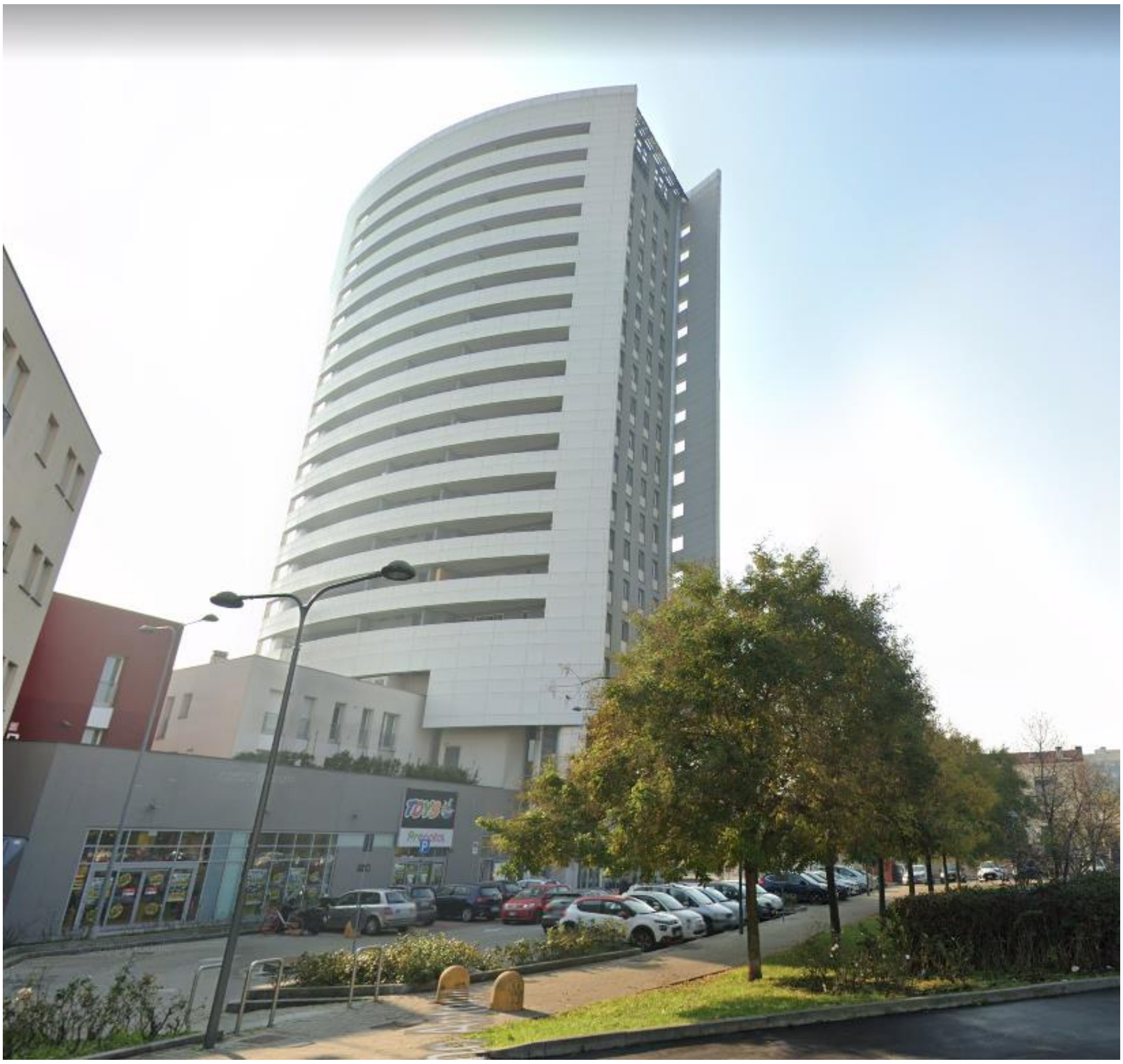
REPORT ON THE FIRE WHICH OCCURRED AT TORRE DEL MORO, MILAN, ITALY ON 29 AUGUST 2021



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Introduction

1.1 On 29 August 2021, a serious fire occurred in an 18-story high rise building in Milan (Milano), Italy, which resulted in most of the building being engulfed in flames. The cause and origin of the fire is still under investigation at the time of writing, but it is thought that the fire may have started due to an electrical short circuit. The flat of origin is on the 15th floor, in the south-west corner of the building, although the seat of the fire within this flat is not yet confirmed. It is possible that it may have started inside the flat and then spread via the door or windows to the external balcony, around which there is an abundance of combustible Aluminium Composite Material (ACM) cladding. The other possibility is that the fire began on the balcony – perhaps an external light or a piece of electrical equipment was to blame – and the cladding was able to ignite.

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 around the building 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 Italy, 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 was no loss of life in this case, although the situation could have been worse if the ends of the building had also been covered in ACM panels, 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, as was the case at Grenfell, in which 72 people died. Nevertheless, both towers had ACM cladding through which the fire spread extensively around the faces of the building.

Building Description

2.1 Torre del Moro is situated in Via Giacomo Antonini in an outer suburb on the southern edge of the city of Milan in northern Italy (*Figs.1 & 2*). The building has 18 storeys above ground and two below, which is why some reports have stated that it has twenty storeys. Its use is primarily residential, although there are several retail units on the ground floor (selling furniture, toys, and goods for babies and pregnant mothers). The residential accommodation occupies all the floors above. The tower was completed in 2011, and is therefore only ten years old. It is 67.4m tall (221 feet), making it the same height as Grenfell Tower.

Figure 1: A Google map showing the location of the Torre Del Moro, whose distinctive shape can be discerned just to the right of the red marker

2.2 It is a building seems to have been designed with an emphasis on aesthetics, with the intention of making it look like a ship, with the curved wings on the north-east and south-west sides, which represent its sails.

2.3 The building consists of a rectangular structural core, with the sails attached to the long sides of the rectangle. These are non-structural and do not part of the main building, and therefore it is safe to say that each of these is in fact an attachment. Located between the sails and the core are balconies, the decks for which horizontally divide what would otherwise be an open space between the outer walls of the core, within which the living accommodation is contained, and the inner wall of the sails. The sails provide a frontage to the balconies, each of which has a parapet wall with an opening above, thus giving the sails a slatted appearance. The balcony decks are extensions of the concrete floor slabs which run through the core of the building.

2.4 In each corner, there is a structural column which is fully exposed at ground level and runs the full height of the building behind each sail. On two of the corners – one on each side of the building and diagonally opposite each other – the sail extends out further and the column can be seen through the openings, running up the back of the sail.

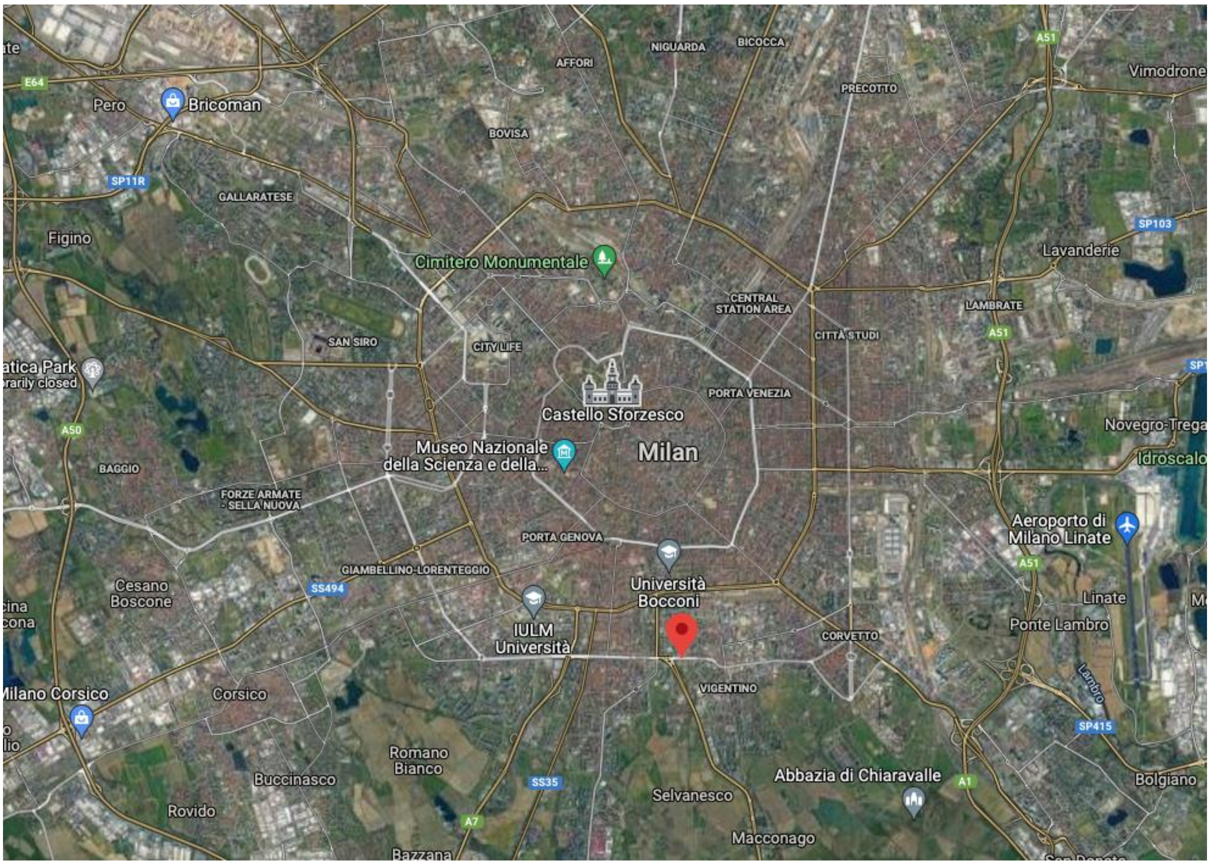


Figure 2: **The red marker points to the location of the Torre Del Moro in the city of Milan**

Design, Geometry & Fire Phenomena

3.1 The overall shape, geometric form and architectural features of the building encouraged the flames to spread and several types of geometrically related fire phenomena were observed on the building during the fire. Each of these shapes, forms and features will now be considered individually.

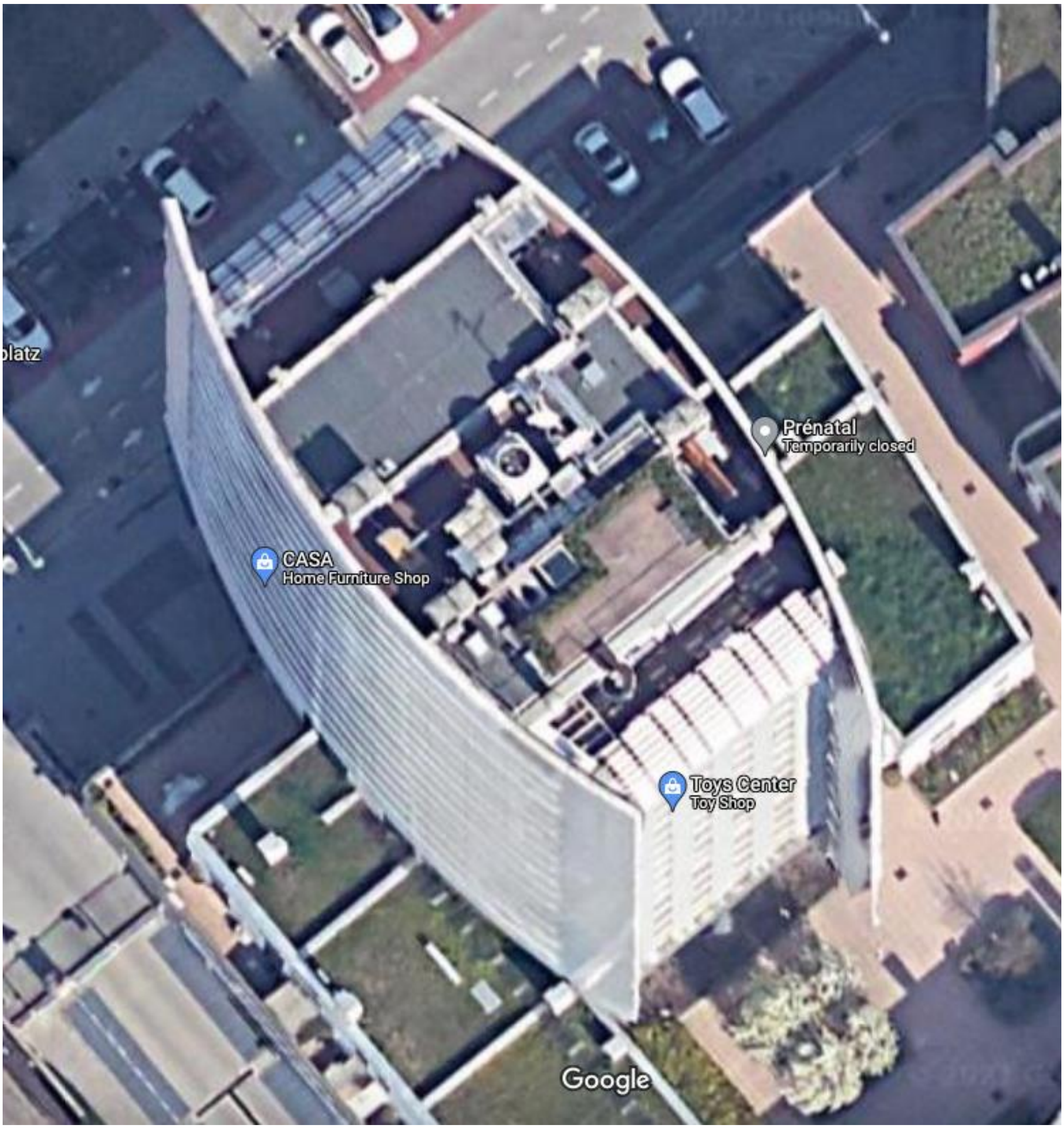


Figure 3: **An aerial view of the building from which the relationship of the sails with the core can be appreciated. The core is rectangular with a curved sail attached to the long sides of the rectangle. These project beyond the short sides of the rectangle (ends) to create vertexes where flames can manifest themselves. At each of the ends, one sail projects further than the other.**

__Figure 4__**: In this photograph the flames are concentrated within the vertex created at the interface where the sail projects beyond the edge of the core. The fire, having rapidly consumed the cladding on the sail, entered the corner where it became concentrated on a band of cladding.**

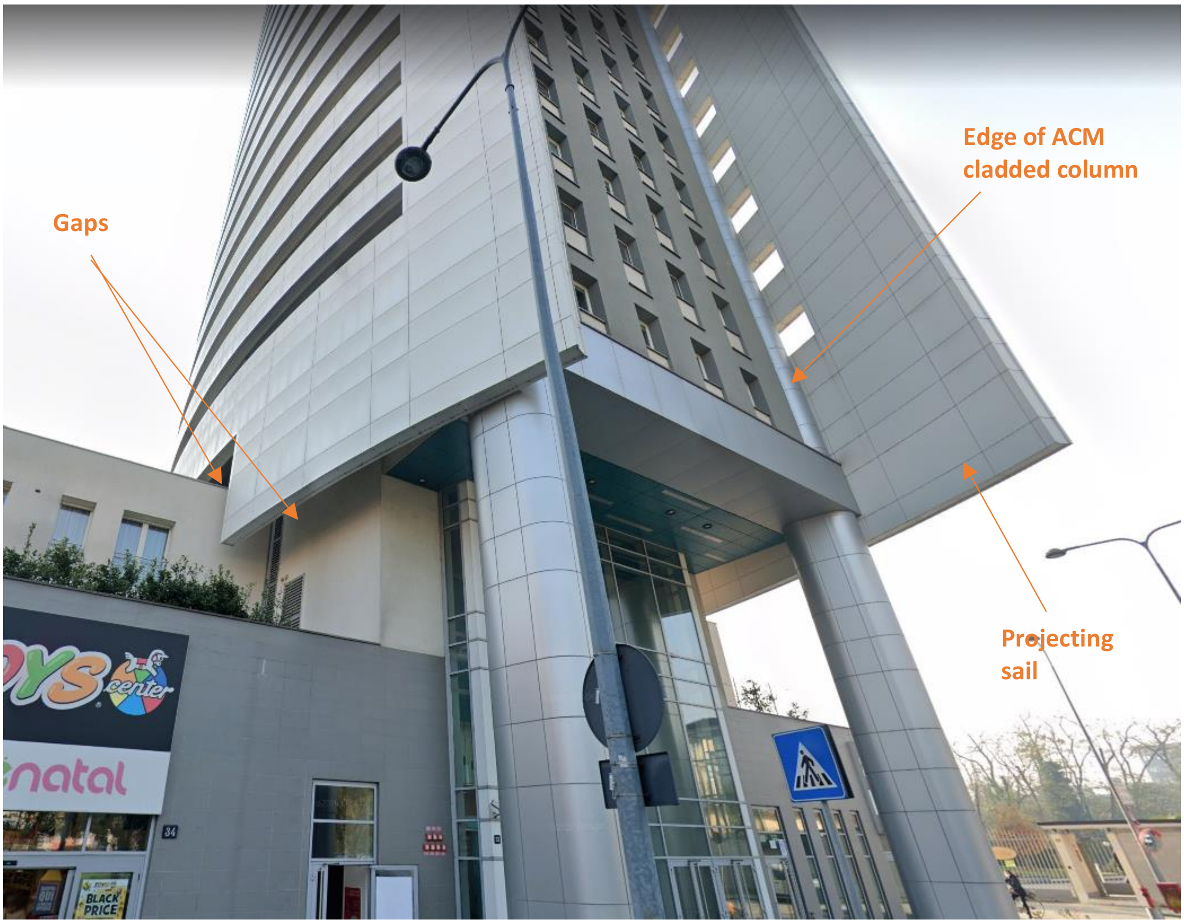
3.2 The sails protrude beyond the ends of the building, extending more on one side than the other on opposite sides at each of the ends (*Fig.3*). The projections create introverted corners at the interface between the core and the sails, therefore providing areas where the flames could become concentrated and intensify the fire spread (*Fig.4*). This is what is known as "Corner Influenced Fire Spread," the definition of which is "*The extension of flame height* *which occurs when the fire becomes confined to an introverted corner (vertex) on a building face*." The fire, as it spread through the sails, was able to enter these corners and then spread rapidly upwards, having ignited the ACM cladding on the vertical columns, the edges of which protruded into this area.

3.3 Fortunately, because the façade on the ends of building was covered with an insulated render system of limited combustibility, the fire could not spread beyond the bands of ACM cladding, although due to its intensity, it was able to enter the flats via the windows. The render is scorched from the fire, but remains largely intact (see the section on "Cladding System Design & Materials" below).

3.4 It is fortunate for another reason that the ends of the building were covered in material of limited combustibility. The narrow ends, recessed between the projecting ends of the sails, create a trench, within which hot gases and flames can become trapped against the building face, thereby increasing the intensity of the fire. This is known as the "Trench Effect", and was first identified following the escalator fire at Kings Cross underground station in London, in November 1987. I was the first to apply it to buildings, and define the Trench Effect within this context in my research report, "*Occurs in recesses where the fire becomes confined and increases in intensity as the recess acts as a vertical trench*." The Kings Cross fire claimed 31 lives, which shows just how deadly this phenomenon can be, and it is fortunate that it did not occur here. Buildings where this effect has occurred include Knowsley Heights in Liverpool, UK in April 1991 and Taksim Ilk Yardim Hospital in Istanbul, Turkey in April 2018.

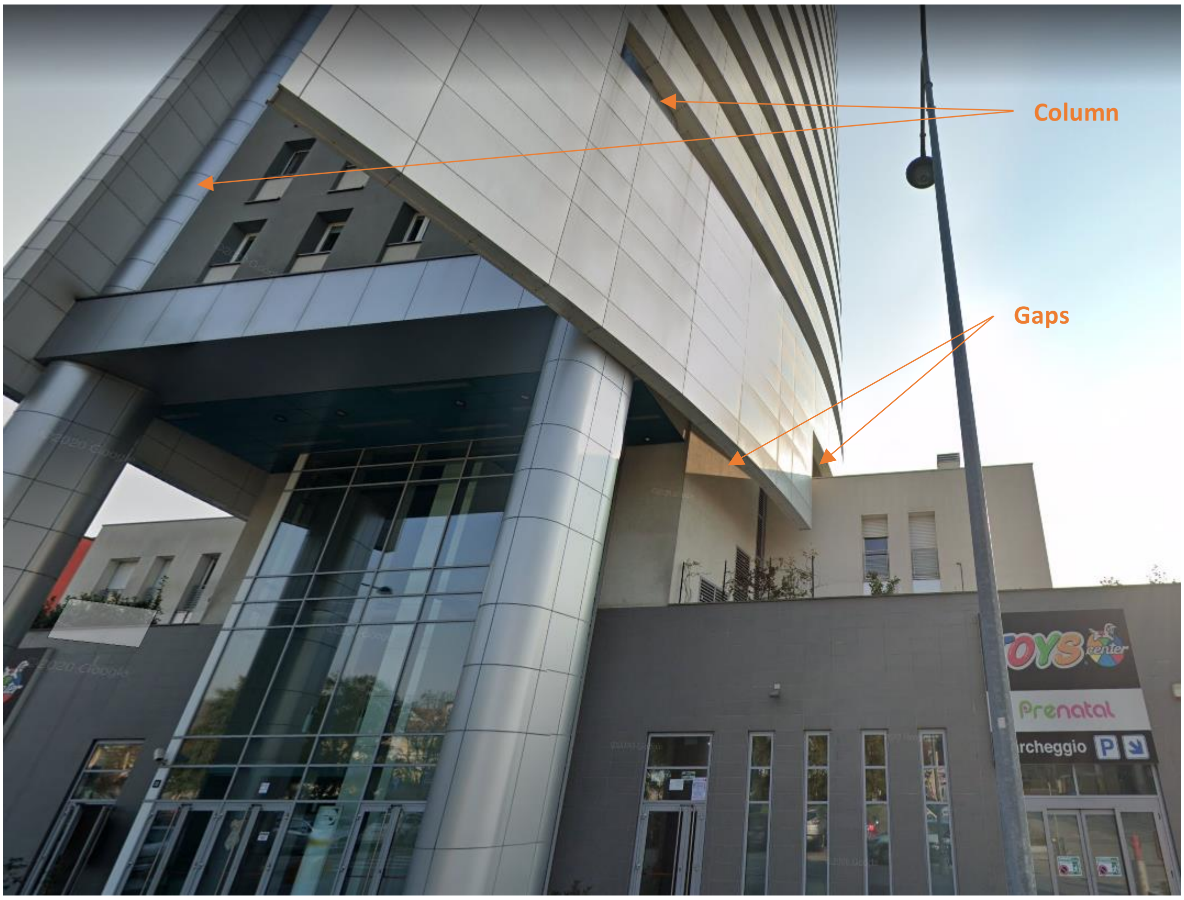
3.5 Both the Trench Effect and Corner Influenced Fire spread cause an intensification of the fire because of the increase in heating of the fuel ahead of the fire front. With *corner influenced fire spread* where the flames become confined to a vertex, the constraint of the flames reduces the amount of oxygen available and the flames elongate as they seek a more plentiful supply. The extension of the flames causes greater heating of the fuel ahead of the fire, leading to rapid upward progression with little or no lateral spread. The less opportunity there is for lateral spread, the more intense the upward flaming will be.

3.6 Below, on pages 8, 9 and 10, are four annotated photographs (*Figs.5, 6, 7 & 8*) which show the construction interfaces, the areas of the building which are covered in ACM cladding and those parts of the building where the façade consists of an insulated render system. *Figures 5, 6 and 7* are all taken from the north-west end of the building and show the view from different angles so that the design of the building and its façade can be appreciated. *Figure 8* is taken from the south-east end with the purpose of showing the extent of the structural columns. Both ends of the building are identical.



<u>Figures 5 (above) & 6 (p.9 below)</u>: The structural columns are exposed at ground level and extend the full height of the building up to the roof. It can clearly be seen that they extend behind the sails, to which they are attached. One sail extends further outwards than the other, and it is here that the column is exposed at intervals, as it extends past the openings for the balconies. The edges of these columns are visible in the corners, and were a means of fire spread on this elevation of the building.

<u>Figures 7 (p.9 below)</u>: This photo shows the balconies, the decks for which are between the sails and the core. The edge of each balcony is protected by a wall, which is covered in ACM cladding with an opening above. In order to provide each flat with its own private space, the balconies are divided at intervals by walls, which provide separation from neighbours. It can be realised that the sails are clad with ACM on both their inner and outer faces.


Column
Gaps
TOYS center
Prenatal
rcheggio P

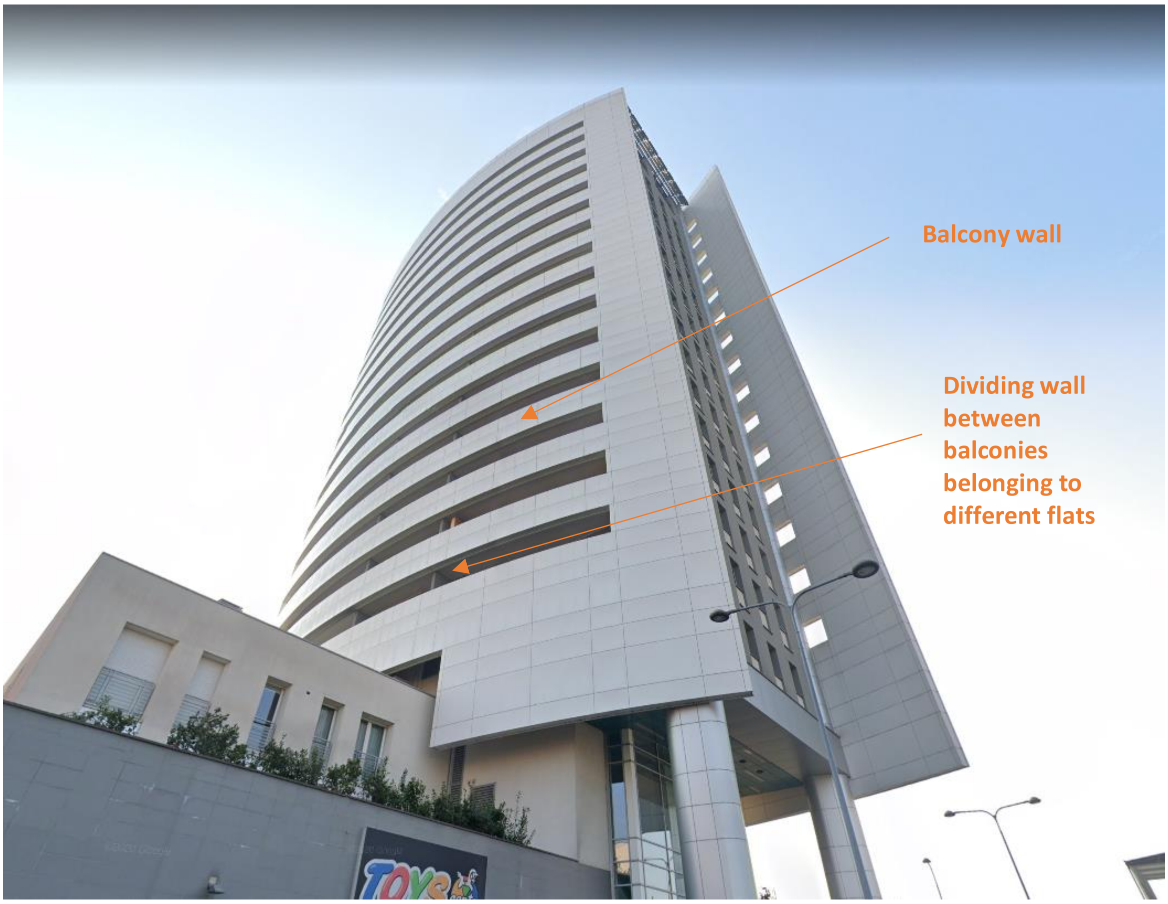

Balcony wall
Dividing wall between balconies belonging to different flats
TOYS

Figure 8: The façade at each end of the building consists of insulated render, but the combustible ACM is in close proximity with the structural columns in direct contact at the interface with the wall. It can also be seen in this photo that there is a feature at roof level which appears to be made of metal, although confirmation would be necessary. This sustained damage during the fire.

3.7 Both sails contain extensive uninterrupted vertical bands of cladding. These will encourage the fire to spread upwards without interruption, but as the bands are fairly wide and there are no projecting features to constrain the flames, some lateral fire spread will be able to occur, and the rate of upward progression will be slowed. The fire will therefore tend to meander around rather than spread vertically upwards. “Upward Vertical Fire Spread”, as it is known, is defined as, *The rapid spread of fire up tall uninterrupted vertical bands of cladding or some other flammable material on the building façade.* The structural columns, which run the full height of the building and extend behind the sails, are also places where Upward Vertical Fire Spread could occur. These columns have the potential to cause rapid upward spread, thus giving the fire an easy means of passage between all levels.

3.8 There are also horizontal bands of cladding along which a fire can spread without interruption. The slats created by the openings for the balconies, increase the surface area and therefore the amount of fuel available for the fire. The slats will also allow air to be drawn through the sails, providing the fire with an increased amount of oxygen and therefore increasing the rate of fire spread. This happened at Grenfell Tower where the increased surface area created by the slats in the crown, along with the draw of air through the structure, intensified the fire. This is described in detail in my research report (see *Appendix A*).

3.9 There are two types of horizontal fire spread which may affect a wall covered in combustible cladding. One of these is “Standard Horizontal Fire Spread,” which 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 speed is reduced due to there being less heating of the fuel ahead of the burning zone. The other type is “Feature Enhanced Horizontal Fire Spread,” where the presence of a horizontally orientated feature of edge will allow the flames to become concentrated within a confined area, and therefore allow for greater heating of the fuel ahead of the burning zone. This leads to an increase in the rate of fire spread.

3.10 It is likely that both types are relevant to the Torre Del Moro. However, the edges of the balcony walls would provide a feature upon which the fire could concentrate itself, and therefore increase the rate of spread.

3.11 At each end of the building, there are gaps at first floor level where the sails are constructed around the podium at the bottom of the building (*Figs. 5, 6 & 7*). The gap represents a pathway for fire which can affect the inside face of the sail and the outer face of the core at the same time. It will also act as a chimney where heat can build and intensify the fire.

3.12 The sails themselves have a curved, which would lead to distortion of the fire front as it passed across the facade. This will cause the front to become diagonally inclined (*Fig.9*). Although this pattern was observed on the more extensive sections of cladding at lower levels, it did not appear on the rest of the façade due to the presence of the balcony openings. Such phenomena is rare and will only appear in circumstance where the right combination of factors are present. Other buildings where this pattern has been observed are Grenfell Tower, London (June 2017), Taksim Ilk Yardim Hosptial, Istanbul, Turkey (April 2018) and the Olympus Tower, Grozny, Chechnya, Russia (April 2013).

Figure 9: The fire started on the 15th floor and spread across the building and downwards, as the cores of the panels melted and burned. In the lower corner of the building, just below the main band of fire and the tree tops, a diagonal pattern can be seen. This is a still image taken from a video where it is easier to observe the effect in motion, although in both cases the large amount of smoke makes it difficult to see.

3.13 There are two main types: "Upward Vertical Fire Spread with an Inclined Front," defined as being *caused by curves on a building face distorting the fire front* and "Downward Vertical Fire Spread with an Inclined Front," defined as being *initiated by fire spreading along a* *horizontally orientated feature at the top of the building.* There is also a subtype which is caused by the fire burning upwards or downwards of a large expanse of cladding, and without anything to constrain the flames, the fronts often become diagonally inclined as differentiations in the speed between the upper and lower ends of the fronts develop. Such fronts are generally quite small when compared to the massive pillars of flame which can develop with each of the main types, often extending the full height of the building. Consequently, this phenomena can be dangerous and devastating.

3.14 It is the sub-type which was observed on the Torre del Moro, where it occurred in association with "Downward Vertical Fire Spread." 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.* See *Figure 9*.

Cladding System Design & Materials

4.1 The sails and the columns are covered in a rainscreen cladding system comprising aluminium composite material (ACM) panels, which have aluminium skins and a polyethylene (PE) core. They are therefore of the same type as those used at Grenfell Tower, although they are the product of a different manufacturer. At Grenfell, the panels were manufactured by *Arconic®*, based in France, but in the case of Torre del Moro, they were manufactured by *Alucoil®,* trading using the name *Larson®*, which is based in Spain. The *Alucoil* panels have a Class E* rating and may therefore quickly lead to a flashover situation and are described as *products capable of resisting for a short period, a small flame attack without substantial flame spread*. This means, in a building situation, a fire may be avoided if the exposure to flame was a matter of seconds, but once the panels are ignited, the fire spreads rapidly with little anyone can do to stop it. This is why Grenfell Tower, the Torre del Moro and other high rise buildings with the same type of cladding have become engulfed in flames very quickly. Therefore, this product is highly combustible and make a significant contribution to fire. Ratings for smoke and droplet production are usually given, but the manufacturer's data sheet, reproduced in *Figures 11 & 12*, does not give any smoke or droplet classifications for its PE panels.

*The Euro Classes (A1, A2 and B-F) are set by BS EN 13501-1:2018 *Fire Classification of construction products and building elements.* The classifications use data from reaction to fire tests, which are carried out under BS 8414 to the criteria specified in BR 135.

4.2 From the data sheet it can be realised that there are two types of "Larson by Alucoil" panel. One of these has a PE core and the other a Fire Resistant (FR) core. The latter is rated Class B s1 d0. Unfortunately, as at Grenfell, the FR version was not used at the Torre del Moro, and therefore the building was given a façade which was a fire risk and a disaster waiting to happen. Euro Class B products will not lead to a flashover situation, but will contribute to a fully developed fire, and are described as being *capable of resisting, for a longer period, a small flame attack without substantial flame spread. In addition, they are also capable of undergoing thermal attack by a single burning item with sufficiently delayed and limited heat release.* This means that although the product is combustible, there will be a longer delay between exposure to fire and ignition. Although safer than a product with a Class E rating, the FR panel is still not suitable for use on high rise residential buildings.

(1) Two possibilities
a) Mineral FR core
(**larson fr**® Fire Class Architectural B-s1,d0 according UNE EN 13501-1)(2)
b) Polyethylene core
(product for exclusive use in low buildings, canopies, signalization and corporate identity)

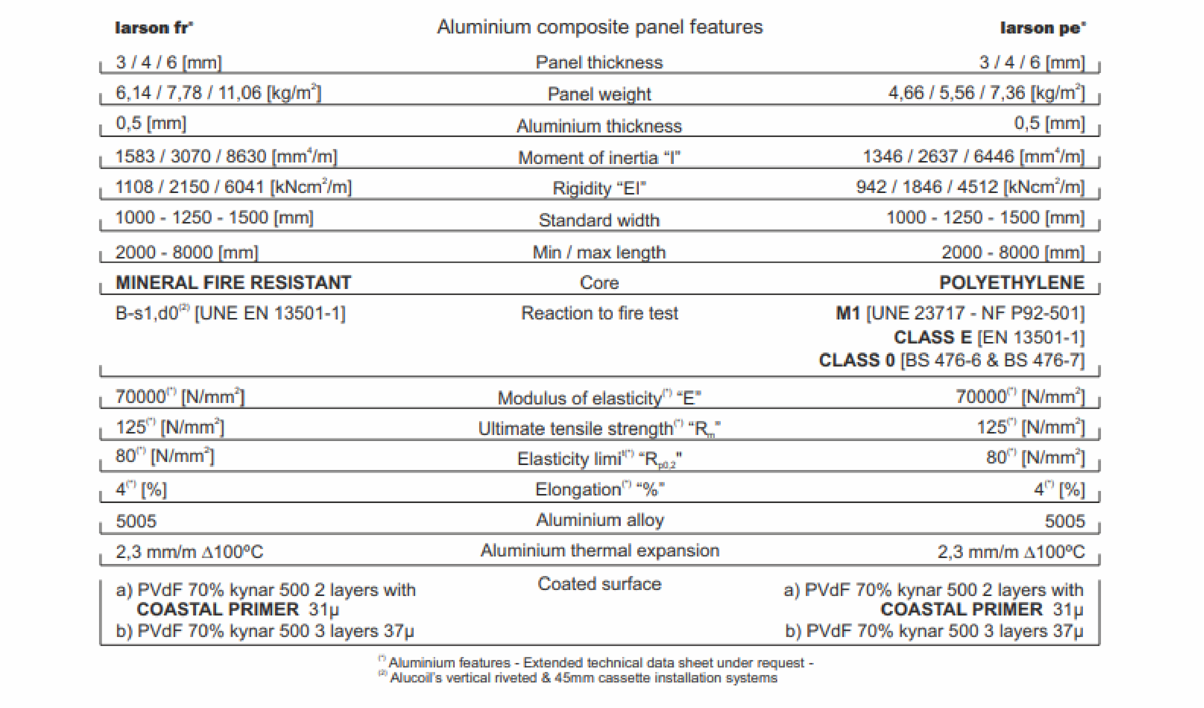
Aluminium composite panels for architectural wall cladding

larson fr® aluminium composite panel, is a high-tech product for architectural façade cladding. It is formed by two aluminium sheets, 5005 alloy, bonded by a mineral fire retardant (FR) core. Thanks to internal developments of our R + D department in Miranda de Ebro, Spain, **Alucoil**® has matured a core that delays panel combustion which allows this material to achieve B-s1,d0(2) classification, according to UNE-EN 13501-1 standard.

Alucoil® also manufactures **larson pe**® composite panel, formed, as well, by two aluminium sheets 5005 alloy but bonded by a thermoplastic resin core (polyethylene PE). This product is meant to be used only in low buildings, canopies, signalization and corporate identity. (**Alucoil**® does not recommend the use of this product in high rise building, limited by specific standards in each country).

larson®, doubles that of the industry standard parameters for any ACM product. It can be easily machined, transformed, drilled, perforated or curved. Its strength by design does not however limit its breadth of design capabilities. For this reason, it has the widest range of coated finishes in the market from the highest quality in liquid PVdF 70% Kynar 500 2 layers with **COASTAL PRIMER** 31μ or 3 layers 37μ.

Figure 11: The first half of the product data sheet for Alucoil/Larson cladding panels



larson fr®	Aluminium composite panel features	**larson pe®**
3 / 4 / 6 [mm]	Panel thickness	3 / 4 / 6 [mm]
6,14 / 7,78 / 11,06 [kg/m^2]	Panel weight	4,66 / 5,56 / 7,36 [kg/m^2]
0,5 [mm]	Aluminium thickness	0,5 [mm]
1583 / 3070 / 8630 [mm^4/m]	Moment of inertia “I”	1346 / 2637 / 6446 [mm^4/m]
1108 / 2150 / 6041 [kNcm^2/m]	Rigidity “EI”	942 / 1846 / 4512 [kNcm^2/m]
1000 - 1250 - 1500 [mm]	Standard width	1000 - 1250 - 1500 [mm]
2000 - 8000 [mm]	Min / max length	2000 - 8000 [mm]
MINERAL FIRE RESISTANT	Core	**POLYETHYLENE**
B-s1,d0(2) [UNE EN 13501-1]	Reaction to fire test	**M1** [UNE 23717 - NF P92-501] **CLASS E** [EN 13501-1] **CLASS 0** [BS 476-6 & BS 476-7]
70000(*) [N/mm^2]	Modulus of elasticity(*) “E”	70000(*) [N/mm^2]
125(*) [N/mm^2]	Ultimate tensile strength(*) “R_m”	125(*) [N/mm^2]
80(*) [N/mm^2]	Elasticity limi(*) “$R_{p0.2}$”	80(*) [N/mm^2]
4(*) [%]	Elongation(*) “%”	4(*) [%]
5005	Aluminium alloy	5005
2,3 mm/m Δ100ºC	Aluminium thermal expansion	2,3 mm/m Δ100ºC
a) PVdF 70% kynar 500 2 layers with **COASTAL PRIMER** 31µ b) PVdF 70% kynar 500 3 layers 37µ	Coated surface	a) PVdF 70% kynar 500 2 layers with **COASTAL PRIMER** 31µ b) PVdF 70% kynar 500 3 layers 37µ

(*) Aluminium features - Extended technical data sheet under request -

(2) Alucoil's vertical riveted & 45mm cassette installation systems

Figure 12: The second half of the data sheet for the Alucoil/Larson cladding products

4.3 It is worth noting that the FR panels appear to have a smoke production classification of s1 and a droplet production classification of d0, which are the best possible classifications in each of these categories. The amount of smoke produced and whether or not the material produces droplets, makes a notable difference in any fire. Flaming droplets of melting material will run down the building face and form pool fires on ledges, allowing the fire to spread to other parts of the building, especially lower levels which would not otherwise be involved in the fire. If the panels have polyethylene (PE) cores, toxic smoke will be produced in significant quantities. Polyethylene contains carbon and hydrogen, meaning that carbon monoxide will be emitted when it burns. As this is the main killer in a fire, it is fortunate that the residents were able to evacuate the building before the interior was affected.

4.4 Initial news and social media reports stated that the panels involved were made by Aza Aghito Zambinini, an Italian company based between Vicenza and Venice (Venezia), and therefore within a reasonable distance of Milan. It is probably the company's approximation to the city that led to this assumption, along with the fact that the products on the main expanses of the sails seemed to match the ones that it sells. Aza Corp. – as it is also known – also manufactures ACM panels with PE cores.

4.5 The sails themselves contain no solid masonry and are constructed entirely from a lightweight steel framework, to which the panels are fixed. This seems to be a hook-in façade system, using rainscreen cassette panels - as was the case at Grenfell – which are attached by being hooked over horizontal rods. The 3D framework has ACM panels on both sides, as is apparent from the photographs showing the inside faces of the sails where they project outwards at the ends of the building. The inside faces of the balcony walls do not appear to have had ACM cladding and have appeared to sustain less damage as a result. Although insultation was probably present where the sails formed the balcony walls, it is likely that the sails contained no insulation at the ends which projected beyond the line of the building due to a lack of solid masonry to attach it to.

4.6 The columns, in contrast, are structural and of reinforced concrete. The panels here are a darker colour and the cladding system may have been constructed differently, although at present information is lacking.

4.7 The walls at the ends of the building (*Fig.8*) are covered with a type of insulated render system, in this case an External Thermal Insulation Composite System (ETICS) containing mineral wool insulation. This has a Euro Class A2 rating which means it is of limited combustibility. In contrast the ACM cladding which covered the sails and columns was highly combustible (Class E), which explains why it burnt so rapidly compared to the insulated render system made little contribution to the fire.

4.8 The photos (*Figs. 13-16*) below, on pages 17 and 18, show the structural details of the cladding system which have been exposed after the panels burned away. It can be seen that the framework which forms the balcony walls is different from that which forms the aesthetic parts of the sail and extends beyond the ends of the building. This consists of vertical support rails with horizontal bolts upon which the panels could be hooked. The diagonal cross-bracing provides additional support for the panels to ensure that they remain stable in windy conditions. The cladding on the balconies, although of the same type, appears to have used a different method of fixing, which at this stage is unclear.

Figure 13: The fire has consumed all of the sail on the south-western side, leaving behind a skeletal framework. It seems that the fire spread along combustible material at roof level to reach the sail on the opposite side of the building.

Figure 14: A close up view of the building from the opposite side to that where the fire started; the end of the sail has borne the brunt of the fire with only the framework surviving. It can be seen that the fire stopped abruptly before the balconies, where the cladding has started to delaminate and deform. This suggests that there may have been fire barriers between the balconies and the ends of the sails.

Figure 15: A close-up view of the balconies which shows the difference in the design of the framework with that on the ends of the sails. It is difficult to tell what lies behind the framework on the balconies, but whatever the material is, it has remained intact. The ends of the sails have burned through completely and the wall behind, at the interface with the core and the balconies, is exposed.

Figure 16: The same areas of the structure in Figure 15 above, but during the fire, where flames can be seen venting through the doors and windows of one of the flats.

The Development and Spread of the Fire

5.1 The fire began in a flat on the south-west side of the building, in a flat located in the right-hand corner (as one stands facing the building) on this side. Footage of the fire was taken by a neighbour who spotted black smoke emerging from the balcony. No flames were visible at this point, but within minutes the cladding system was alight. The flames took hold in the top right corner of the balcony opening, and then rapidly spread upwards. The fire also quickly spread sideways and downwards, eventually destroying the entire sail and affecting the cladding on the structural columns which extend the full height of the building. Combustible material at roof level and the intensity of the heat enabled the fire to spread to the sail on the opposite side of the building, one end of which was destroyed.

5.2 The photos below (Fig.17) have been arranged in a sequence to show the initial development of the fire.

Figure 17: These four photos show the initial stages of the fire's development, from wisps of black smoke in Photo 1, to a small flame in the top corner in Photo 2, to a larger flame in Photo 3 and finally an established fire in Photo 4, which is venting through the balcony opening and impinging on the cladding above.

5.3 Polyethylene is a thermoplastic polymer with a low *thermal conductivity*, which means that heat has a tendency to accumulate at the surface rather than being transferred deeper into the body of the solid by conduction. This results in a rapid rise in temperature, enabling the material to ignite more easily. As polyethylene is of low density, it will heat up quickly when subjected to a heat, especially as it has a low *specific heat capacity*, meaning that it takes less energy to raise the temperature by a given amount. The PE cores of the panels have a high *heat release rate*, which results in a higher *rate of combustion*, causing extremely rapid fire spread. The *rate* at which the heat is released is of greater significance to the spread of fire than the *amount* of heat which is produced.

5.4 The next series of photos (*Figs.18-23*) shows the development of the fire as it spread around the building.

Figure 18: The fire is now well developed and has destroyed the cladding on the top right corner of the sail. It has spread upwards, downwards and horizontally from the flat where it started. It is now affecting the combustible material at the top of the sail, around the edge of the roof.

Figure 19 (top photo, p.22): The fire has now swept its way across the tower with fierce flaming at the opposite end of the sail to that where it started. There appears to be a strong wind which is blowing in the same direction as that in which the fire is spreading. However, although in this case the wind may be helping the fire to spread faster, examination of previous fires has shown that geometry is of greater importance, and a fire will even spread into an oncoming wind (ie. A wind blowing in the opposite direction to that in which it is travelling) if the profile and features are such that they promote fire spread.

Figure 20: **Most of the cladding has now been destroyed and the fire on the sail has burned itself out. However, the structural column (which extends behind the sail) continues to burn (left photo) and the interior of the flats (which the fire entered from the outside) are still alight.**

Figure 21: The tower viewed from the other side; the opposite one to where the fire started. The fire has spread around both ends of the building to affect both ends of the sail. On the left side there is evidence of horizontal fire spread along the balcony walls. There is also evidence of extensive fire spread via the perimeter of the roof.

Figure 22: The same side is viewed again from a different angle, where flaming can be seen at roof level against the darkened sky.

Figure 23: **A night-time view of the side where the fire started showing that the interior of flats remain alight and there is still substantial flaming at roof level.**

5.5 It is possible that the support framework for the cladding system helped the fire to spread, by conducting heat to other parts of the system not yet affected by the fire. Metal is a good conductor of heat and in steel framed buildings, a metal girder passing through a wall into a neighbouring compartment may conduct sufficient heat to enable the contents of that compartment to ignite, without the fire actually needing to enter the room itself. This is a recognised problem, especially in steel framed industrial buildings. If this is applied to a rainscreen cladding system, heat will be conducted along the support framework and it is possible that this may transfer enough heat to ignite combustible material ahead of the fire front.

Conclusion

6.1 There are several parallels which can be drawn between the fire at the Torre del Moro in Milan and the fire at Grenfell Tower fire in London. Both buildings were of the same height and both were covered in combustible ACM cladding panels rated Class E. Both fires burned very quickly, affecting most of their respective buildings; the flames were able to enter the flats from the outside and therefore breach the compartmentation. In the case of the Torre del Moro, there were no fatalities, but at Grenfell, 72 people lost their lives. Those living in the building in Milan evacuated as soon as they realised there was a fire, but many at Grenfell remained in their flats, following advice to stay-put or believing that they would eventually be rescued. A stay-put policy will only be successful if the compartmentation on which it depends is maintained. The breach in compartmentation at Grenfell caused the building to fill with toxic smoke which made it difficult for residents to evacuate once the fire took hold.

6.2 However, the fire at the Torre del Moro could have been worse if the building had been designed differently. A consideration of the relationship between building design and fire spread is important here. If the ends of the building had been clad with ACM instead of the ETICS, the fire would have been far more intense because the shape of the building would have allowed heat to be trapped within the recess created by the protruding sails, and a Trench Effect would have occurred. The ACM cladding was separated from the outside wall of the flats by the presence of balconies, and therefore the fire was not directly around the edges of the windows as it was at Grenfell. Even the slight delay this would have caused to the fire entering the interior of the flats, may have been enough for people to get out before the smoke and flames could make it more difficult.

6.3 Nevertheless, the tower was still affected by several shape-related fire phenomena, including fire spread in an upward, downward and horizontal direction as it followed the geometry of the cladding. Corner influenced fire spread, as well as a tendency for the flames to follow the line of the cladding at roof level, intensified the fire and helped it to spread to other parts of the building.

Appendix A - Research into the Effect of Building Shape upon Fire

A1 In 2017, I began a research project with the aim of assisting the investigation into the Grenfell Tower fire, which I believed would help explain why the fire spread and behaved as it did. When I saw the images of the fire for the first time, it seemed that the shape, form and features of the building were influencing the behaviour of the fire, and that some of these (such as the columns and the roof-top crown) were encouraging the fire to spread. I therefore started analysing the relationship between building design and fire spread, looking at how the overall shape, geometric form and architectural features affect the way in which a fire spreads on a high rise building if it has a combustible façade.

A2 The research has revealed that there are specific types of fire behaviour associated with particular shapes, forms and features. A set of principles has been developed based on these findings, and consequently, it is now possible to use these principles to predict how a fire will spread across the façade by examining the geometric profile of the building. At Grenfell, it was acknowledged that geometry had a role in the fire spread, and my research was able to fully explain the fire dynamics behind the type of behaviour observed.

A3 The findings of the research were published in a technical report in October 2019 which was submitted to the Grenfell Tower Inquiry: *The Relationship between Building Design and Fire Spread: How the Shape, Form & Features of a building can influence the behaviour of fire.* Please send an email to olympusfiresafety@gmail.com if you would like a copy. This is highly recommended because it will provide a detailed understanding of the relevant principles and how the fire was able to affect the Torre del Moro so extensively.

A4 The principles have several useful applications. Firstly, they can be used in fire investigations to explain why a fire spread and behaved in the way that it did. Secondly, they can be applied to architectural design. If a particular shape, form or feature has been shown to facilitate fire spread, it could be eliminated at the design stage before planning consent is sought and construction begins. Thirdly, firefighters can be trained to understand the principles, which will allow them to arrive at the scene of a high-rise building fire fully prepared for what may happen. This will allow them to plan an appropriate and effective firefighting and evacuation strategy. Fourthly, the principles can be applied to the testing of façade construction types by allowing the test apparatus to be representative of the building on which the cladding is to be installed and on which it can be tested for its geometric performance. Fifthly and finally, the principles can be used for the remediation of unsafe buildings, especially with interim measures. For example, the cladding could be removed from the most hazardous parts of the building initially, until such a time that the remainder can be done. Perhaps the most important interim measure is a fire alarm and detection system called Intelliclad, which is designed to be installed within the cladding system itself. The sensors are placed in strategic locations according to set criteria, one of which is the geometric principles developed from my research. In April 2021, I produced a report on Intelliclad: *Intelliclad – A Safer and Cost Effective Alternative to a Waking Watch,* copies of which can be obtained from Olympus Fire Safety olympusfiresafety@gmail.com

A5 My other report examines the details of the design, installation, defects and materials of the cladding system at Grenfell Tower. It was published in September 2020 and submitted to the Grenfell Tower Inquiry. Please send an email to olympusfiresafety@gmail.com if you would like a copy. This one is also recommended because it explains several technical issues associated with cladding systems.

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Websites:

www.fmparchitecture.com
www.olympusfiresafety.com
www.intelliclad.co.uk
www.metalline.co.uk

Appendix B - Useful Links:

Fire in Milan, the Spanish company advised against those panels for skyscrapers: "Classified as normally flammable" - Open

Incendio Milano, fabbricati in Spagna i pannelli della torre bruciata: "Non erano ignifughi, consigliati solo per edifici bassi" (repubblica.it)

Milan: exclusive images of how the Torre del Moro fire developed (italy24news.com)

The «Torre dei Moro», the dream of the ship under full sail in the new vertical Milan-Corriere.it (italy24news.com)