THE RELATIONSHIP BETWEEN BUILDING DESIGN AND FIRE SPREAD:

How the shape, form & features of a building can influence the behaviour of fire

By Frances Maria Peacock

Fire Engineer at Intelliclad

INTRODUCTION

- Fire Engineer (MIFireE);
- Chartered Building Engineer (CBuildE FCABE);
- Chartered Architectural Technologist (FCIAT);
- Architectural Historian & Accredited building conservationist (IHBC);
- International Fire Safety Standards Coalition – Standards Setting Committee;
- CIAT Fire Safety Task Force;
- CIAT Project Task Force (Corresponding Member for Fire);
- Other professional Institution memberships: SFPE, RIBA, IRSE & Lincoln's Inn;
- Working towards obtaining CEng and registration with the Engineering Council

OBJECTIVES

- To contribute to the Grenfell fire investigation by using my work to help determine and explain what went wrong;
- To enable a greater understanding of how fire behaves and spreads on the exterior of high rise buildings so that the risks can be recognised;
- To establish a set of principles from which the spread and behaviour of fire can be predicted;
- To improve the safety of building design, firefighting and testing;
- To develop a safety assessment which can determine the likelihood and severity of external fires based on façade design, which will allow the fire risk to be fully appreciated;

APPLICATIONS

- Fire investigation
- Architectural design
- Firefighting
- Façade testing
- Remediation/mitigation of fire risk in unsafe buildings

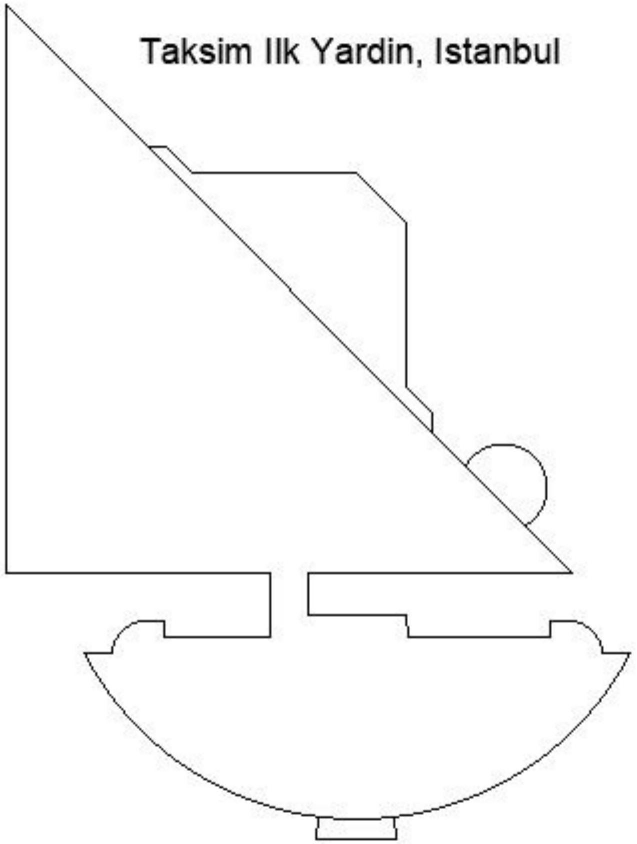
MAIN CASE STUDIES

- **Grenfell Tower, London, UK** (14 June 2017)
- **Olympus Tower, Grozny, Chechnya, Russia** (3 April 2013)
- **Taksim Ilk Yardim Hospital, Istanbul, Turkey** (5 April 2018)
- **Monte Carlo Casino & Hotel, Las Vegas, USA** (25 January 2008)
- **Shanghai high rise apartment building, China** (15 November 2010)
- **Kaifeng high rise building, China** (14 March 2019)
- **Wooshin Golden Suites, South Korea** (1 October 2010)
- **Knowsley Heights, Liverpool, UK** (5 April 1991)
- **Polat Tower, Istanbul, Turkey** (17 July 2012)
- **Garnock Court, Irvine, Scotland, UK** (11 June 1999)

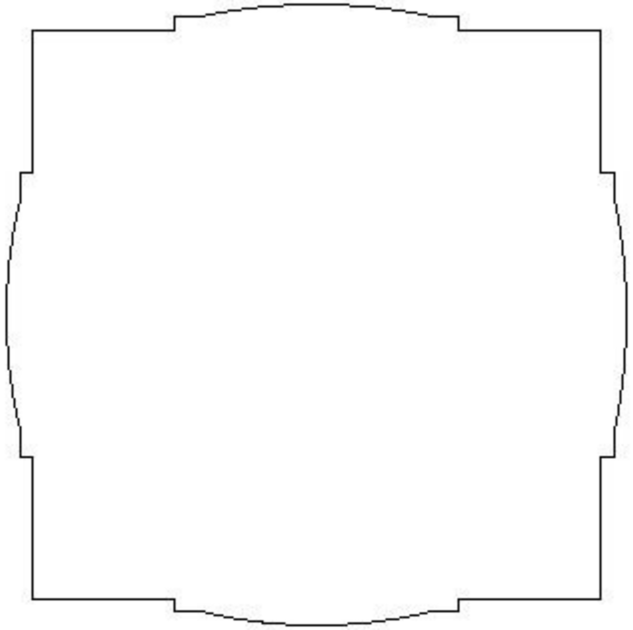
MAIN CASE STUDIES

- **Luoyang high rise building, China** (29 May 2019)
- **Lacrosse Building, Melbourne, Australia** (25 November 2014)
- **Mermoz Tower, Roubaix, France** (14 May 2012)
- **Torch Tower (“The Torch”), Dubai, UAE** (21 February 2015 & 2017)
- **Sulafa Tower, Dubai, UAE** (20 July 2016)
- **The Address Hotel, Dubai, UAE** (31 December 2015)
- **Tamweel Tower, Dubai, UAE** (18 November 2012)
- **Saif Belhasa, Dubai, UAE** (6 October 2012)
- **Nasser Tower, Sharjah, UAE** (1 October 2015)
- **Al Baker Tower 4, Sharjah, UAE** (18 January 2012)

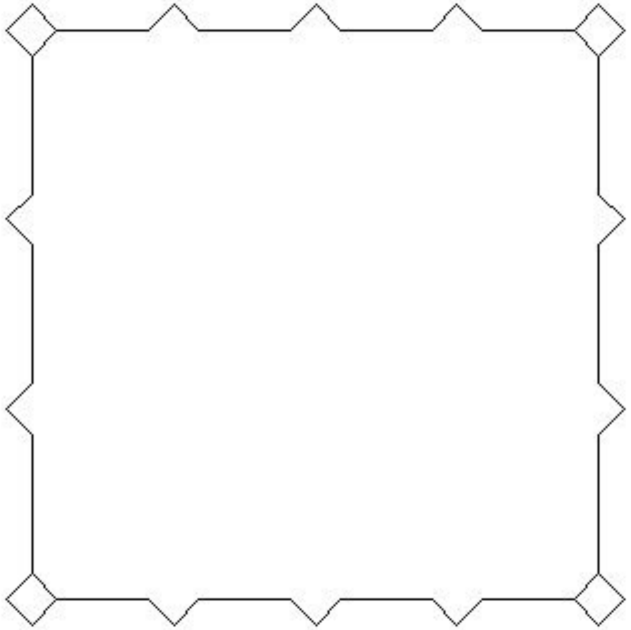
OVERALL SHAPE, GEOMETRIC FORM & ARCHITECTURAL FEATURES



Taksim Ilk Yardin, Istanbul



Olympus Tower, Grozny



Grenfell Tower, London

SHAPE RELATED FIRE PHENOMENA

- Upward fire spread
- Downward fire spread
- Horizontal fire spread
- Edge influenced
- Corner influenced
- Trench influenced
- The relationship between shape, air movement and fire

- Vertical, inclined, feature enhanced;
- Vertical, inclined, feature enhanced;
- Standard, feature enhanced, rotational;
- Enhanced by architectural features;
- Introverted corners, cross-radiation;
- Recesses, cross-radiation;
- Vortexes, pressure zones, flow of air around the building;
- Exposure & constraint of the flames;
- Surface area;

UPWARD FIRE SPREAD

- Upward vertical fire spread: *The rapid spread of fire up tall uninterrupted vertical bands of cladding or some other flammable material on the building façade;*
- Feature influenced upward fire spread: *The tendency for the fire to concentrate itself on a vertically orientated projecting feature; this will enhance the rate of flame spread;*
- Corner Influenced: *The extension of flame height which occurs when the fire becomes confined to an introverted corner (vertex) on a building face;*
- The Trench Effect: *Occurs in recesses where the fire becomes confined and increases in intensity as the recess acts as a vertical trench;*
- Upward fire spread with an inclined front: *Caused by curves on a building face distorting the fire front;*

EXAMPLES OF UPWARD FIRE SPREAD

Upward vertical fire spread

EXAMPLES OF UPWARD FIRE SPREAD

Corner influenced

UPWARD FIRE SPREAD

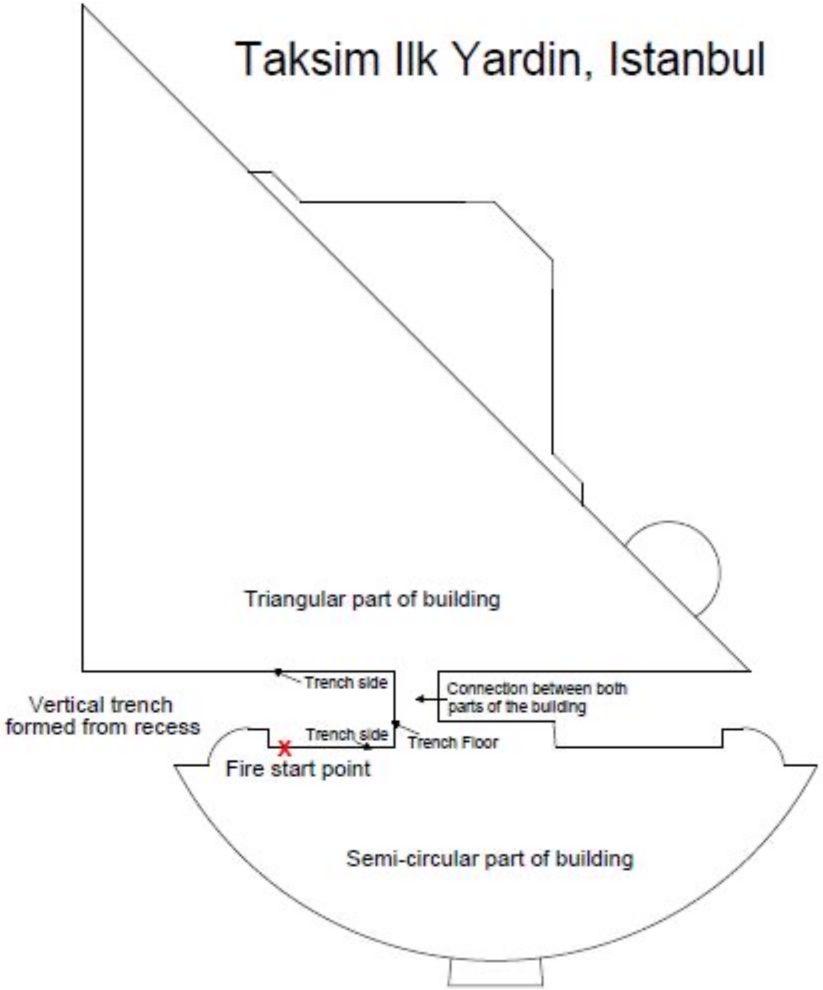
Feature Influenced

Upward fire spread with an inclined front

THE TRENCH EFFECT

Recesses

THE TRENCH EFFECT



THE EFFECT OF CURVES

- Curve characteristics:
- Orientation – vertical or horizontal;
- Convex or concave;
- Pronounced or slight & gently sweeping;
- *All these can affect the behaviour of fire, with orientation being the most significant*

THE EFFECT OF CURVES

- The curvature of the building face distorts the fire front, as the flames start to move faster at higher levels than lower levels;
- Has been observed on convex curves, but would probably occur on concave curves too;
- *The resulting diagonal inclination is horizontal and vertical fire spread occurring simultaneously, caused by a differentiation in flame speed between the upper and lower levels of the building;*
- *It is the extent of the lateral spread in relation to the upward spread which determines the angle of the deflection;*
- *The more pronounced the curve is, the greater the angle will be;*

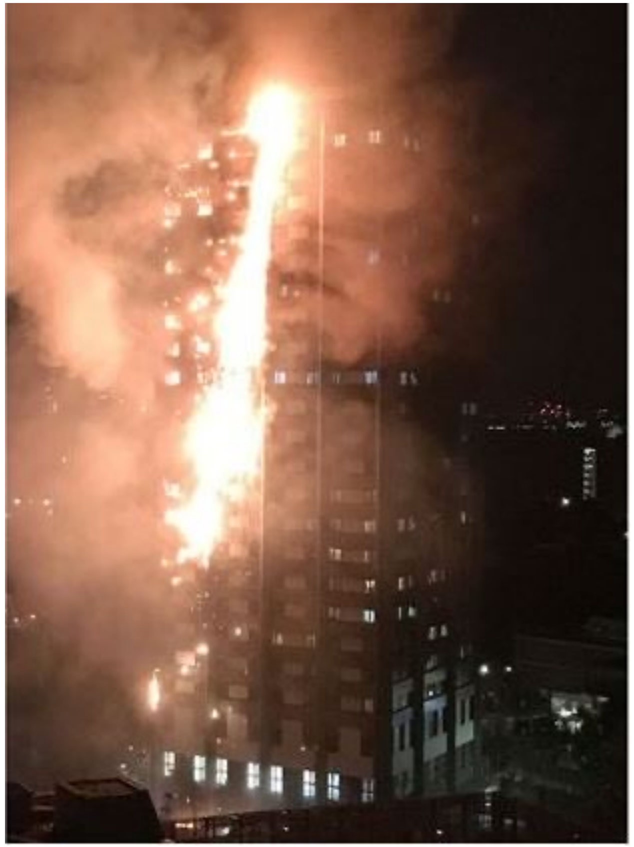
DOWNWARD FIRE SPREAD

- Downward vertical fire spread: *The downward spread of fire affecting continuous bands of cladding due to the flowing and dripping of molten burning material. The does not involve projecting features;*
- Downward fire spread with an inclined front: *Initiated by fire spreading along a horizontally orientated feature, at the top of a building;*
- Feature influenced downward fire spread: *The tendency for the fire to concentrate itself on a vertically orientated projecting feature; this will interrupt the diagonal pattern if the fire is spreading with an inclined front;*

DOWNWARD FIRE SPREAD

Downward vertical fire spread

Downward fire spread with an inclined (diagonal) front



Feature influenced downward fire spread

DOWNWARD FIRE SPREAD

HORIZONTAL FIRE SPREAD

- Standard horizontal fire spread: *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;*
- Feature enhanced horizontal fire spread: *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;*
- Perimeter (roof-top) fire spread: *This is essentially Feature Enhanced horizontal fire spread which occurs at roof level, involving a parapet, crown or rim around the perimeter of a building. It is influenced by exposure of the architectural feature;*
- Rotational fire spread: *The action of the fire transferring around the corners of the building without the aid of roof-top features. It generally occurs at lower levels and is influenced by the shape of the building's corners and any other feature connected to or close to the corners, such as string courses and cornices;*

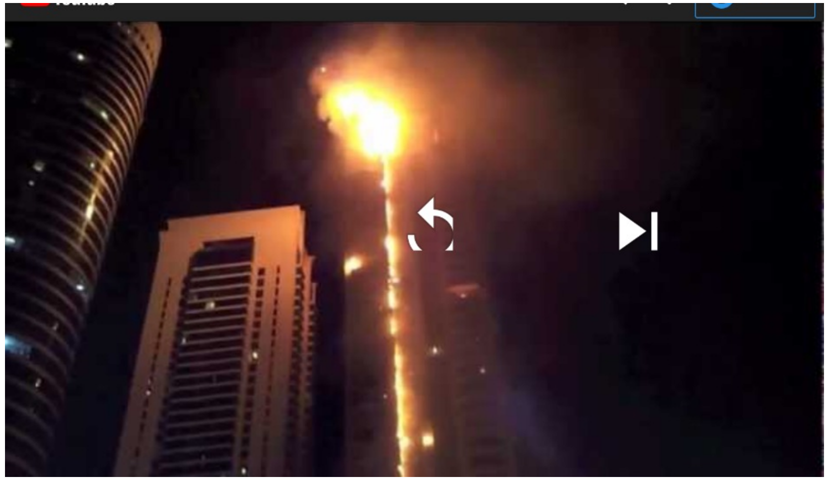
HORIZONTAL FIRE SPREAD

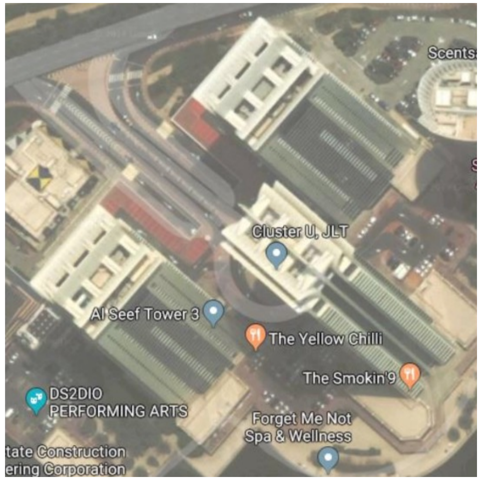
Standard

Feature enhanced

Rotational fire spread

ROOF-TOP FIRE SPREAD

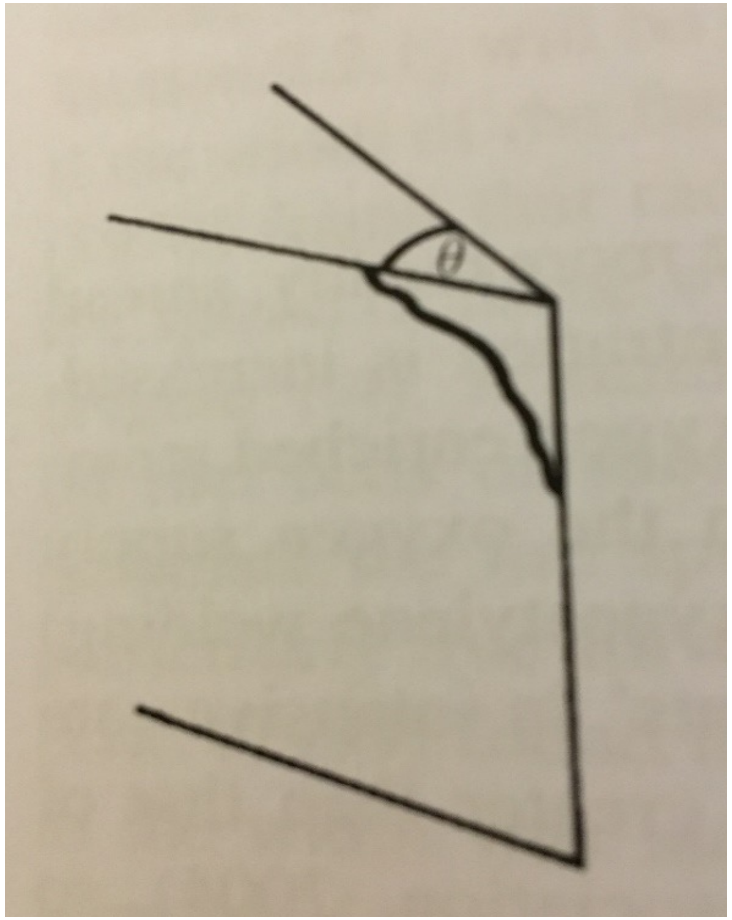




Tamweel Tower, Dubai, 2012

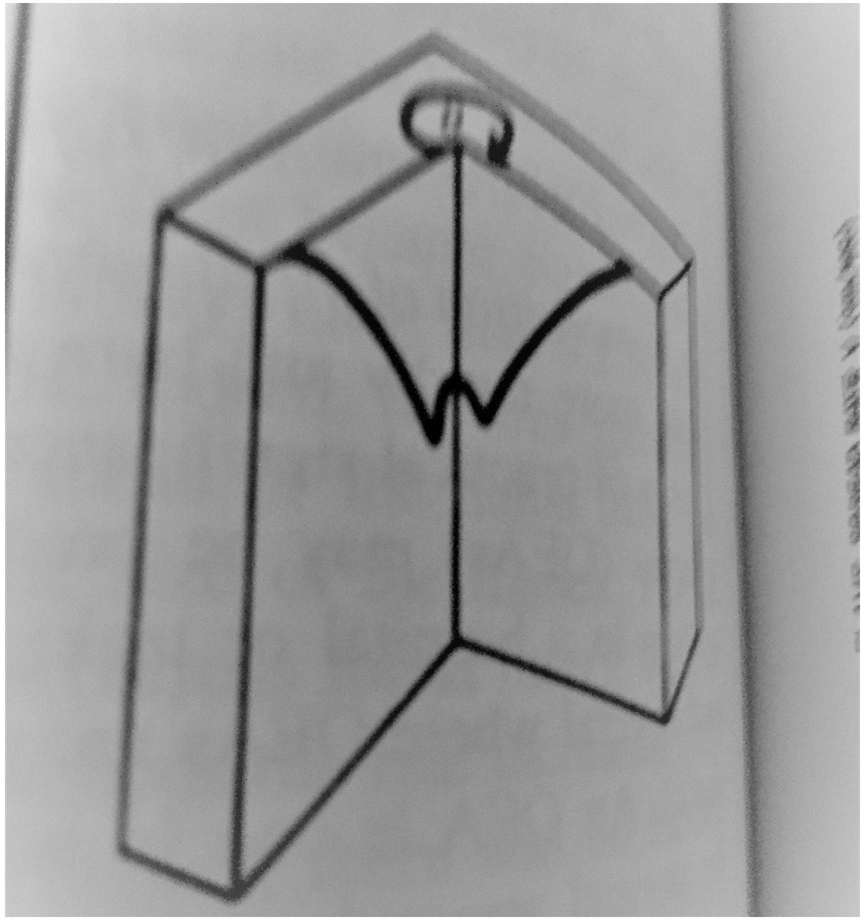
THE EFFECT OF CORNERS (extruded)

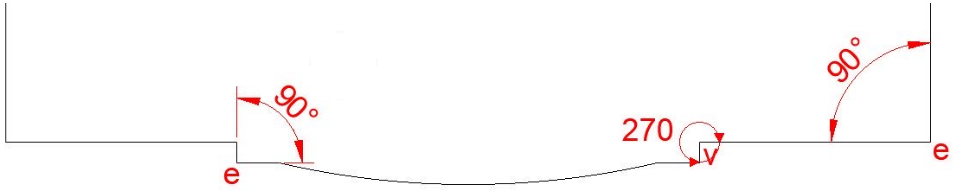
- A fire will not generally spread around the corner of a building unless another factor is present;
- The behaviour of fire *around* corners can be affected by wind and the presence of horizontally orientated architectural features;
- If the inside angle of the corner is less than 90° (outside angle more than 270°), the "Edge Effect" will become an issue;



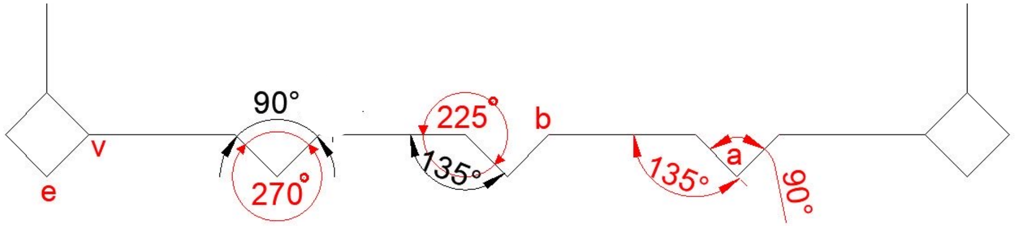
THE EFFECT OF CORNERS (introverted)

- Introverted corners will encourage rapid upward fire spread because the flames will concentrate themselves in the vertex;
- If the fire occurs adjacent to a vertical row of balconies, these will act as a barrier to horizontal flame spread, and the fire will sit in the vertex;
- If re-entrant corners are present, and the outside angle is in excess of 270° (inside angle less than 90°) inward facing surfaces will become an issue and cross-radiation will occur;
- The behaviour of fire *in* corners can be affected by wind and the presence of horizontally orientated architectural features;





Olympus Tower, Grozny



Grenfell Tower, London

EXPOSURE & CONSTRAINT

- Flames will spread randomly in multiple directions unless there is something to restrict them;
- This is a reason why fires can progress around a building in opposing directions (eg. Grenfell Tower and the Monte Carlo Casino & Hotel);
- Is more of an issue towards the top of a building where features such as rims and parapets are more exposed;
- The random nature of horizontal flame spread has been observed in scaffolding, which is also highly exposed;
- Will also occur on flat faces and curves at high levels on a building, giving rise to a sub-type of diagonal fire spread;

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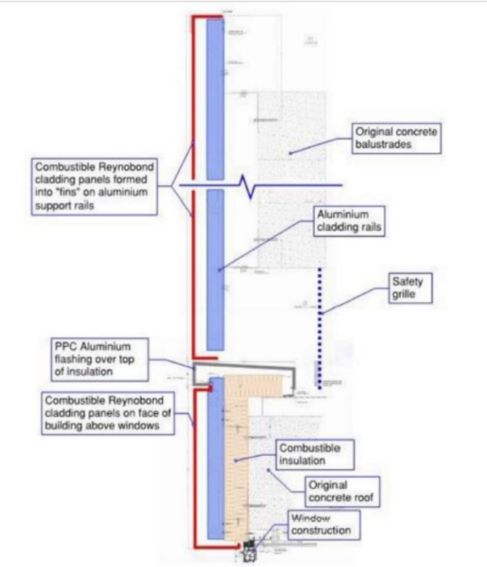
GRENFELL TOWER



EXTERNAL SAFETY ASSESSMENT

- Is the only assessment which takes external geometry into consideration;
- Allows a building to be assessed at critical stages such as design, or prior to its mitigation;
- Enables quantitative risk assessment using a series of matrices to give a Risk Factor;
- Enables qualitative analysis of the risk to give a Safety Rating;
- Is able to provide a numerical factor which shows how safe/unsafe the building actually is;

INTELLICLAD

- The findings of this research are used to determine the location of Intelliclad sensors;
- Sensors are placed in areas of the façade deemed to present the greatest fire risk;
- Sensors are installed directly into the cladding in order to detect a fire at the earliest stage;
- Can replace the Waking Watch or be used as part of a long-term mitigation strategy

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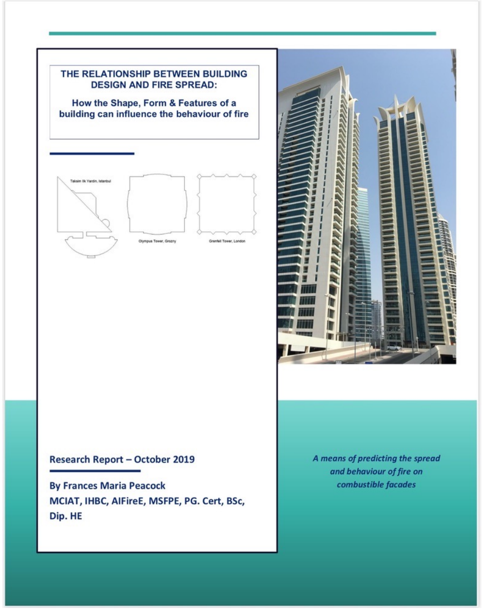
CONCLUSION

- A set of principles for the prediction of the spread and behaviour of fire on the exterior of buildings has been established;
- Work is continuing;
- Several reports, including the original research report, are available;
- The research is already seeing real-life application in fire investigation and fire risk mitigation (Intelliclad);

THANK YOU!

MY REPORTS


THE RELATIONSHIP BETWEEN BUILDING DESIGN AND FIRE SPREAD:

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Research Report – October 2019

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MCIAT, IHBC, AIFireE, MSFPE, PG. Cert, BSc, Dip. HE

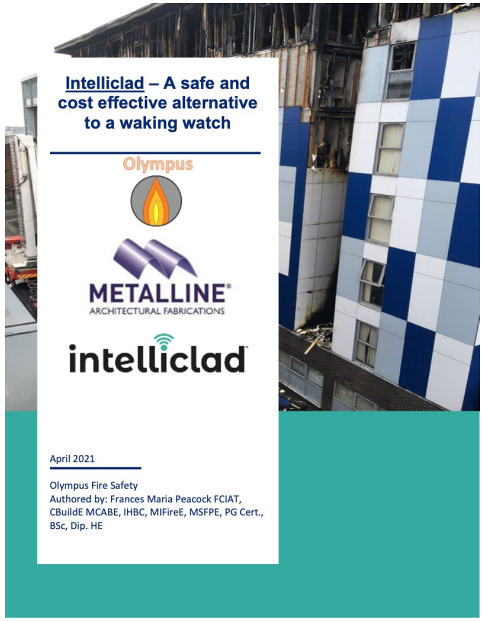
A means of predicting the spread and behaviour of fire on combustible facades


"The lack of fire protection around the windows, the use of combustible materials, poor design and bad installation, all combined to create a situation where the cladding system was incapable of resisting the spread of fire, and was thus a disaster waiting to happen"

An Analysis of the Design, Installation & Materials of the Rainscreen Cladding System at Grenfell Tower

An Insight into what went wrong

Frances Maria Peacock


Intelliclad – A safe and cost effective alternative to a waking watch

April 2021

Olympus Fire Safety

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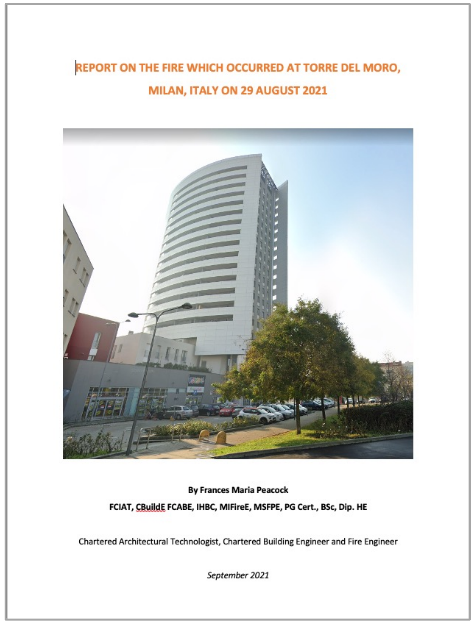
REPORT ON THE FIRE WHICH OCCURRED AT TORRE DEL MORO, MILAN, ITALY ON 29 AUGUST 2021

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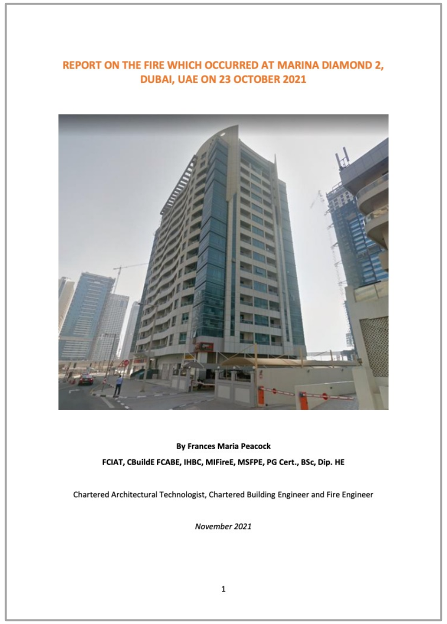
Chartered Architectural Technologist, Chartered Building Engineer and Fire Engineer

September 2021


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

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