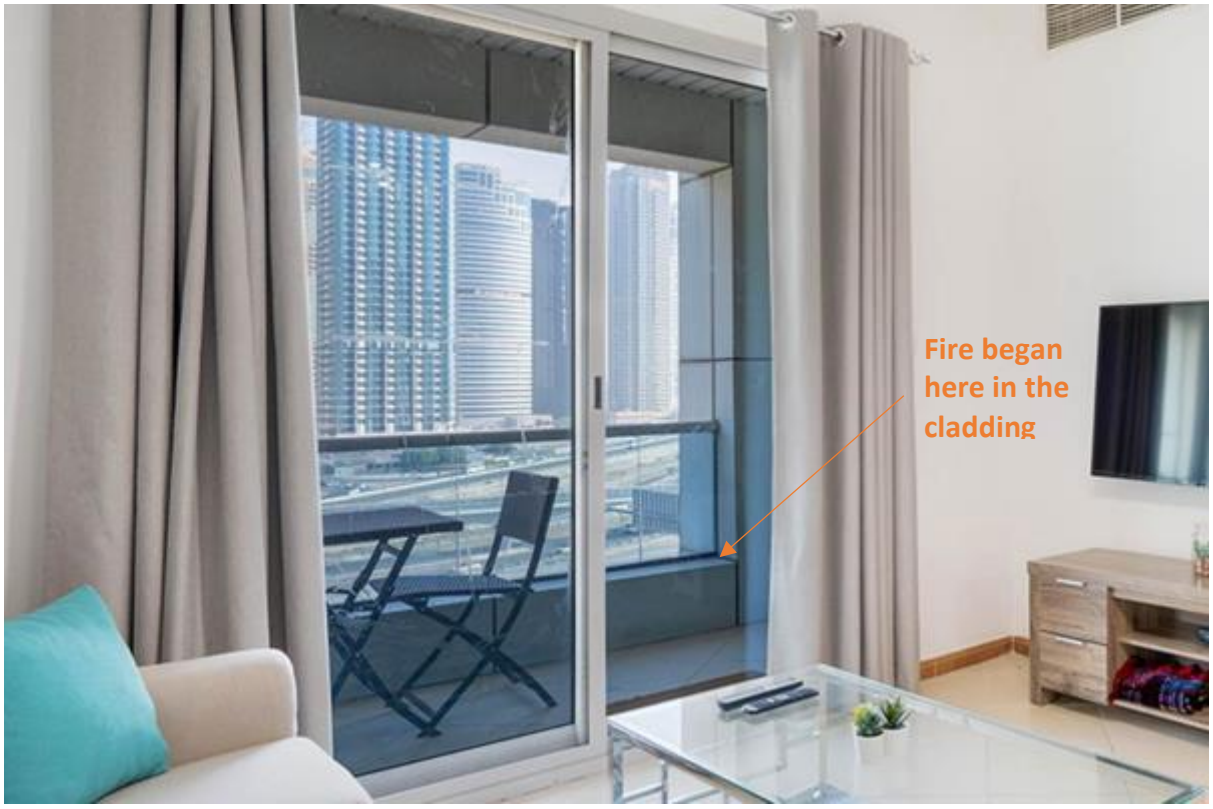


Figure 15: The living area of a two-bedroomed flat which is a mirror image of the one where the fire began at the opposite end of the building. An area of cladding equivalent to that where the fire started can be seen through the balcony doors. Photos (Figs.14 & 15): Kennedy Towers www.kennedytowers.com

5.10 The fire started in the location shown in Figure 15, where there are multiple locations for it enter the interior of the cladding system. These include panel joints, as well as the point at which the balustrade rail penetrates the cladding system (Fig.14). The location as seen from outside the balcony, is shown in *Figure 16*.

5.11 It should be noted that *Figures 14 and 15* show another flat of the same type as the one where the fire originated, because no such images of the apartment itself are available. *Figure 16* however, does show the actual apartment where the fire began.

Figure 16: The flat of origin in December 2016, in its undamaged state. An arrow points to the area of the cladding where the fire is thought to have started. *Photo: The Author*

5.12 The exact cause of the fire has not yet been announced, but the point of origin suggests:

- A carelessly discarded cigarette which either directly ignited the cladding or items placed adjacent to it
- A candle placed on the ledge next to the balustrade
- A faulty lamp which was placed on the ledge next to the balustrade
- A portable air conditioning unit which malfunctioned

5.13 When the cladding in this location first ignited, the fire could only go upwards, confined to the narrow strip at the front of the balcony. At that stage there would not have been sufficient heat for the fire to spread horizontally and there were also limited places for it to spread to. The side walls are covered with plaster, which would have prevented the fire from entering the interior of the balcony, and although the balcony ceiling is covered in combustible material, the flames remained confined to the cladding system as they progressed upwards.

5.14 As the flames reached the balconies of the floors above, the situation began to change. By the time the fire reached the 10th floor – the next floor above where it had started – it had become sufficiently well developed to allow it to spread beyond the band of cladding where it had started, and therefore it was able to enter the balcony at ceiling level.

5.15 Now that the fire was established on floors which were bounded by the fin, the heat could building to the extent where full involvement of the balconies and noticeable horizontal spread became possible (*Figs.17, 18 & 19*). The balcony on the 11th floor became engulfed in flames at ceiling level, and on the 12th floor it appears that flashover conditions occurred. On that floor, the fire was able to enter the apartment through the balcony doors and the living, dining and kitchen area became fully involved. Internal damage to the apartments occurred on the 10th, 11th, 12th, 13th and 14th floors. Damage on the 10th floor was slight, it was moderate on the 11th floor, and severe on the 12th , 13th and 14th floors (*Figs.20 & 21*). The balcony doors on the 12th floor were probably open at the time, therefore providing an easy path for the flames, as well as cross-ventilation when the door to the common corridor was opened.

5.16 Although the fire reached the 15th floor, the damage was less because the apartments at this level have no balconies on the elevation affected by the fire. Instead, each has a fully exposed triangular balcony which is located on top the glazed sections at the corners of the building (*Fig..22*).


The National
A blaze has been put out at a residential tower in Dubai Marina.
0:05 / 0:50
1x


The National
Firefighters brought the fire under control.
Play
0:12 / 0:50
1x

Figure 17 (top photo, p.21): An extract from a video made by a witness to the fire which shows the fin well alight with the flames concentrated along its edge. The flames are also in the vertex behind the fin and are affecting the adjacent balconies.

Figure 18 (bottom photo, p.21): Another extract from the same video, but taken seven seconds after the one in Figure 17. The cladding on the fin is being consumed by the fire and the balcony of the 12th floor flat is glowing orange due to the extent of its involvement in the fire.

Figure 19: A third extract from the same video, taken at 21 seconds (9 seconds after the second extract in *Figure 18* and 16 seconds after the first extract in *Figure 17*). The fire has intensified, especially on the fin and the balcony on the 12th floor is approaching flashover conditions.

5.17 It has widely been reported that the flat on the 15th floor sustained severe damage, but the image above shows that this is not the case. The reason for this confusion arises from its external appearance; because it lacks the large windows and recessed balconies of the floors below, it is not easily identifiable as being another floor. Therefore the 14th floor gets mistaken for being the top floor, especially when no lights are visible in the windows.

In order to provide clarity and confirmation, an image showing the arrangement of all the floors with their numbers can be seen in Appendix A.

Figure 20: Most of the fire has now been extinguished and the firefighters are damping down. A light can be seen in the 9th floor balcony, which is coming from the living area and projecting through the glazing of the balcony doors. It has illuminated the ceiling of the balcony which appears to be undamaged. The lights are also on in the 15th floor flat where the damage is confined only to the external cladding. ***Photo: www.gulftoday.ae***

© Nicholas Webster Aftermath of fire. Nicholas Webster / The National

Figure 21: The fire has now been extinguished. Most of the cladding on the fin has been destroyed and the balconies from the 10th to the 14th floor are blackened and damaged.

Figure 22: The plan showing the layout of the flats on the 15th floor, where the outer wall on one side follows the curved profile of the fins. The fully-exposed triangular balcony is at the top of the glazed corner section.
***Image:* www.bayut.com**

Fire Protection

Passive Fire Protection

6.1 The most obvious fire protection is compartmentation, which makes each flat a fire-resisting unit in its own right. However, because the fire was able to enter some of the flats from the exterior of the building (ie via the balconies), the compartmentation was breached from the outside.

6.2 There is no available information about the fire doors or any other forms of passive fire protection such as fire stopping.

Active Fire Protection

6.3 The building appears to have been fitted with a sprinkler system (*Figs.22 & 23*). This would activate upon detection of fire and raise the alarm, allowing residents to leave the building whilst limiting the spread of fire within the interior of the flats. The building manager, Mr. Siddiqi, stated that "*The fire sprinklers were activated, so there is some water damage as a result. Everything in those areas is wet, with only five or six apartments seriously affected by the fire itself*."

6.4 The building had a fire alarm system, with smoke detectors present in the kitchens of the flats, as well as common corridors. It appears to be an LD5 system. Interestingly, none of the residents claim to have heard a fire alarm, and instead describe being alerted to the fire only by neighbours banging on their door. This has led to suggestions that the alarm did not activate, but Mr. Siddiqi insists that this was not the case and says *"All of the fire alarms were activated at the time – the damage is mainly on the balcony areas"*.

6.5 One resident who heard no alarm was Adnan Shauqat who fled the building with his three children after being alerted by other occupants. He says, "*It's 3.30am and we heard shouting from downstairs. We woke up and came downstairs. There was no fire alarm … we came down immediately …*". Another resident, Parakshit Shah who lives on the fourth floor said, "*I was deep asleep and woke up to the neighbour knocking on my door*." Mr. Shah was due to return to India the following morning and had packed his luggage ready to depart. He says, "*He told us there was a fire and I quickly grabbed the luggage I had already packed for my flight tomorrow and we ran down the stairs*."

Figure 23: The interior of a one-bedroomed flat in the Marina Diamond 2 building, which has an open plan kitchen/diner/living area. A fire extinguisher, sprinkler head and smoke detector are visible. Such provisions do not appear to be anywhere else within the flat other than the kitchen. *Photo: www.bayut.com*

Figure 24: The kitchen and dining area in a two-bedroomed flat of the same plan (but in reverse) as the one where the fire started. There is a smoke detector and a sprinkler head. These provisions are only found in the kitchen and not elsewhere in the flat. *Photo: Kennedy Towers www.kennedytowers.com*

6.6 Despite residents not hearing the alarm, smoke had clearly been able to enter the interior of the building, as described by Julia, a tourist from Russia who was staying in a flat which was being used as a holiday let. She says, "*We could smell smoke when we went out into the corridor. It was very scary and we were all in a state of panic. We took the stairs down as fast as we could*."

6.7 For the fire alarm and the sprinkler systems to activate, the heat and smoke from the fire would have to be detectable in the kitchen of each flat. The fire began in a corner of the balcony of a flat on the 9th floor and spread upwards, without affecting the interior of the flat. Therefore, neither system would have been able to detect the fire at this particular time. As it began to affect the floor above and the fin became involved, the fire began to affect entire balconies eventually was able to enter the building. It was at this point that the sprinkler and fire alarm would have been activated. This will explain why residents had to be alerted by neighbours and why they did not hear the alarm. When the alarm eventually did activate, the residents in the affected part of the building had already left.

6.8 The building manager is probably correct in stating that the alarm sounded, especially as there is clear evidence from the sodden interior that the sprinkler system activated, but the residents were unaware of it for the reasons explained in *paragraph 6.7* above. Therefore, this can be taken as a plausible explanation as to why the building manager's account is at odds with that of the residents.

Evacuation Considerations

6.9 Although there were no deaths or injuries on this occasion, the potential for casualties and fatalities exists with any building fire. Considering that the fire was able to enter some of the flats and smoke penetrated the building as far as the communal corridors, the situation could have been quite different and it is only the fact that the occupants were able to evacuate so promptly which prevented any deaths or injuries from occurring. Given that the smoke was produced by burning ACM panels, it would have contained toxic carbon monoxide, a gas which is responsible for fatalities in many fires.

6.10 The evacuation is also dependent on people having the opportunity to self-evacuate with little or no assistance. The only means of escape was down the stairs. The building has three lifts, but these were not used during the evacuation, seemingly because they were not designed to be used during a fire. I am still trying to establish whether the building had one staircase or two, but with three lifts for residents to use in normal circumstances (ie when there is not a fire), it is likely that it only had one.

6.11 If the fire had affected the whole building or a larger part or it, the situation may have been rather different because most buildings will have occupants who are elderly, have mobility problems or a various other physical or mental health conditions. For example, if someone had hearing problems, they may not have heard the neighbours shouts and knocks on the door, and there would have been no other means of them being alerted to the fire, especially if they lived alone. They would also not be able to hear the alarm.

6.12 In most buildings there are also young families with pregnant mothers, babies and young children. A woman in an advanced state of pregnancy would find it difficult to negotiate the stairs and make evacuation from an upper floor difficult. Babies and very small children would need to be carried and slightly older children would need guidance, with the parents also having to ensure that the family kept together and the children did not get lost among other fleeing residents.

6.13 One only needs to consider Grenfell to realise how many people lived in that building who were either unable to self-evacuate or had difficulty in doing so. Many of them sadly lost their lives. The situations as described in *paragraphs 6.11* and *6.12* are therefore very relevant. At the Marina Diamond 2, even though the number of people who had health or disability issues is unknown, there were certainly young families in the building, such as that of Adnan Shauqat (*paragraph 6.5*) who fled the building with three children, the youngest of which had to be carried (*Fig.25*).

Figure 25: Adnan Shauqat with his three children, two of which are aged under 10 with the youngest aged under 5 and requiring carrying in order to evacuate. The family lived on one of the upper floors affected by the fire and therefore had a descend a lot of stairs in order to leave the building. ***Photo: Sarwat Nasir, The National***

Remediation Measures & Solutions

7.1 It is believed that there are up to 1000 buildings in Dubai covered in ACM cladding, as well as the many thousands of others in the UK and throughout the rest of the world, which also have ACM and other types of combustible materials in their facades. The most obvious solution is to remove the combustible materials from the external walls, but this is not a straight forward option due to the practicalities and substantial costs involved. Consequently, it is likely to be many years – probably decades – before all materials which pose a fire risk are removed.

7.2 Therefore, it is necessary to consider interim measures and possible alternatives, also bearing in mind that in some cases – due to the method of construction used – complete removal of all hazardous materials may not be possible.

7.3 In the UK, the main interim measure has been to introduce a "waking watch" patrol in buildings where a decision has been made to change from a stay-put strategy to one of simultaneous evacuation, following realisation that the external wall of a building contains combustible materials and requires remediation. However, waking watches are expensive because of the ongoing infinite cost, and they can be unreliable too, as has been shown by numerous reports of staff sleeping whilst on duty or watching television instead of looking out for signs of fire. Consequently, this has led to the National Fire Chiefs Council (NFCC) recommending that an appropriate fire alarm system installed to BS 5839 should be introduced as an alternative.

7.4 Basically, the guidance states that all rooms which overlook the combustible cladding should have a heat sensor, with perhaps the exception of bathrooms and toilets. In the case of the Marina Diamond 2, the sensor would have been placed in the living area, close to the patio doors, not further back in the kitchen area. The moment the smoke started to enter a flat, the system would have activated.

7.5 However, by the time the fire would have been detectable from inside the building, even with a more enhanced system as described in *paragraph 7.4* above, it was already well established on the façade and affecting an increasing number of floors as it progressed rapidly upwards. If the sensors had been placed directly into the cladding system instead, the fire would have been detected as soon as it began to affect the façade and before it had even left the 9th floor where it started. The external alarm system which can do this is called Intelliclad and its sensors are placed according to set criteria which takes into account those areas of the façade which present the greatest risk. This includes the author's principles relating to the influence of building geometry on the spread and behaviour of fire, with the sensors being positioned so as to detect fire which may affect features which encourage fire spread.

7.6 If Intelliclad had been installed on the façade at the Marina Diamond 2, its own sensors would have sounded as soon as it detected the fire. This would have triggered the main building alarm to also sound and residents would also have been alerted individually via an app on their mobile phones. Any occupants with hearing problems would have been alerted by a vibrating pager. This would have been a much more effective way of alerting residents and would have eliminated the need for them to knock on doors to alert their neighbours to the fire. To find out more about Intelliclad, please visit www.intelliclad.co.uk

7.7 Research carried out by Intelliclad using data from Imperial College, London, shows that worldwide, 60% of façade fires start internally. In Dubai, this figure is much higher, and using statistics from case studies I have looked at for my own research reports, the figure is in excess of 90%. Most fires seem to start on balconies or elsewhere on the exterior such as discarded rubbish at the base of the building (Tamweel Tower 2012) or a faulty external light (The Address Hotel 2015). It is quite evident that buildings in Dubai would benefit from an external alarm system.

7.8 Another solution which has been put forward in Dubai by engineers from WSP, with whom I met when I visited the city in September 2019, is the creation of fire breaks in the façade. This would involve sections of cladding being removed, and those that remain being protected by cavity barriers. The intention would be to create the fire breaks at set intervals, ensuring that they are wide enough for the fire not to be able to transfer across. To take this one step further, the cladding could be removed from the parts of the façade which pose the greatest risk, such as projecting features like columns, pilasters, string courses, crowns, parapets and fins. In addition to the protection provided by cavity barriers, the remaining sections of cladding could also be fitted with Intelliclad to provide a warning to residents if a fire should start. As is already well known, there are several situations in which cavity barriers can be rendered ineffective during a cladding fire, even if they are installed correctly. Please refer to *Appendix B* for an illustration of these solutions.

Conclusion

The information in this report is based on my own analysis of the fire, whilst drawing upon my personal experience of other similar fires and applying the principles of my research to what I observed in video footage and photographs of the fire.

The events at the Marina Diamond 2 on 23 October 2021 demonstrate the ongoing problem with the large number of buildings throughout the world which are covered in ACM and other combustible forms of cladding. This is just the latest in a series of fires to occur in the UAE in recent years and there are likely to be many more unless something is done to remediate the risk arising from the combustible materials in the facades of these buildings. By writing this report, it is hoped that lessons will be learned from this fire, not just in Dubai and the rest of the UAE, but around the world where there have also been many similar fires, including some resulting in a large loss of life (Shanghai 2010, 58 deaths and Grenfell Tower 2017, 72 deaths).

The objective of this report is to help explain what happened and why, so that the cause, spread and behaviour of the fire can be better understood. I also look at ways in which the problem could be remediated and the risks mitigated, bearing in mind that full removal of the cladding is costly, and in the UK this cost is unfairly being passed on to residents.

My research into the effect of building geometry (shape, form and features) upon the behaviour of fire has significant safety benefits because it enables a better understanding of the phenomena which can occur if the building has a combustible façade. The principles I have developed mean that the spread of fire can now – for the first time – be predicted. This has several important applications, including for remediation and mitigation of the risk, with solutions such as façade fire breaks or innovations like Intelliclad.

The fire in this case began on a 9th floor balcony and spread to the floors above, causing extensive damage to some of the flats involved, but fortunately no injuries of loss of life. All residential fires have the potential to kill, and therefore they should all be taken seriously and the lessons learned, regardless as to how insignificant they may appear to be.

APPENDIX A – FLOOR NUMBERING ARRANGEMENT

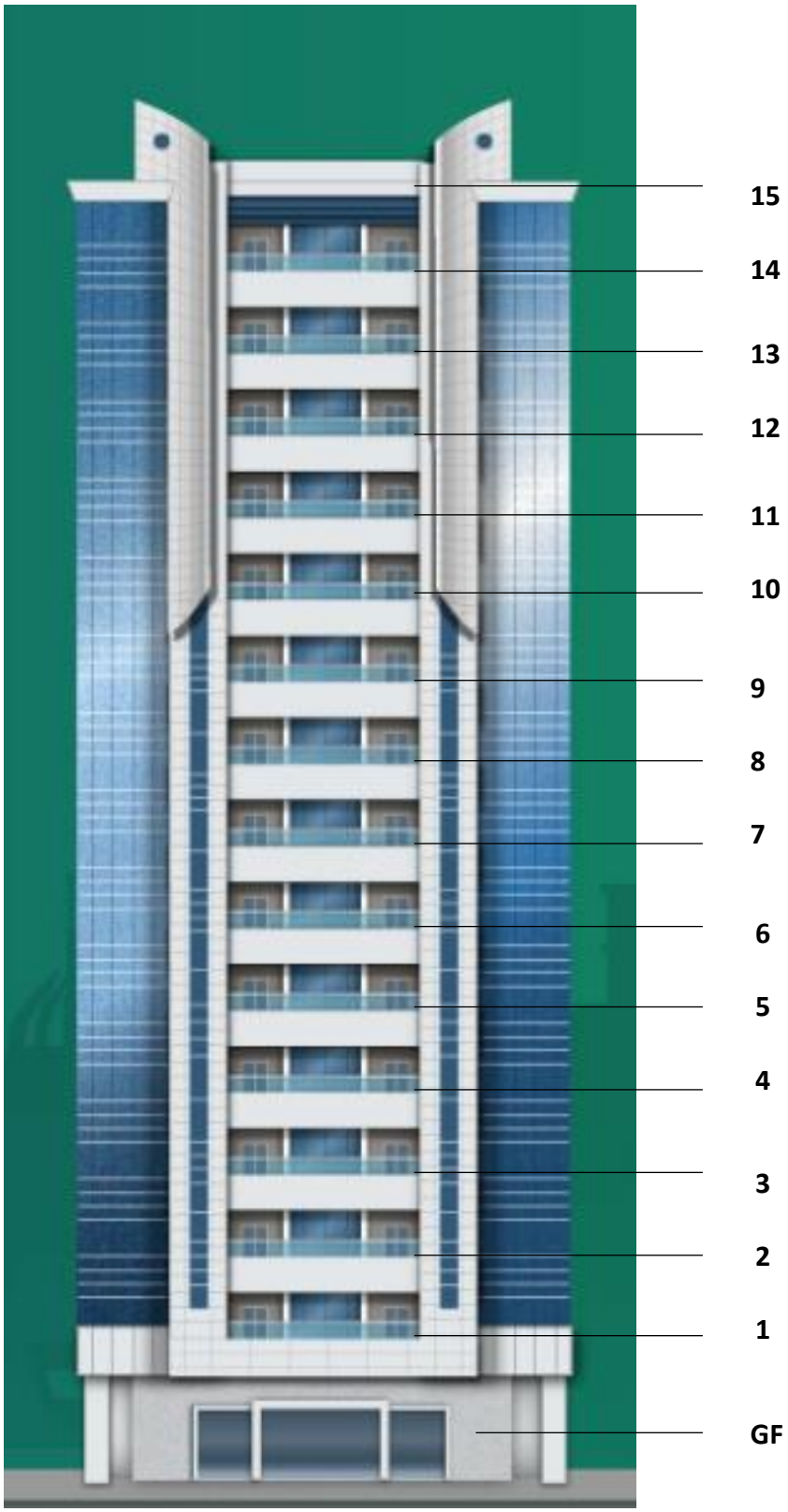
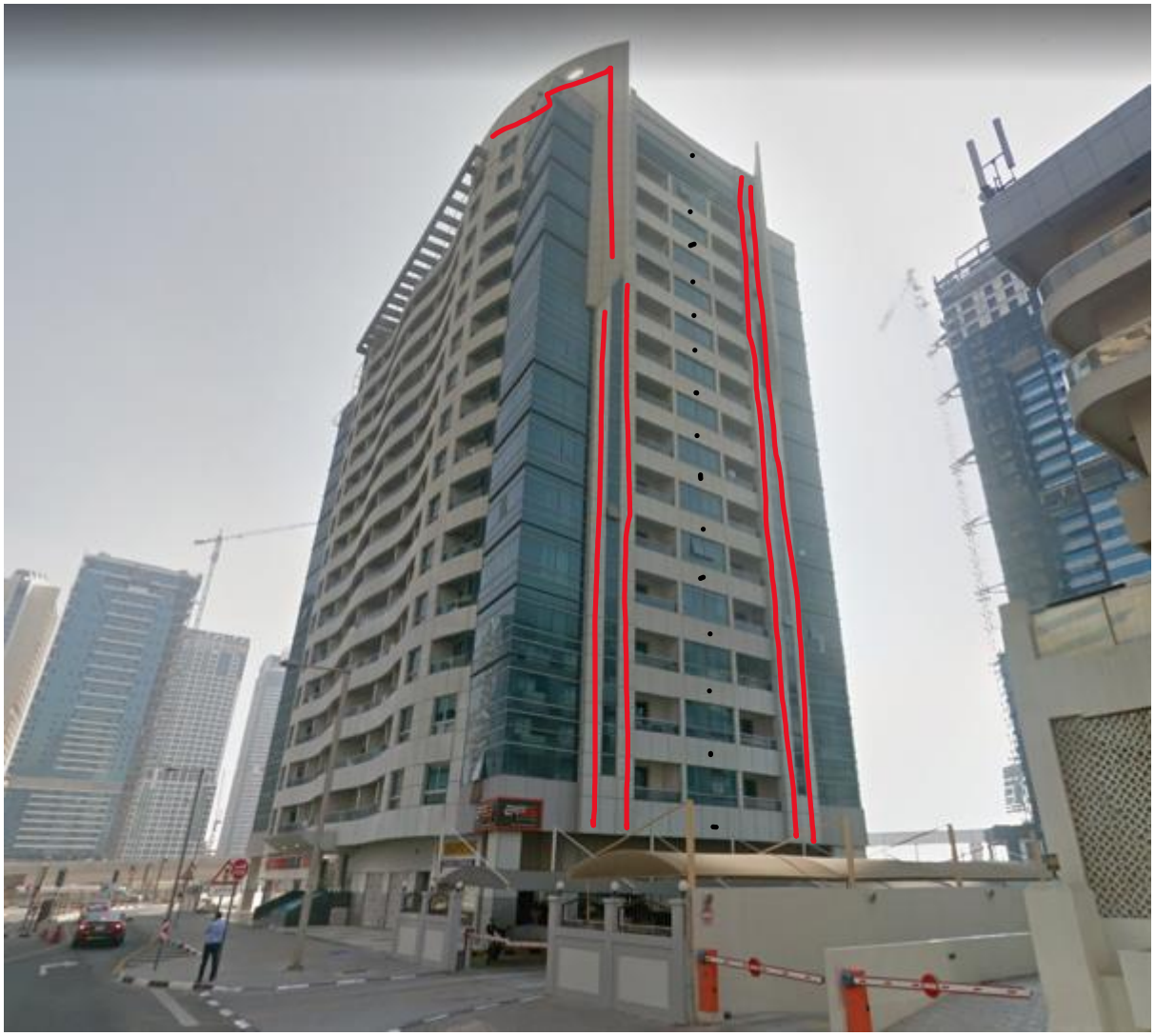
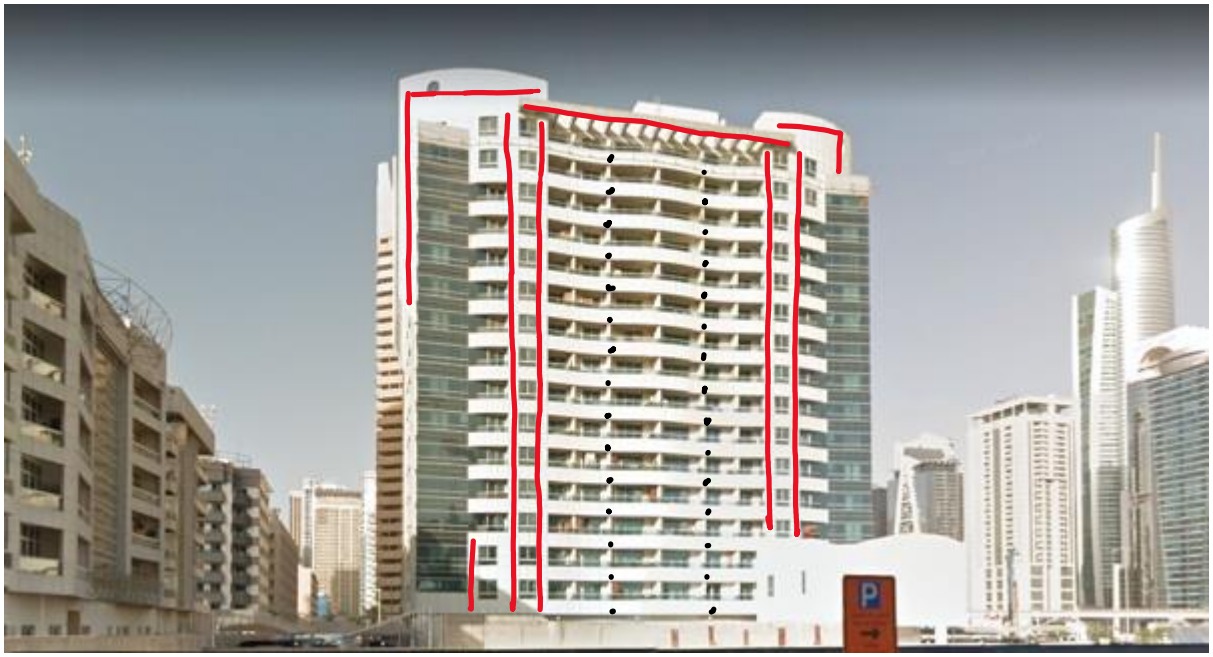


Photo: www.bayut.com

APPENDIX B – REMEDIATION SOLUTIONS

- The photograph above shows where Intelliclad sensors would be placed on the façade to give adequate coverage and appropriate protection;
- On the ends of the building there are three vertical rows of sensors. The middle row protects the middle balconies, whereas those at the sides are staggered alternately between the two vertical bands of cladding to ensure that any fire which starts on one of the adjacent balconies is detected. Residents can then be alerted before the fire takes hold in these bands of cladding.
- On the front and back of the building the sensors are arranged in four vertical rows to ensure protection of all balconies, as well as adequate coverage of the curves on the façade.
- The fins – which pose a significant risk – are also protected. The inner side is covered by sensors on the vertical bands of cladding. On the outer side there are two sensors on each fin; one adjacent to the 15th floor balcony and the other near the 15th floor window.
- The two photos below show where fire breaks should be created and where Intelliclad sensors should be placed to protect the retained sections of cladding.





The red lines denote the sections of cladding which should be removed, and this includes the complete de-cladding of all four fins. The black dots indicate the position of Intelliclad sensors on the retained sections.

REFERENCES

Marina Diamond 2 Building Guide | Bayut

Fire in Dubai Marina residential building now under control | Al Arabiya English

Fire in Dubai Marina Diamond 2 brought under control - GulfToday

Dubai Marina fire: No injuries after early morning tower blaze (thenationalnews.com)

Sharjah fire: Aluminium cladding blamed as authorities to probe towers across emirate (thenationalnews.com)

New fire code for UAE sets out need for materials that halt spread of fire (thenationalnews.com)

The Relationship between Building Design and Fire Spread: How the Shape, Form & Features of a building can influence the behaviour of fire (October 2019);

The Design, Installation & Materials of the Cladding System at Grenfell Tower – An insight into what went wrong (September 2020);

Intelliclad – A Safe and Cost Effective Alternative to a Waking Watch (April 2021);

Report on the Fire which occurred at Torre del Moro, Milan, Italy on 29 August 2021

If anyone would like to receive copies of any of these reports, please send an email to olympusfiresafety@gmail.com or visit the website www.intelliclad.co.uk to download a copy of the Intelliclad report.

ABOUT THE AUTHOR

Frances Maria Peacock is a Fire Engineer at Olympus Fire Safety, a research based fire consultancy, and Intelliclad (part of Metalline Services – www.metalline.co.uk). Olympus is also a partner of Intelliclad.

She is a also a Chartered Building Engineer and a Chartered Architectural Technologist, as well as an accredited building conservationist, Heritage Consultant and Architectural Historian.