FIRE PROTECTION ENGINEERING
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Exterior Cladding and Fire Protection: More Than Skin Deep

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THE TRAGEDY THAT BEFELL GRENFELL TOWER LAST SUMMER WAS, quite literally, a wake-up call for all of us who gathered early that morning at Southbank Centre in London for a symposium on building physics and conservation.[1] What we saw unfolding before us was, sadly, immediately recognizable—another building engulfed in flames in a pattern all too reminiscent of The Address hotel fire in Dubai and so many other high-rise buildings around the world over the past 10 to 15 years.

Public outcry was understandable and swift: Why did this happen? Who is responsible? What can be done?

As human beings, we mourn those who were lost and feel deeply for those left behind who continue to grieve and now turn to us for answers. As architects and engineers, problem solving is familiar territory for us. Solving for "why" is the assignment we have been given—a first-principles approach to safeguard lives and restore the public trust.

Recent Events

Unlike the exterior cladding fires in Dubai where occupancies are often seasonal and buildings may therefore be lightly occupied, the fire at Grenfell Tower[2] was particularly tragic for the number of casualties and the time at which it occurred (overnight), a time when much of the building was occupied and many of its occupants may have been asleep. For that reason, reaction from the manufacturer of the cladding panels supplied for the refurbishment of Grenfell Tower and the response from the government came quickly:

> "The loss of lives, injuries, and destruction following the Grenfell Tower fire are devastating, and our deepest condolences are with everyone affected by this tragedy. While the official inquiry is continuing and all the facts concerning the causes of the fire are not yet known, we want to make sure that certain information is clear…
>
> We sold our products with the expectation that they would be used in compliance with the various and different local building codes and regulations. Current regulations within the United States, Europe, and the UK permit the use of aluminum composite material in various architectural applications, including in high-rise buildings depending on the cladding system and overall building design. Nevertheless, in light of this tragedy, we have taken the decision to no longer provide this product in any high-rise applications, regardless of local codes and regulations."[3] (Manufacturer's statement—June 26, 2017)

and…

> "Following the Grenfell Tower tragedy, the government has established a Building Safety Programme with the aim of ensuring high-rise residential buildings are safe, and residents feel safe in them..."
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> "Screening tests at the Building Research Establishment (BRE) have been identifying whether Aluminum Composite Material (ACM) cladding samples from buildings meet the limited combustibility requirements of current Building Regulations guidance."[4] (Regulatory response—June 15, 2017 and June 29, 2017)

The position taken by the manufacturer is understandable. Current building codes governing the use of combustible materials in high-rise construction, while not strictly prohibited in many jurisdictions, are typically governed by combustibility of the product or material itself in addition to building height, use, and occupancy. It is not surprising at all, therefore, to see the industry and regulatory response focus first on combustibility of the cladding material itself before focusing more closely on the fire risk posed by the entire exterior wall assembly and its interaction with other building features.

Historical Context

In the United Kingdom, the *Great Fires of London* (c. 1666) and Warwick (c. 1694) taught us long ago that "… old paper buildings and the most combustible matter of tarr, pitch, hemp, rosen, and flax…"[5] were undesirable cladding materials at any height, and that "… the close-packed nature of the environment and amount of combustible building material all lead to the fire's start and spread…".[6] In the United States, the *Triangle Shirtwaist (c. 1911)* and subsequent fires during the first half of the 20th century[7] also taught us a great deal and began to shift our focus to combustibility of interior finishes and a more holistic approach to fire protection that included fire separation, egress requirements, and a "shift in emphasis in building design and construction from the protection of property to the protection of lives."[8]

Over time, lessons regarding combustible building materials would result in the development of British Standard (BS) 476, *Fire Test to Measure Surface Spread of Flame*, first published in 1932, and ASTM E84/NFPA 255, *Standard Test Method for Surface Burning Characteristics of Building Materials*, first published in 1944 and often referred to less formally as the Steiner Tunnel Test after its inventor, Al Steiner of Underwriter's Laboratories. For code developers and the authorities having jurisdiction over the adoption and enforcement of those codes, these tests were a step toward protecting property and saving lives. For manufacturers, they also represented a new threshold to be met for the same reasons and to ensure access-to-market for their products and materials.

New Drivers Emerge

Since about 1970, new drivers continued to emerge in product development and the evolution of building codes and standards, most notably energy use and the steadily increasing demand for conservation of our natural resources. Of these, the rising cost of energy has arguably had the single most significant and quantifiable influence on design and construction. Beginning in earnest with the Oil Embargo of 1973, rising energy costs—in particular, fossil fuels—led directly to the development and introduction of new guidelines and standards to assess the thermal performance of buildings and a corresponding advancement in the development of new products, materials, and technologies to optimize and improve whole building performance.[9]

When measured today simply by comparing the published cost of electricity in the United Kingdom and a handful of other countries in the European Union—versus the same costs in the continental United States, Canada, and other nations (setting aside taxes, subsidies, and other factors that may influence these figures)—we find that by some estimates, the cost of energy in the United Kingdom and Western Europe can be as much as 12₵ to 15₵ higher per kilowatt hour (kWh) than in the United States and other nations.[10] It should come as no surprise, then, that the trend-line in the construction products industry in the United Kingdom and elsewhere has been toward thinner, lighter, more cost-effective and energy-efficient products and materials, including exterior cladding and insulation.

Product development in this space increased dramatically during the 1980s and 1990s, resulting in the introduction and more widespread acceptance and use of exterior cladding and insulation products that included rigid- and semi-rigid foam, foam-insulated "sandwich" panels, and lightweight exterior cladding products with metal facer-sheets and core materials that included thermoset and thermoplastic materials. These included polyurethanes (PUR), polyisocyanurate (PIR), expanded polystyrene (EPS), extruded polystyrene (XPS), polyethylene (PE), and similar products—all derived from or otherwise refined and formulated in part from petroleum-based products.

In the United States, concerns regarding the horizontal and vertical spread of fire associated with these products resulted in the development of a full-scale fire testing program that began in 1980 and ultimately led to the publication of Test Standard 17-6 in the 1988 edition of the Uniform Building Code (UBC). Since that time, this standard has undergone several changes and exists today as NFPA 285, *Standard Fire Test Method for Evaluation of Fire Propagation Characteristics of Exterior Non-Load-Bearing Wall Assemblies Containing Combustible Components.* In the United Kingdom, concerns associated with this trend led to the publication in 1988 of the first edition of BRE 135, *Fire Performance of External Thermal Insulation for Walls of Multi-Storey Buildings*.

As designers, we are drawn to these new products and materials not just for the range of options they offer aesthetically, but also for all of the performance attributes cited by industry: thinner, lighter, more cost effective, and energy efficient. This is particularly true when faced with the challenge of improving energy performance in existing buildings and an aging building stock.

In fact, when we consider the effects of climate-specific heat, air, and moisture transport across a building envelope, the fundamentals of building science and the physics of building envelope performance often tell us to insulate outboard of the primary air barrier in an exterior wall system to optimize thermal performance and minimize the risk for direct rainwater penetration and condensation within the envelope of the building. This, of course, results in detailing that includes a layer of insulation located directly behind the exterior cladding in new construction, refurbishment, and adaptive re-use of existing buildings. These are good intentions with an environmentally friendly noble purpose and a change in design and construction philosophy that has been incentivized in recent years through the efforts of the United States

Green Building Council (USGBC); the Building Research Establishment Environmental Assessment Method (BREAMM) in the United Kingdom; the European Commission Joint Research Centre on Sustainability (ESTIDAMA); similar efforts across the UAE; and various other voluntary guidelines and standards published around the world.

Déjà Vu (All Over Again)

Fire as a principal driver in the development of building codes and standards resurfaced again at the turn of the last century and continued during the first two decades of the 21st century. In the United Kingdom, three fires in particular gained public notice for the materials associated with each fire and the challenges faced by fire services in fighting those fires.

The first, at Knowsley Heights in Liverpool (1991), included a rainscreen exterior cladding system over an existing building façade and saw rapid propagation of fire inside the cavity space behind the exterior cladding. The regulatory response included a new requirement for horizontal fire stops at each floor level inside the cavity space behind the exterior cladding, and, perhaps more noteworthy, the start of a discussion about large-scale assembly testing in addition to small-scale product testing to assess both combustibility and reaction-to-fire.[11]

The second, at the Sun Valley Poultry cold storage facility in Herefordshire (1993), included foam-insulated sandwich panels on the walls and ceilings that, in the aftermath of the event, spurred further discussion about the combustibility of the core material used in the manufacture of those panels (EPS and PUR). This discussion was spurred by concern for the challenges faced by fire fighters who entered the facility to fight a fire below ceiling panels with a core material that had begun to melt and fall into that space.

The third, at Garnock Court in Scotland (1999), included glass-fiber reinforced plastic exterior cladding installed in a rainscreen configuration over exterior insulation and an existing building façade. Once again, rapid fire propagation inside the rainscreen cavity space at this property occurred, reigniting several of the same concerns raised following the Knowsley Heights fire and accelerated the discussion regarding the need for large-scale assembly testing in addition to small-scale product testing to more fully understand reaction-to-fire.

Each of these fires and the discussions that followed would lead ultimately to the development by the BRE of BS 8414, *Fire Performance of External Cladding Systems*, first published in 2002 and republished today to include BS 8414-1 for cladding systems applied to the masonry face of a building and BS 8414-2 for cladding systems fixed to and supported by a structural steel frame.

In the United States, fire at the Monte Carlo Casino and Resort (2008) was notable for its use of an exterior insulation and finish system (EIFS) as exterior cladding. Unlike the external thermal insulation composite systems (ETICS) more commonly found in Europe over a layer of mineral wool fiber insulation, EIFS used in the construction of the Monte Carlo Casino and Resort included a continuous layer of rigid EPS board as insulation below the exterior finish. When exposed to fire, EPS will melt. This resulted in fire spread on the façade of the Monte Carlo in all directions, most notably downward as the EPS material began to melt.

Around the globe—and as building codes and standards struggled to keep pace—fires associated with exterior cladding continued to occur. Perhaps the most notable of these were the widely publicized series of fires in the UAE that began with Tamweel Tower in Dubai (2012). followed soon thereafter by The Address Hotel, Al Haffeez Regal Tower, and Torch Apartment fires in Dubai (2015). During the same period, we also witnessed similar events across Europe, including the fires at Mermoz in Roubaix, France, and Polat Tower in Istanbul, Turkey (2012), Grozny City Tower in Chechnya (2013), and Grenfell Tower (2017).

Evolution and Progress

Returning to the tragedy at Grenfell Tower, we now recognize and perhaps understand more clearly the evolution in thought that has occurred relative to exterior cladding and fire protection. In the United Kingdom, this evolution has been informed in large part through the wisdom and experience of practicing design professionals, fire services personnel, and an Expert Panel convened by the BRE in the aftermath of Grenfell Tower. The advice given today by BRE to building owners and investors goes on to state:

"Large scale tests[12] have been undertaken to understand whether and when it may be safe to use ACM as part of a wall system in high rise buildings…"[13]

"The Expert Panel's advice following these tests is that ACM with an unmodified polyethylene filler with any type of insulation (behind the cladding panels) presents a significant hazard on buildings over 18 metres…"

"It is possible ACM with a fire-retardant filler could be used safely with non-combustible insulation (behind the cladding panels), but this is highly dependent on the insulation used and how it is fitted…"[14]

In the UAE, we see a similar trend. The UAE *Fire and Life Safety Code of Practice*, first published in 2011, has recently undergone a thorough review in response to exterior cladding-related fires in that region, and, when adopted, will no longer allow small-scale product testing for combustibility alone to satisfy code requirements for fire and life safety. Beginning in 2017, the updated code will require (in addition to small-scale product testing for combustibility) large-scale assembly testing and pass/fail criteria as described in BRE 135, *Fire Performance of External Thermal Insulation for Walls of Multi-Storey Buildings,* when tested in accordance with BS 8414-1 or -2; NFPA 285; or ISO 13785-2. Today, full-scale assembly tests very similar to BS 8414 are reflected in ISO 13785-2 and a variety of other test standards currently under development or already adopted and enforced in countries from Europe to Australia.[15]

Where Do We Go From Here?

When we're asked as a society to respond to issues and events that affect our day-to-day lives and have consequences that may cause death, injury, or irreversible property damage, it is tempting to assume that we can simply legislate our way to solutions that will relieve us of that burden. That notion was reflected most recently in the findings published by the BRE DCLG in its independent review of building regulations and fire safety following Grenfell Tower:

"The current regulatory system for ensuring fire safety in high-rise complex buildings is not fit-for-purpose. This is a problem connected both to the culture of the construction industry and the effectiveness of the regulators…"

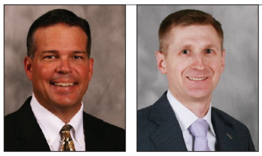
"Even where there are requirements for key activities to take place across design, construction and maintenance, it is not always clear who has responsibility for making it happen..."[16]

While these findings are significant and a necessary response if our building codes and standards are to continue to evolve, they do not relieve design and construction professionals from our responsibility to maintain a level of intellectual curiosity that allows us to understand and responsibly reconcile the demands of energy efficiency and fire safety. When we fail in this regard, we violate the public trust. Requirements for large-scale assembly testing alone will never fully protect lives and property, just as small-scale product testing failed to do the same after the inception of those standards nearly 100 years ago. Public trust is safeguarded when design and construction professionals take time to understand the fundamentals of building science and the physics of building enclosure performance—in the context of heat, air, and moisture transport and in fire science and engineering.

A First-Principles Approach

A more holistic approach to fire protection allows for the interaction of individual products, materials, components, and systems—the pieces, if you will—to be considered collectively, evaluating gaps or overlaps in the overall strategy while allowing for the cumulative effect of the individual systems to be fully considered. This approach is fundamental to our understanding of fire and life safety strategy and is first-principles thinking reflected in NFPA 550, *Guide to Fire Safety Concepts*, which includes a decision tree that addresses ignition prevention, fire spread management, and occupant/exposed management.

Tools to accomplish the defined goals include review of available compartmentalization, means of egress, fire-rated exit enclosures and lighting, fire suppression (sprinkler) systems, fire alarm, and occupant notification systems. When considered in the broader context of a fire- and life-safety strategy for an entire building, NFPA 550 allows design and construction professionals the freedom to design using fire protection firstprinciples rooted in fire science and technically sound fire protection engineering.



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