

Figure 1 – Grenfell Tower fire, June 2017.  
Shutterstock photo.



# FIRE RESISTANCE OF EXTERIOR CLADDING MATERIALS

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**T**he Grenfell Tower fire (*Figure 1*) that occurred in London on June 14 is the most recent tragic example of a safety issue that has been plaguing the building industry for some time—specifically, the use of combustible materials with a high propensity for flame spread as part of a building’s exterior wall system. Accounts of this event report at least 80 deaths attributed to the fire, with another 70 injured.

Early reports suggest that the fire began in a fourth-floor apartment and that the point of origin may have been a fridge-freezer. The specifics of the origin and cause of the fire are the subject of an ongoing investigation, and, at the time of this writing, should not be considered definitive. The building had recently been reclad with aluminum composite panels, which are reported to be the main contributor of fuel for the fire. The event has triggered an interest in checking other similarly clad buildings in Great Britain and elsewhere.

The Address Downtown Dubai hotel fire on December 31, 2015, is another example. The 63-story hotel, with the backdrop of fireworks exploding in the distance, captured the attention of onlookers and television viewers anticipating a New Year’s Eve fireworks display and celebration. As the fireworks began to light up the night sky, a small but rapidly growing flame on the exterior wall system took center stage (*Figure 2*).

Initial reports and rumors suggested that the fire may have been triggered by fireworks displays nearby. Concerns and discussions of potential terrorism or foul play soon followed. However, it was not long before building industry professionals began looking at the building’s exterior cladding system as contributing to the rapid fire spread along the exterior curtainwall system. What reportedly started as an electrical short on the 14th floor of a terrace eventually engulfed a significant portion of the building’s exterior. The fire



*Figure 2 – The Address Downtown Dubai fire, January 1, 2016. Shutterstock photo.*

had a devastating impact on the façade, but fortunately resulted in only one related fatality, attributed to a heart attack during the evacuation process from the building.

In late November of 2014, a fire with remarkable similarity to the Grenfell fire in London occurred in Melbourne, Australia. The 21-story Lacrosse apartment building's exterior cladding was fully involved with flames from a fire that was reported to have been initiated by an improperly discarded cigarette on an eighth-floor balcony. Aluminum exterior wall cladding panels with an integral interior insulation core layer were blamed for the rapid fire spread that permitted the flames to race up 13 floors of the building exterior in a mere 11 minutes.

Other examples of similar fires linked to combustible exterior wall assemblies throughout the world include:

- Monte Carlo Hotel, Las Vegas, Nevada - 2008
- Harbin Residential Tower, Harbin, China - 2008
- Mandarin Oriental Hotel, Beijing, China - 2009
- Shanghai Residential Tower, Shanghai, China - 2010

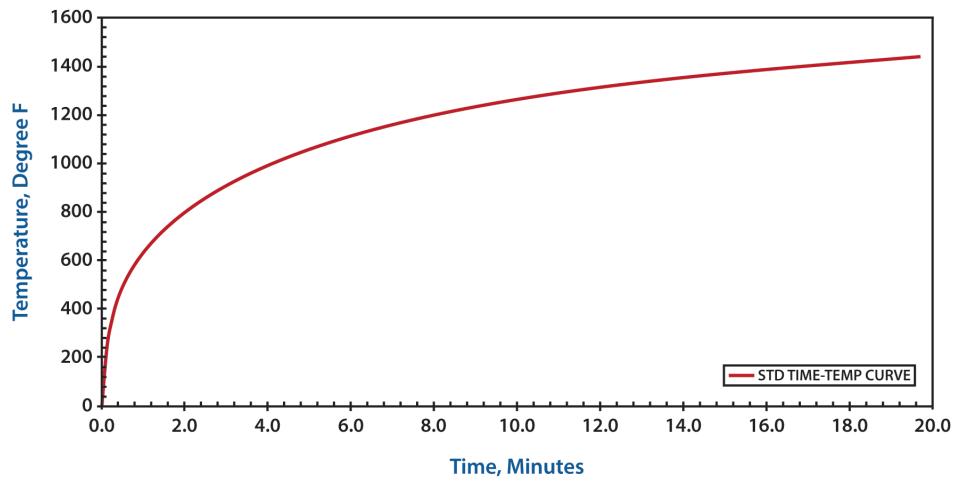


Figure 3 – ASTM E-119 standard time-temperature curve.

- Mermoz Tower, Roubaix, France - 2012
- Tamweel Tower, Jumeirah Lakes, Dubai, UAE - 2012
- Polat Tower, Istanbul, Turkey - 2012
- Torch Tower, Dubai, UAE - 2015<sup>1</sup>
- Sulafa Tower, Dubai, UAE - 2016

today is subject to ignition under the right circumstances. However, the increased use of foam plastic<sup>2</sup> for insulation and other types of construction has increased the amount of combustible materials that are in these wall systems. We will focus particularly on two of these exterior wall types with increased amounts of foam plastic insulation, although there are others.

#### EXTERIOR WALL SYSTEMS

Virtually any exterior wall system that is constructed with combustible materials



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## Fire-Resistance Rating for Exterior Walls Based on Occupancy Type and Fire Separation Distance

Fire Separation Distance = X (feet)	Type of Construction	Occupancy Group H <sup>1</sup>	Occupancy Groups F-1, M, and S-1 <sup>2</sup>	All Other Occupancy Groups
X < 5	All	3	2	1
5 ≤ X < 10	IA	3	2	1
	Others	2	1	1
10 ≤ X < 30	IA, IB	2	1	1
	IIB, VB	1	0	0
	Others	1	1	1
X ≥ 30	All	0	0	0

1. High-hazard use groups, such as flammable liquid storage buildings.
2. Moderate-hazard industrial and storage buildings and mercantile/retail F-1, M, and S-1.

Figure 4 – This table represents a simplified version of Table 602 from IBC and does not address detailed information specifically called out in the table's footnotes. Fire-resistance ratings in hours.

### Metal Composite Material (MCM) Systems

MCMs are exterior wall coverings that consist of corrosion-resistant metal skins permanently bonded to both faces of a solid extruded plastic core. Aluminum (ACM) is the predominant facing. MCMs can be cut, routed, curved, rolled, and connected in a variety of ways, making them a great design option for architects and builders. MCMs are thin and lightweight materials, and generally range between 2 and 6 mm thick. MCMs are typically fastened directly to the building exterior with a bracket system, and may be implemented as a component in a rainscreen assembly. The thin metal can

heat up rather quickly, and the plastic cores are combustible, creating the potential for hazardous conditions when the assembly is exposed to high temperatures resulting from fire conditions. Many manufacturers offer MCMs with fire-resistant cores, which can be successful in reducing the hazard level for these assemblies.

### Exterior Insulation and Finish Systems (EIFS)

EIFS are non-loadbearing, exterior wall cladding systems that consist of insulation board attached either adhesively or mechanically to the underlying substrate. The insulation is topped with a base coat

and a protective finish coat.

EIFS components generally consist of a water-resistive barrier that covers the substrate, a drainage plane between the water-resistive barrier and the insulation board, an insulation board (typically expanded polystyrene) secured mechanically or adhesively to the substrate, a water-resistant base coat applied on top of the insulation with an embedded glass fiber reinforcing mesh as a weather barrier, and finally, a finish coat that typically uses an acrylic copolymer technology that aids in permitting the finish to retain its color and overall appearance. The foam plastic insulation boards are combustible, and fire can

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spread within the insulation component of the wall system. However, some EIFS with a maximum 4-inch insulation thickness have passed the major fire tests that are required by the building codes, including fire resistance, ignitability, and intermediate multi-story (NFPA-285), and full-scale multistory corner tests.<sup>3</sup>

Back-wrapping the mesh and base coat behind the insulation board at terminations of the EIFS is used to protect exposed edges of the system from ignition, as well as to partially contain the insulation within the system, should a fire occur.

### Rainscreen Systems

Rainscreen systems are generally comprised of two distinct elements: an outer leaf and an inner leaf, separated by a small ventilation cavity. The ventilation cavity for back-ventilated systems ranges in depth from  $\frac{3}{8}$  to 1 in., while for pressure-regulating rainscreens, the cavity must be precisely designed based on building loads and conditions. The outer leaf is intended to control most of the rainwater. The inner leaf acts as a water barrier, air barrier, thermal barrier, and possibly even a vapor barrier, and is also a component of the wall's structural element. Rainscreens rely either on a drained/back-ventilated approach to both drain and dry out residual water captured by the rainscreen, or otherwise employ a pressure-equalized design that uses a ventilated and drainable cavity, along with areas of compartmentalization to limit water penetration. Rainscreens, although good from a weatherproofing perspective, can create an effective "chimney" within the exterior wall system, allowing materials above to be preheated at a quicker rate than in a more conventional wall system.

### U.S. BUILDING CODE REQUIREMENTS

The majority of state and local building code authorities in the United States adopt the International Building Code (IBC) as the basis for all or most of their local building code. Exterior wall system requirements are largely covered in Chapter 14 of the IBC, and address performance characteristics, materials, and installation issues related to various exterior wall systems. With regard to fire-related performance issues, fire resistance and flame spread characteristics are the two performance characteristics that are of greatest concern to both designers and building code authorities.

### Fire Resistance

The IBC defines fire resistance as "that property of materials or their assemblies that prevents or retards the passage of excessive heat, hot gases, or flames under conditions of use." In the United States, the fire resistance of a material or assembly is evaluated based on its performance when subjected to ASTM E119, *Standard Test Method for Fire Tests of Building Construction and Materials*. This test exposes the tested assembly to a standard time-temperature

fire curve (*Figure 3*), and evaluates the assembly's ability to achieve certain minimum pass-fail criteria (e.g., passage of flame, heat transmission through the surface) at specified time benchmarks (e.g., one hour, two hours, three hours).

Fire resistance discussion in Chapter 14 is limited to a general reference that requires the materials being used to have a fire resistance rating per Chapter 6 of the code. Fire resistance rating requirements for non-load-bearing cladding are limited



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Figure 5 – NFPA 285 test in operation. Photo courtesy of Underwriters Laboratories.

to those in Table 602 of the IBC, which is summarized in Figure 4. These ratings are intended to prevent fire from spreading from building to building, and are predicated on building separation distance, anticipated fuel load, and occupancy (use) group hazard classification.

### Flame Propagation

While fire resistance is intended to measure a material's resistance to ignition after exposure to a standard test fire, flame propagation is intended to measure a material's propensity to permit vertical and lateral flame spread. The IBC relies upon a nationally accepted test method laid out in National Fire Protection Association

(NFPA) Standard 285, *Standard Fire Test Method for Evaluation of Fire Propagation Characteristics of Exterior Non-Load-Bearing Wall Assemblies Containing Combustible Components*, for protocols with which to evaluate flame spread on non-load-bearing exterior wall building components.

The test procedure and evaluation of flame propagation over exterior wall building systems tested per NFPA 285 (Figure 5) are based on the assumption that the source fire is most similar to an interior fire that has reached post-flashover conditions. In other words, the fire originated in the building's interior and reached a point where all combustibles in the room of origin have ignited, resulting in flashover, and that

exterior windows have broken as a result, permitting exposure to the exterior building wall components. Fire spread based on NFPA 285 is not based on the assumption of fire spread from an exterior source, such as an adjacent building.

Similar to the ASTM E119 test, the NFPA 285 test subjects a test specimen to a standard test fire condition—in this case, representative of 30 minutes of exposure to an interior post-flashover condition. Passing criteria for assemblies subjected to the NFPA 285 test include the ability to limit temperature rise and resist flame passage to the story above and adjacent spaces. Likewise, the assembly must successfully limit vertical and horizontal flame propagation at the assembly's face, as well as along combustible components and insulation.

In the United States, exterior wall assemblies—including EIFS, MCMs, and rainscreens—are required to comply with major fire-resistance testing requirements, such as ASTM E119 and NFPA 285, in order to be acceptable for installation per applicable codes and standards.

IBC requires exterior cladding materials for buildings of any construction type other than Type V (commonly referred to as “ordinary” or “stick” combustible construction, such as for typical one- or two-family homes) that are over 40 feet in height and contain a combustible water-resistive barrier to be tested per the requirements of NFPA 285.

IBC waives requirements for passing the NFPA 285 test in instances where the water barrier is the only combustible component and is covered with substantial, non-combustible construction such as brick, concrete, stone terra cotta, stucco, or steel with prescribed minimum thicknesses.

Water barriers that comprise the only combustible component and that can be demonstrated to have low combustibility and smoke production properties may also be exempt from the NFPA 285 test procedure. This exception requires the peak heat release rate, total potential heat release, and the effective heat of combustion be limited and not exceed prescribed maximums. Additionally, the water barriers' flame spread and smoke developed ratings must be considered of the highest measurable grade. Specifically, they must be consistent with what would be otherwise permitted for Class A interior finishes—finish ratings that the code would permit in nonsprinklered exit stairs and passageways.

### MCM SYSTEMS (IBC SECTION 1407)

Chapter 14 requires that when MCM systems are used on exterior walls required to have a fire resistance rating, the complete assembly—including the MCM—must achieve the required fire resistance rating of the wall being submitted to the local building authorities for approval (Section 1407.8). Testing information from a nationally recognized laboratory, with test results from the complete assembly, including MCM, would be acceptable evidence. Otherwise, the local jurisdiction may be able to accept a thoroughly conducted engineering judgment prepared by a licensed expert third party that has evaluated the fire resistance properties of the combined proposed assemblies.

In order to effect some controls on the exposure of buildings to potential flame spread conditions, IBC has incorporated a number of requirements intended to mitigate risks to exterior wall flame spread, depending on the characteristics of the MCM, the installation method, as well as other building properties, including building height, construction type, and whether or not automatic sprinklers or a horizontal

flame barrier is installed as part of the exterior wall assembly. These requirements implement graduated limitations to the use of MCMs with combustible material up to a maximum building height of 75 feet above finished grade. A thermal barrier between the MCM and the interior of the building—which can be a layer of Type X gypsum wallboard—is also typically required. However, it is important to check with the local authorities, as some municipalities have different restrictions.

### EIFS SYSTEMS (IBC SECTION 1408)

The IBC does not lay out specific fire resistance or flame spread requirements for these systems within Chapter 14; however, Section 1408 covers general performance characteristics for EIFS systems based on performance as part of the ASTM E2568 test (*Standard Specification for Polymer-Based [PB] Exterior Insulation and Finish Systems*). This standard covers a wide variety of minimum performance requirements for EIFS systems, with ignition resistance and fire endurance being the most pertinent to this discussion.

EIFS systems must achieve minimum

results for fire resistance, ignitability, and flame propagation, while surface-burning characteristics tested per ASTM E84 must be achieved by the combustible insulation components. Flame and smoke spread ratings per ASTM E84 may not exceed 25 and 450, respectively.<sup>4</sup>

Fire resistance for EIFS is tested via application of the ASTM E119 test, where there must be no effect on the fire resistance of a rated wall assembly. Regarding ignitability, NFPA 268 is used as the test method, and no ignition must result from application of 12.5 kW/m<sup>2</sup> after 20 minutes' exposure. As with MCM, flame propagation is gauged using the NFPA 285 criteria. Most systems are limited to a maximum insulation thickness of 4 inches. Some local municipalities allow trim and other accessories to be thicker than 4 inches, and others do not (*Figure 6*). As with MCMs, a thermal barrier is required between the insulation and the interior of the building.

### Rainscreens

Rainscreens in exterior veneer systems, which have continued to become more and



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*Figure 6 – Large foam shapes.*

more popular over the past several years, do not contribute to the flammability or combustibility of veneer systems.

The stated intent of NFPA 285 is to pro-

vide a standardized test procedure by which to evaluate the performance and suitability of exterior curtainwall assemblies that are manufactured with combustible compo-

nents as part of the installation, where local building codes require the exterior walls to be noncombustible. It is important that where rainscreens are a component of the exterior wall assembly, that the assembly as installed be subject to the NFPA 285 test, so that the performance of the system, as installed, can be evaluated based on performance in the test.

#### **FIRE RISK**

When considering the fire risk associated with combustible materials used in building construction, it is important to take into account the measurable base characteristics of the materials involved. This information, such as flashpoint (piloted ignition temperature), heat release rate, and flame spread characteristics—combined with the means and arrangement by which they are installed—may impact the ability for flame to be initiated, sustained, and spread, thus affecting the overall fire risk.

The components of MCM and EIFS materials that are of greatest concern with regard to fire resistance and flame propagation are the combustible materials that



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consist of plastics or expanded foam materials. These items tend to have much lower ignition temperatures (i.e., they are easy to ignite) and much higher heat release rates (they burn with a higher intensity) than traditional cellulosic (wood-based) materials and, of course, non-combustible materials, which by definition are not subject to ignition or heat release rate contribution.

Expanded polystyrene foam (EPS) can contribute a great deal to flame spread when exposed to the wrong conditions. Prior to ignition, after exposure to temperatures in a range of 180° to 212°F (82° to 100°C), EPS can become very soft and begin to deform and melt. When burning, EPS can emit a dense black smoke. Unpiloted (i.e., no flame contact) ignition temperature for EPS is approximately 850°F (454°C), with piloted ignition (the ignition temperature when a test sample is exposed to high temperatures as well as a small flame) being approximately 610°F (321°C). Temperatures in this range are consistent with temperatures that can be experienced immediately outside of a post-flashover compartment following an uncontrolled fire, meaning it is reasonable to expect that EPS exposed to a post-flashover fire will ignite.

MCM and EIFS assemblies installed as part of an exterior wall building system—particularly those that include combustible materials—are by their nature installed in a vertical orientation that is very conducive to promoting flame spread.

#### **ALTERNATIVE PRODUCTS AND SOLUTIONS**

There are steps that the design community can take to mitigate the potential fire risk with exterior wall systems. One measure is to be mindful of the products being used and their orientation. MCMs with fire-resistant cores are available. Reducing the thickness of EIFS systems will lower the amount of combustible materials available if a fire should occur. Be mindful of the exterior cladding materials that are used near residential balconies, where inadvertent combustion from a cigarette or barbecue can occur.

When possible, non-combustible insulation types such as mineral wool can be good alternatives—particularly in a rainscreen application. The inert stone insulation resists the propagation of fire and will not release gases. The material is also hydrophobic and will resist absorbing water, which makes it an ideal insulation

for use with rainscreen walls.

Energy codes, which are mandating higher R-values, can seem at odds with fire and life safety-related codes and standards. While often, higher mandated R-values are being achieved through the use of increased thicknesses of foam plastic insulation, the insulation thicknesses used for both exterior walls and roof assemblies cannot exceed those for which they have been tested. Avoid overstuffing the building envelope with additional foam plastics.


#### **CONCLUSION**

Years of laboratory testing, as well as a general understanding of the nature of flame spread and heat transfer, have demonstrated that combustible materials installed in a vertical orientation exhibit increased flame spread and fire growth rates when compared to similar materials arranged in horizontal orientations. This is primarily a result of the buoyancy created by the fire plume, preheating of the fuel load above, as well as the availability of oxygen to



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contribute to conditions required to support combustion.

We have been pretty lucky in the United States and Canada thus far, and the proactive measures incorporated into the codes appear to be appropriate. However, designers need to be mindful to use combustible wall systems and insulation within the parameters to which they have been tested in order to remain compliant. Make sure to pay attention to the building codes in the years to come, as the IBC and local municipalities may face increasing pressure to tighten and/or clarify requirements with regard to combustible exterior wall assemblies as a result of the recent tragedies in London and elsewhere. 

### REFERENCES

1. As this issue of *RCI Interface* was about to go to press, another fire whose rapid spread was likely related to the cladding on the Torch Tower occurred, with fire propagating over 40 stories of the building's exterior.
2. IBC defines foam plastic insulation as: "A plastic that is intentionally expanded by the use of a foaming agent

to produce a reduced-density plastic containing voids consisting of open or closed cells distributed throughout the plastic for thermal insulating or acoustical purposes and that has a density less than 20 pounds per cubic

foot (pcf) (320 kg/m<sup>3</sup>)."

3. "EIFS FAQs," published by the EIFS Industry Manufacturers Association, [www.eima.com/eifs/faq](http://www.eima.com/eifs/faq).
4. EIFS Industry Members Association (EIMA).



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