
The purpose of this session is to talk to you about the fire safety of modern construction materials
The term ‘modern construction materials’ covers a broad range of topics,
I’m going to talk to you about two key areas that we as designers are dealing with in the industry at present
– combustible façade insulation and timber construction
And just to give you a bit of background to me so that you understand the context in which I’m am giving this talk
I’m a fire safety engineer and I work for Arup who, if you don’t know, are a global firm of consulting engineers, designers and planners
In my role as a fire safety engineer, I work with architects, developers, contractors and other clients on the fire safety design construction and operation mainly of buildings.
And as requested by Sheila, I’ve tried to focus this talk around the information we use when designing using modern forms of construction
At the end of this presentation I have provided a list of references that might be useful should you need to know more

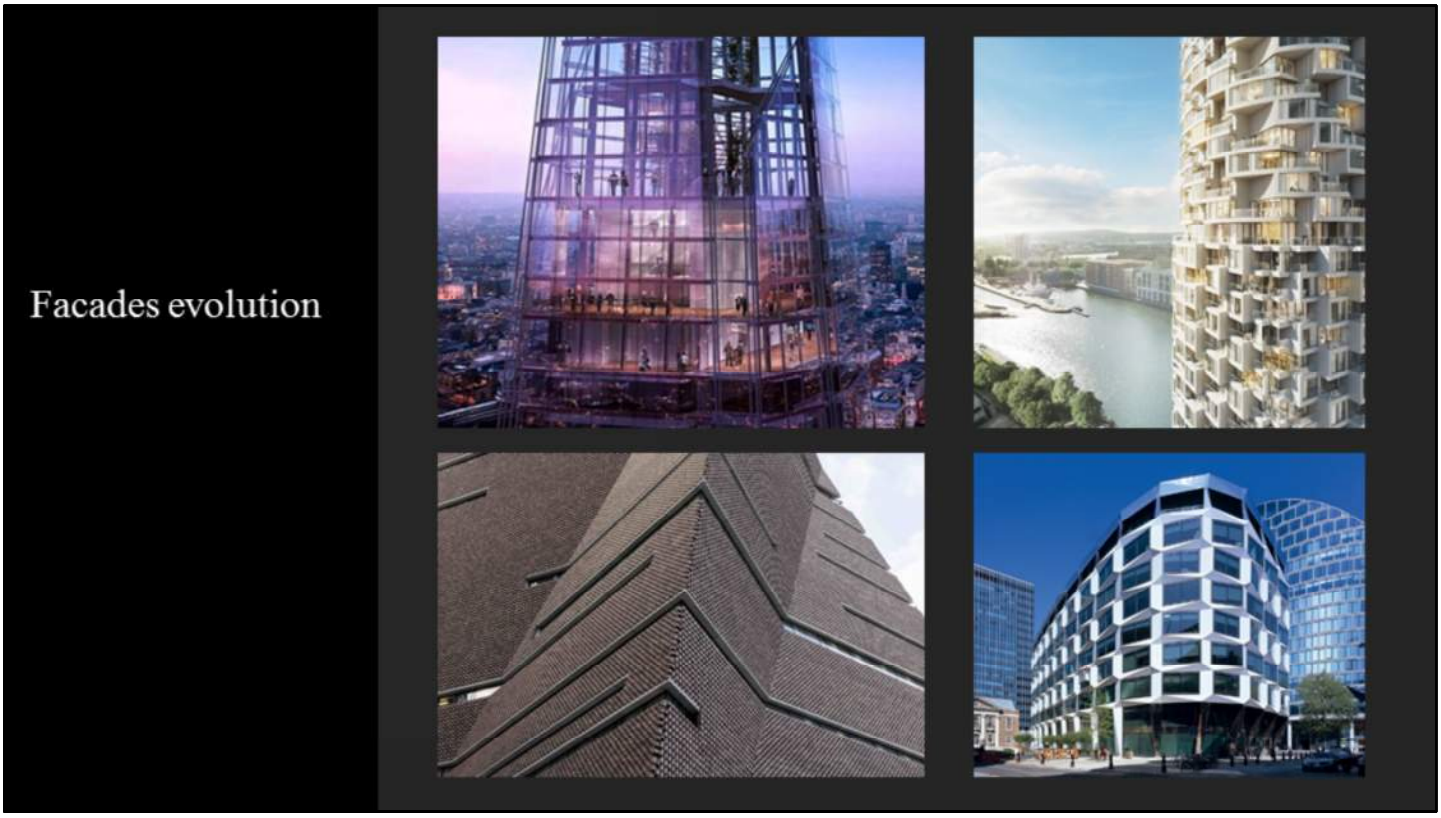

So, let’s get started
Fire has been a source of heat, light and comfort to people throughout the ages.
It is a familiar process
Familiarity however does not mean competency, and that is fundamental to some of the issues in our UK construction industry today.
Because fire on a larger scale can be powerful, uncontrollable, and dramatic in effect and consequences.


So how people and property are protected from fire, has a long history too.
In the UK our regulations stem from the consequences of the Great Fire of London in 1666.
A time when the city was built with timber, which burnt unnecessarily, disproportionately even, with apparently very low loss of life, but with significant consequences for the City.
The Great Fire of London therefore changed everything
Charles II appointed three commissioners to look at the lessons learnt and how best to rebuild London to avoid this happening again
This resulted in very first Building Regulations – a key part of which was the control of materials of construction.
Since the Great Fire and almost consistently until recent times, a fundamental principle of fire safe design has been to rely on non-combustible construction materials.
But over recent years things have been changing
And the purpose of this talk is to look at a couple of examples of modern construction materials
- combustible façade insulation
- and timber frame construction
To examine some of the fire safety risks involved
And to identify what gaps in our knowledge that need to be filled in order to allow us to design knowingly

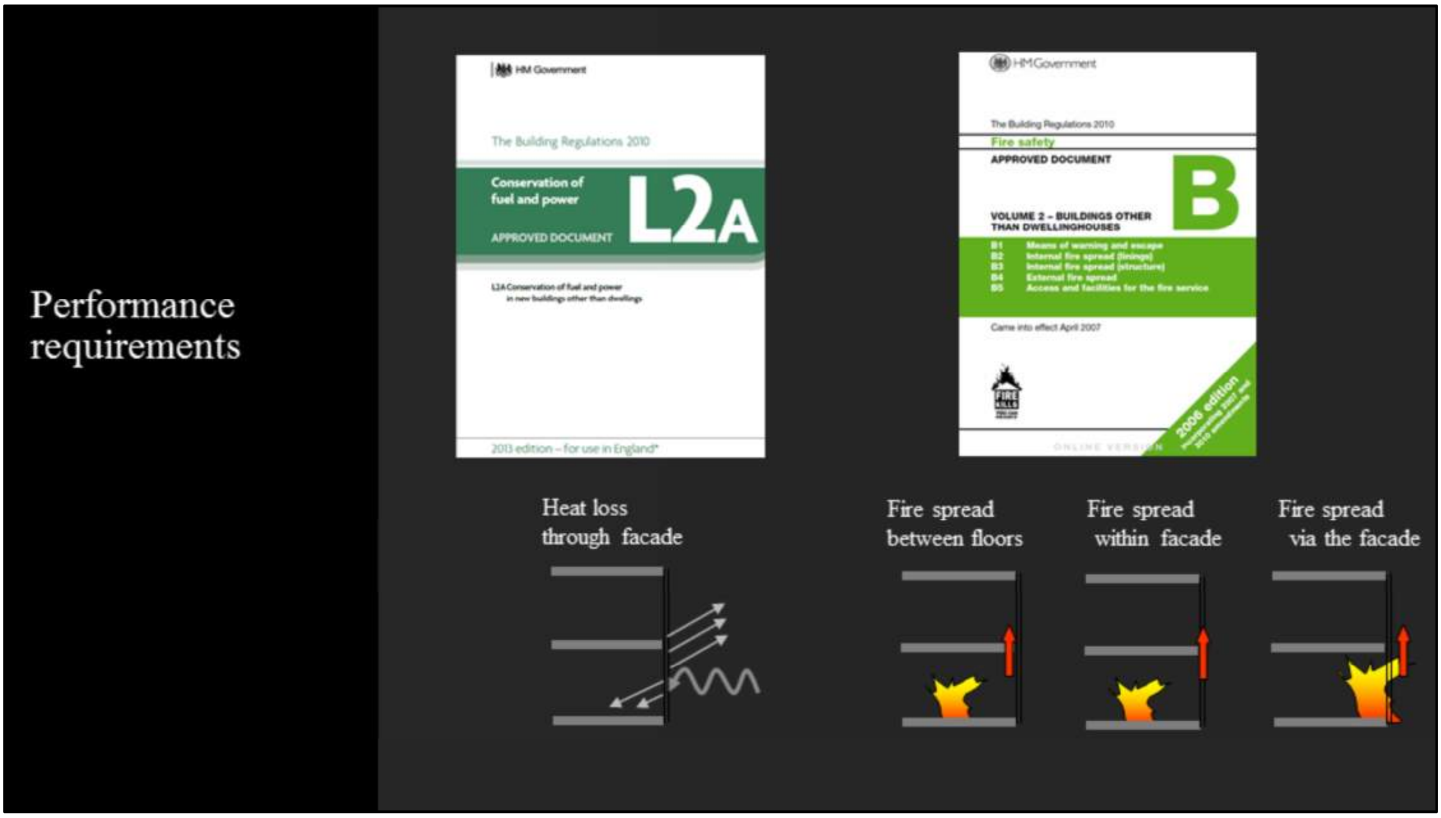
# Facades

So starting with facades
I'll look at how façades have evolved over the years
And what the fire safety challenges posed by modern façade systems are


Since the advent of the Building Regulations, the primary construction materials for buildings has therefore been non-combustible
Pre-war this was primarily brick and other masonry
After the war, and the massive rebuild needed to rehouse people, this included prefabricated construction for quicker build times
– but still using non-combustible construction
During this period and through to the 70’s and 80’s, the performance that a facade had to achieve was almost non-descript.
It had to provide an envelope that was wind and water tight and which looked good.
But ventilation and thermal performance were not on the horizon at that time.




Since the 90’s, the main driver for facades has been the demand for high thermal efficiency
highly insulating and also highly screening out the sun in hot climates
There have been huge developments in the use of lightweight systems featuring aluminium curtain walls and glazing systems.
Rainscreen systems featuring many differing types of external lining have been developed.
Precast concrete is back on the scene.
People are using bricks again for major buildings like the recent Tate Modern extension
Timber frames are being used as a lightweight alternative to masonry
Glass technology has developed enormously, such as high performance coatings applied to the glass to reduce solar gains but still providing an excellent level of day lighting into the building.
Now we have super efficient double and triple glazing systems, arranged as ventilated cavities, spanning the full height of a building




The Building Regulations have set higher and higher targets for thermal performance and air tightness in order to meet global requirements to address climate change.
So we now pack the external walls of buildings full of thermal insulation
But net lettable area: a big deal in congested cities, and a big deal when building tall, means the thinner the envelope and the lighter, the better.
But unfortunately the nice thin high performing thermal materials, are in the main, combustible.
Things like Polyisocyanarate (PIR)
Polyurethane (PUR)
Phenolic
Expanded Polystyrene
Extruded polystyrene
All are combustible materials
So we are seeing a conflict between meeting Part L for energy efficiency requirements, and Part B for fire safety requirements.
Not only does there appear to be a conflict – there is also confusion in the industry about what these requirements actually are..

## Combustibility

**Insulation Materials/Products**

**12.7** In a building with a storey 18m or more above ground level any insulation product, filler material (not including gaskets, sealants and similar) etc. used in the external wall construction should be of limited combustibility (see Appendix A). This restriction does not apply to masonry cavity wall construction which complies with Diagram 34 in Section 9.

| National Class | European Class |
|---|---|
| a) Any non-combustible material described in Table A6 of ADB | a) Any material which is listed as non-combustible in Table A6 of ADB |
| b) Any material which passes the test criteria specified in BS 476: Part 11:1982 | b) Any material/product classified as Class A2-s3, d2 or better in accordance with BS EN 13501-1:2002 *Fire classification of construction products and building elements, Part 1 – Classification using data from reaction to fire tests* |
| c) Any material with a non-combustible core at least 8mm thick having combustible facings (on one or both sides) not more than 0.5mm thick. (Where a flame spread rating is specified, these materials must also meet the appropriate test requirements). | |

| Insulation | European Class |
|---|---|
| Polyisocyanarate (PIR) | C-D |
| Polyurethane (PUR) | D-E |
| Phenolic | B-C |
| Expanded Polystyrene | E-F |
| Extruded polystyrene | E-F |
| Stone wool | A1-A2 |
| Glass wool | A1-A2 |

Typical European classification for insulation materials [Stec & Hull, 2011]

Fire safety guidance in the UK (for example Approved Document B or British Standard 9999) is clear that the external envelope of a building **should not provide a medium for fire spread** if it is likely to be a risk to health or safety.

In tall buildings (those >18m), insulation products should be of *limited combustibility* or better

So what is *limited combustibility*?

Using a UK classification it's either something which is inherently inert (like masonry)

Or it's something that passes a BS 476 Part 11 test or an A2 rating when tested to BS EN 13501 part 1

You can see from the table on the right that none of the main modern insulation materials we talked about a minute ago (PIR, PUR, phenolics etc) achieve this.

Only insulation materials like mineral wool meet the required performance

However, for many facade designers and clients out there, mineral wools are not preferred, as these require greater thicknesses to achieve the same thermal performance impacting on net area and cost.

It is also important to note that these combustibility classifications have no relation to the surface spread of flame performance.

Many panel manufacturer's data does not state their products are combustible but will refer to them achieving Class 0

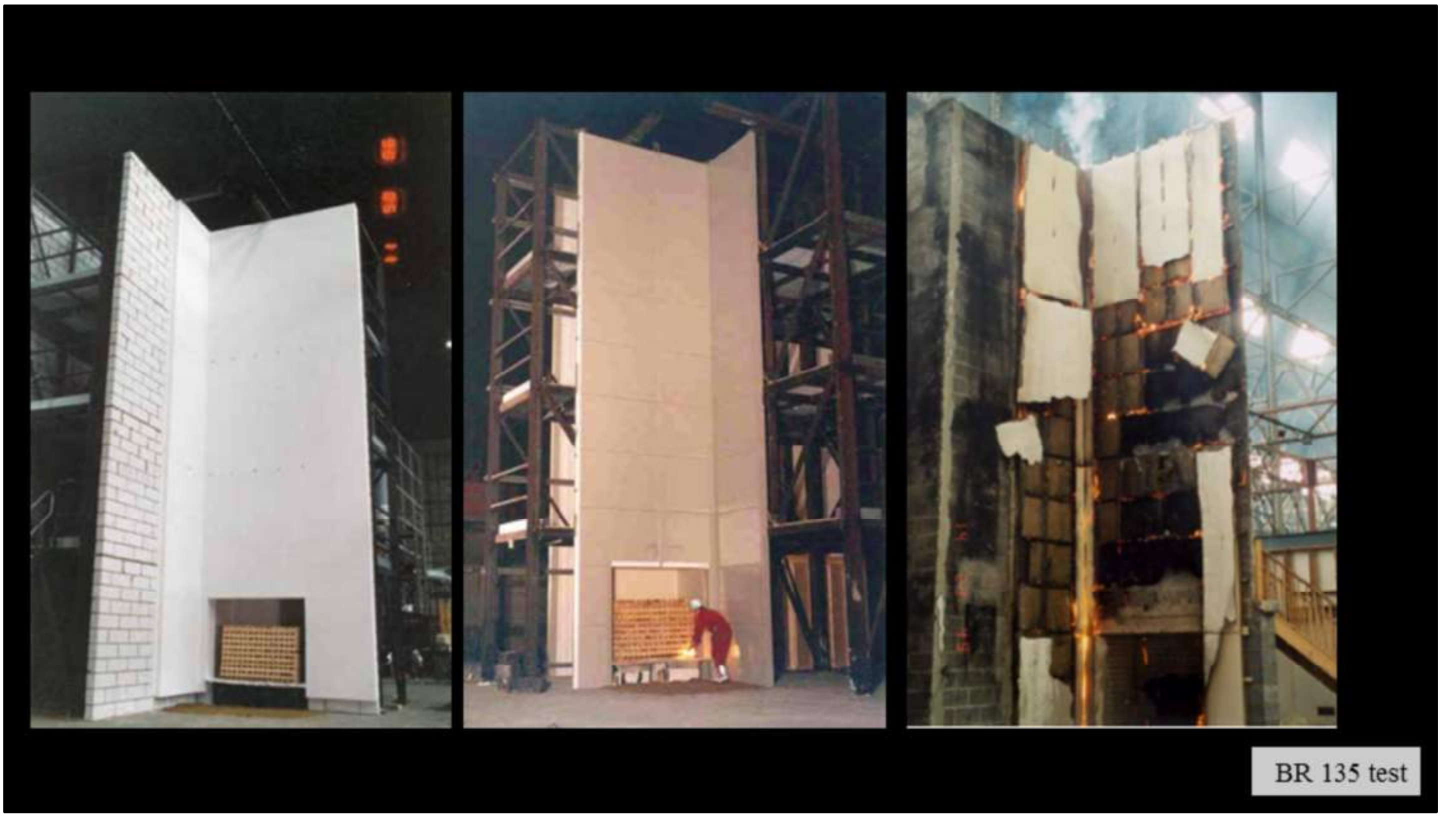
Class 0 is not a combustibility test

For example – even an expanded polystyrene (which is highly combustible) can achieve Class 0 if it is wrapped in aluminium foil.

Often Class 0 is confused with non combustible – they are not the same


So what does this lack of understanding of the available information mean?
Unfortunately this means that too often these materials are used within building facades unknowingly.
It means people are potentially using materials which will perform significantly worse in a fire than the regulations require
As an example you can see here the comparative performance of mineral wool with polymer based insulations

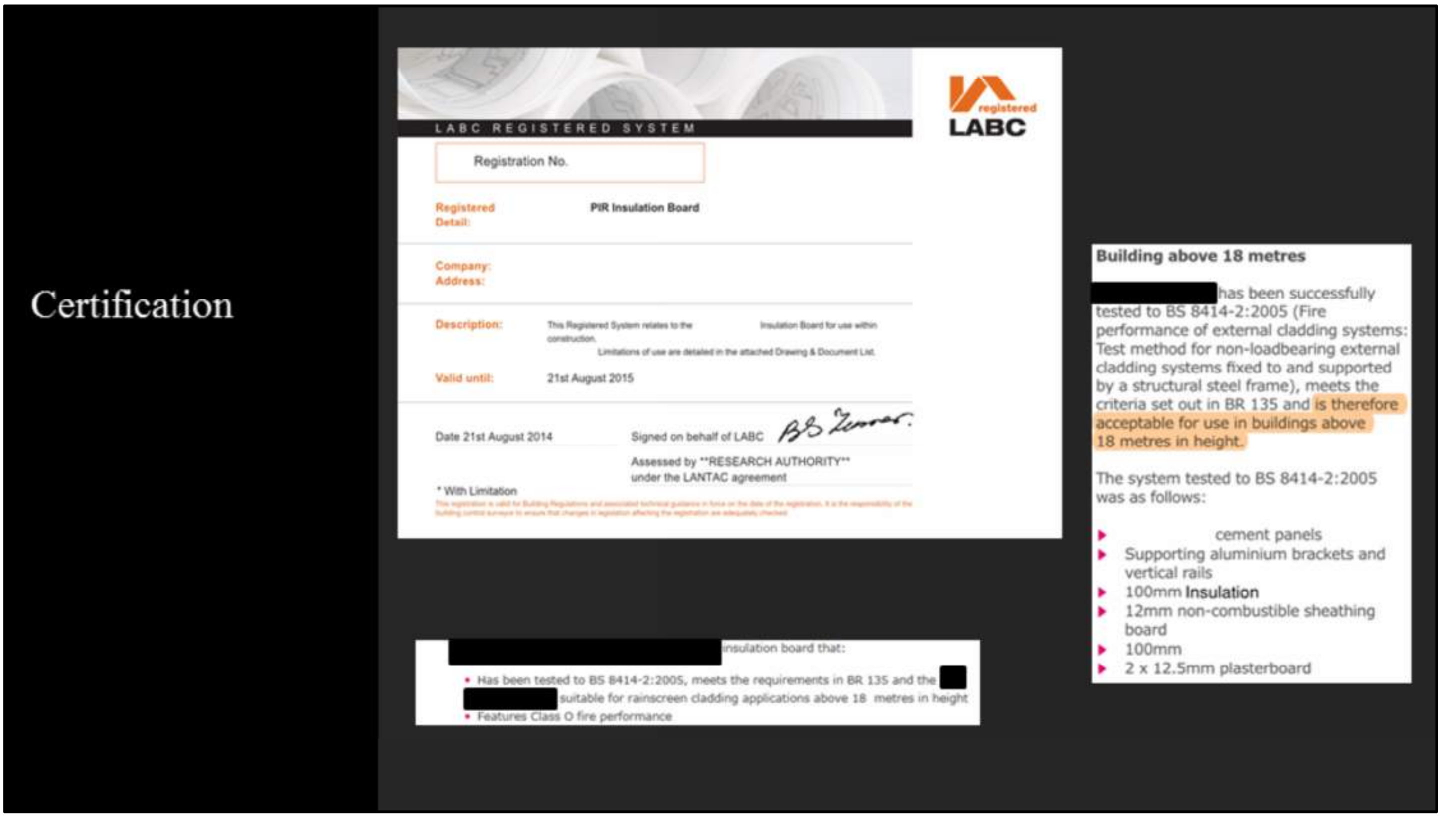

And you can see here in practice one the many recent fires that have occurred in Dubai's residential towers
All due to the combustibility of facades and the incorrect specification of materials.
So if a designer chooses to use a combustible insulation, you can see how important it is for them to do so KNOWINGLY
By understanding the risks a material poses, it may be possible to put appropriate protection measures in place
But it may not.
And to do that, there has to be much more information available about the behaviour of each of these materials / products




In terms of facades, one way to do this is to undertake large scale fire testing of the proposed insulation product as part of an overall facade build up.
This is also recognised by fire safety guidance as an acceptable approach.
For example the BR 135 test for cladding systems using full scale test data from BS 8414.
The criteria for this test is in relation to

1. internal fire spread, within the core of the panel; and
2. external fire spread up the face of the panel; and
3. mechanical performance.

These tests are being done by a number of manufacturers and do provide very helpful insight into the relative performance of different insulation materials.
HOWEVER the certification provided by the test house applies only to the system exactly as tested and detailed in the test report.
**As do all test reports**
This means that when you change any part of the build up, e.g. the thickness of the insulation, the type of substrate, the type of external cladding, the spacing of cavity barriers, the fixing details etc – the certificate is no longer valid
And this is where there is a significant amount of confusion in the industry.
To date, we have not yet come across a single facade design which has been installed or designed as it was tested and certified to BR135 exactly.




So we have a situation where designers who may not fully understand the requirements and the subtleties of these test requirements may be tempted into thinking their facade design complies.

And suppliers who may not be clearly identifying the limitations of their products

We are often presented with the types of information you can see here (anonymised).

For example, a product data sheet which states that the product can be used >18m.

Or a BBA or LABC certificate for the product for such use.

Unfortunately these pieces of information don’t tell us the full story.

It would be all to easy for the designer to accept this at face value

But it is important that all parties ask questions about the system that was tested, and how it compares to the system that is being designed or used.

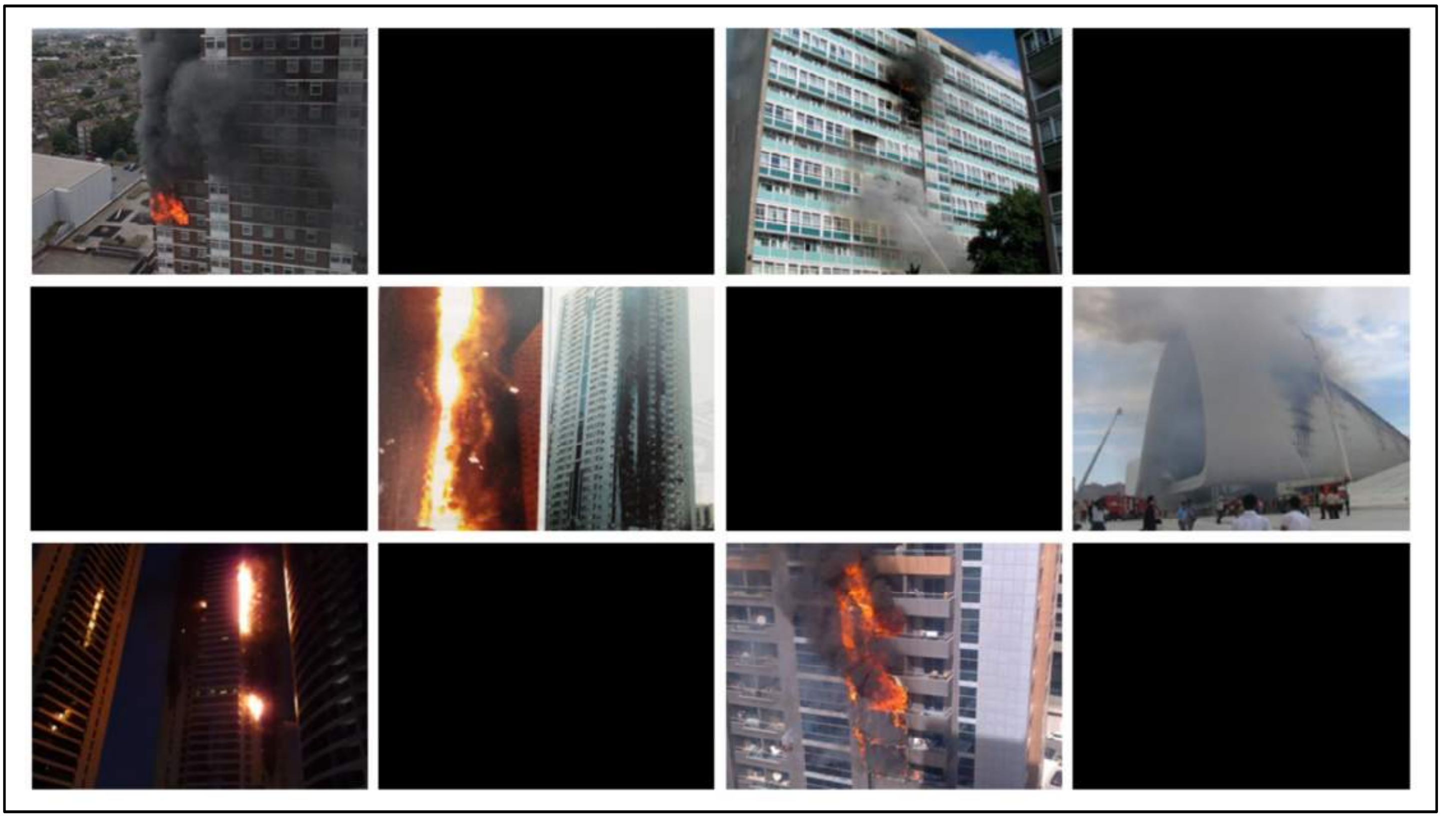
To make sure we are using products within the bounds of their applicability

This test data should be readily available.

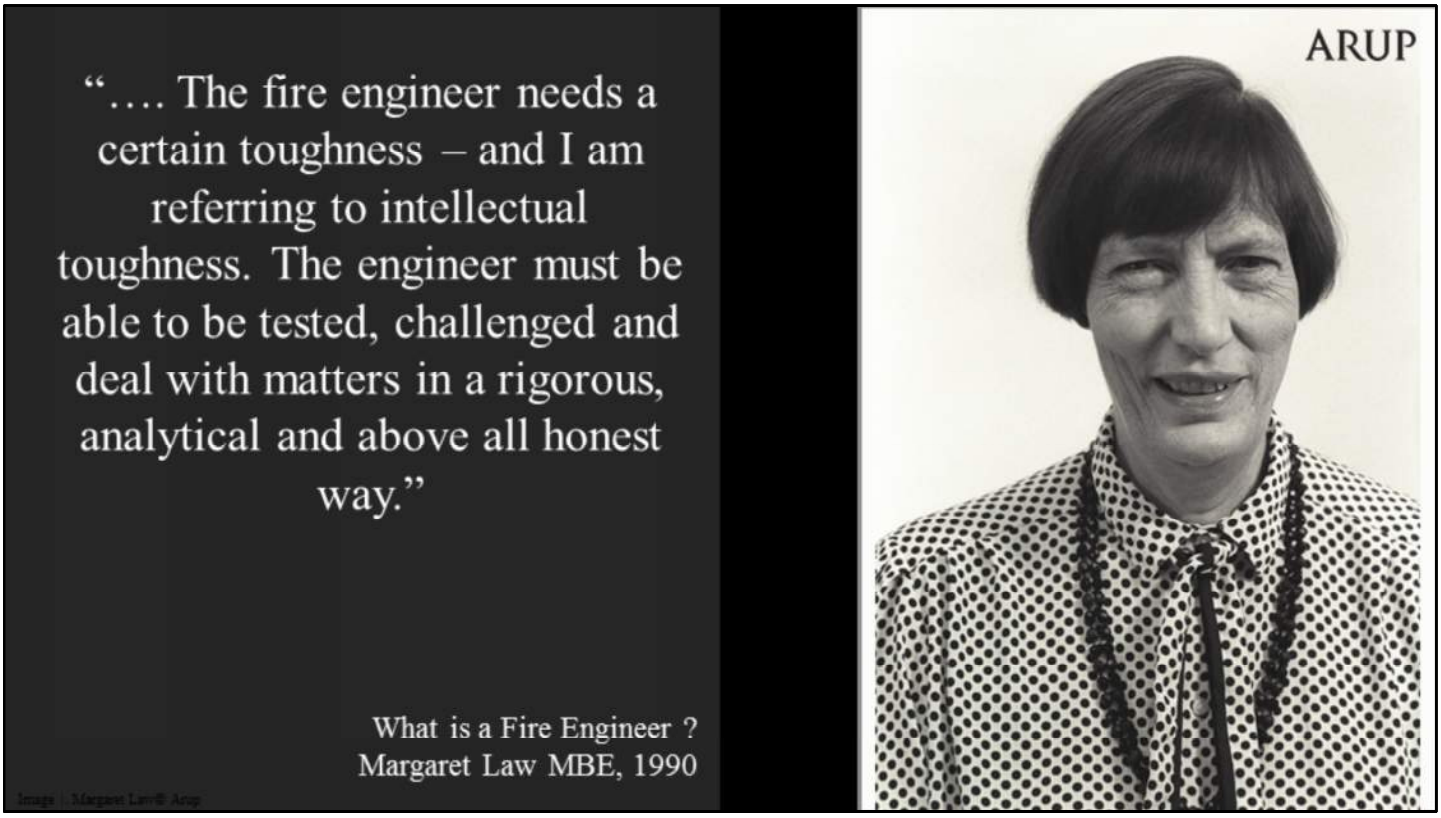
And what we think would also be helpful would be to release information about what made certain façade systems fail, so that this kind of design can be avoided in future

Unfortunately this information isn’t always forthcoming

But blind acceptance of fire performance claims on a product data sheet should not be accepted



Because the consequences of incorrectly designing, specifying and constructing combustible materials within the facade can be significant,.
With the most recent known UK example being Lakanal House, where a Class 0 surface performance was confused with a combustibility performance and the replaced facade panels did not comply with current guidance
This was one of several factors resulting in fire spread over multiple floors which lead to 6 deaths.
Some are still using the old ‘well we used it on the last job’ or ‘Building Control have accepted it’ as some substitute for competent proof of performance in end use.
Information is needed for the end use performance.
This information needs to be reviewed and accepted by those competent to do so.




And as designers we need to have rigour in how we approach the issues
It can be difficult when everyone from the client, façade designer, architect, QS, construction manager – all want to use a certain product.
And they are being told by a supplier that it is suitable
And they have used the same product on the last job (or the last 10 jobs)
And the building control officer is saying it is ok to use
As Margaret Law, the founder of Arup Fire said, the fire engineer needs a certain toughness – intellectual toughness – to deal with matters in a rigorous and honest way
That can be very challenging to say the least


And there is another dimension to this at the much larger city scale.
The regulations introduced after the Great Fire Of London were designed to prevent fires spreading between buildings
But we are seeing buildings constructed with combustible façade systems now allowing fire to spread
Today in cities like Dubai and Melbourne the challenge of highly combustible building envelope systems, built without due consideration of fundamental fire performance, are now requiring consideration of mass scale recladding or mass scale mitigation measures.


And it’s not just suppliers who need to up their game
From an engineering perspective there is much more that we can do.
At Arup we are sponsoring two PhD’s
- One at Edinburgh on façade failure mechanisms and risks
- And one at Imperial on fire safety optimisation of façade design

We are also undertaking our own internal research on:
- a facades research roadmap to inform future work
- a facades whitepaper to guide our designers and the industry

And we actively participate with industry bodies such as the Centre for Window and Cladding Technology (CWCT)
All of the above is to enable us to answer some of the questions which cannot be answered by the current information available.

# Timber

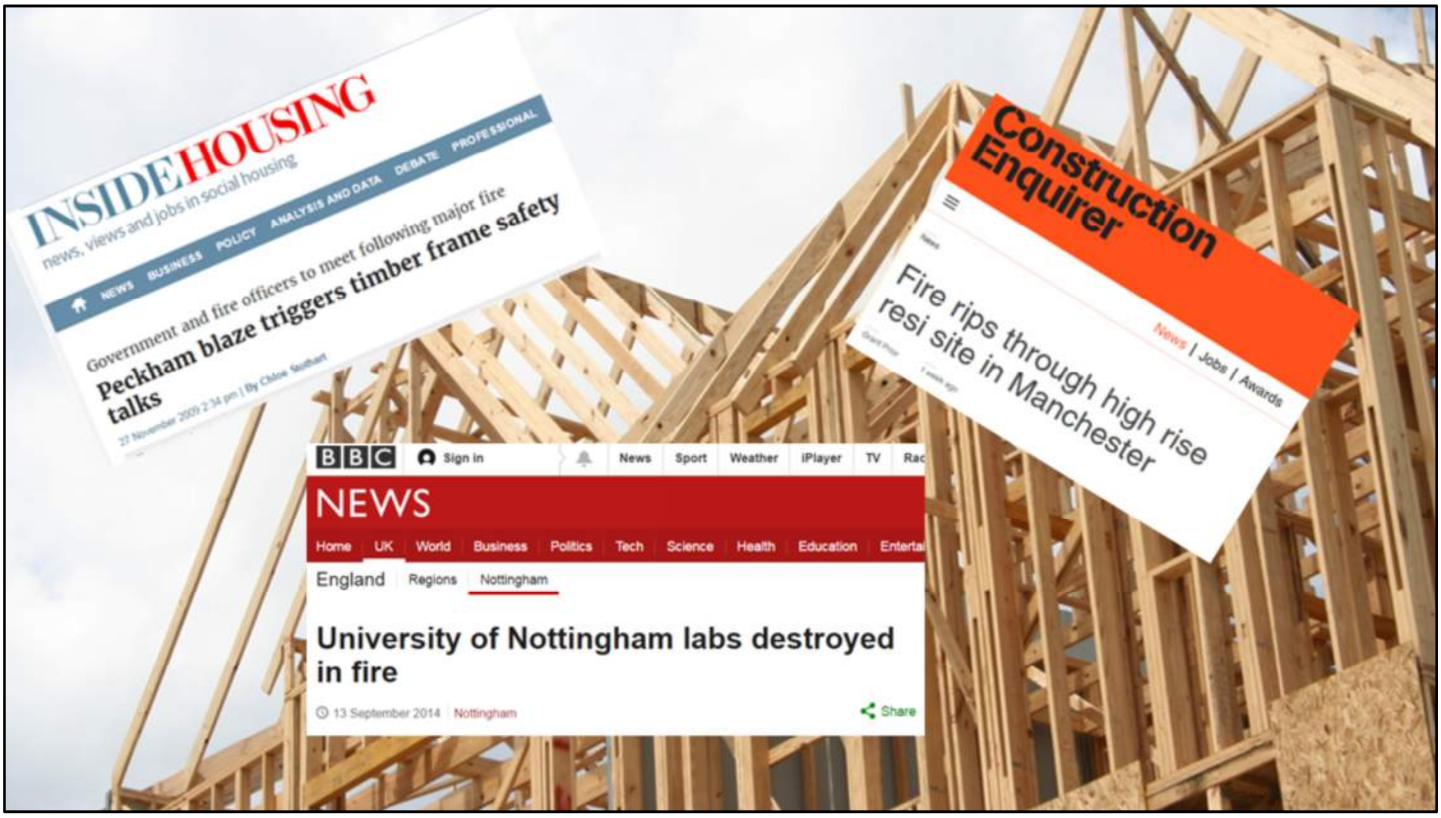
And moving on now from facades, there is growing trend to use timber as a construction material
As the framing system for ever taller buildings (particularly residential buildings)
And as the exposed internal wall, floor and ceiling system
So similar to facades, timber technology is also evolving at a pace like never before
And as designers we need to understand how these materials will behave in fire so that we can design accordingly

# Why timber?

- Speed of Construction
- Lightweight
- Sustainability
- Aesthetics + Innovation
- Technology & Prefabrication


So why the demand for timber structures?
– clients want it, engineers want it, architects want it.
The primary issue seems to be speed.
Speed of construction, speed to full occupancy, speed to full return on investment


But timber isn't a new material
It has been used as the framing system for buildings for centuries
Indeed it's probably the oldest construction form out there
But the use of timber frames for increasingly taller and more complex buildings is on the rise
And we have seen some major fires, particularly during the construction phase, as a result
And new guidance produced by the HSE to address the risks




In their finished state, timber frame structures meet strict fire protection requirements. Typically they are encased in plasterboard construction so that a fire can’t attack the timber.

However, during the construction phase, they are more vulnerable because the precautions for the finished building are not in place.

There have been a number of large and serious fires involving timber frames during construction

And a particular risk is the resultant fire spread to neighbouring properties

Such fires have demonstrated the need for clients to consider carefully neighbouring properties and activities in line with their duties under the Construction (Design and Management) Regulations 2015.

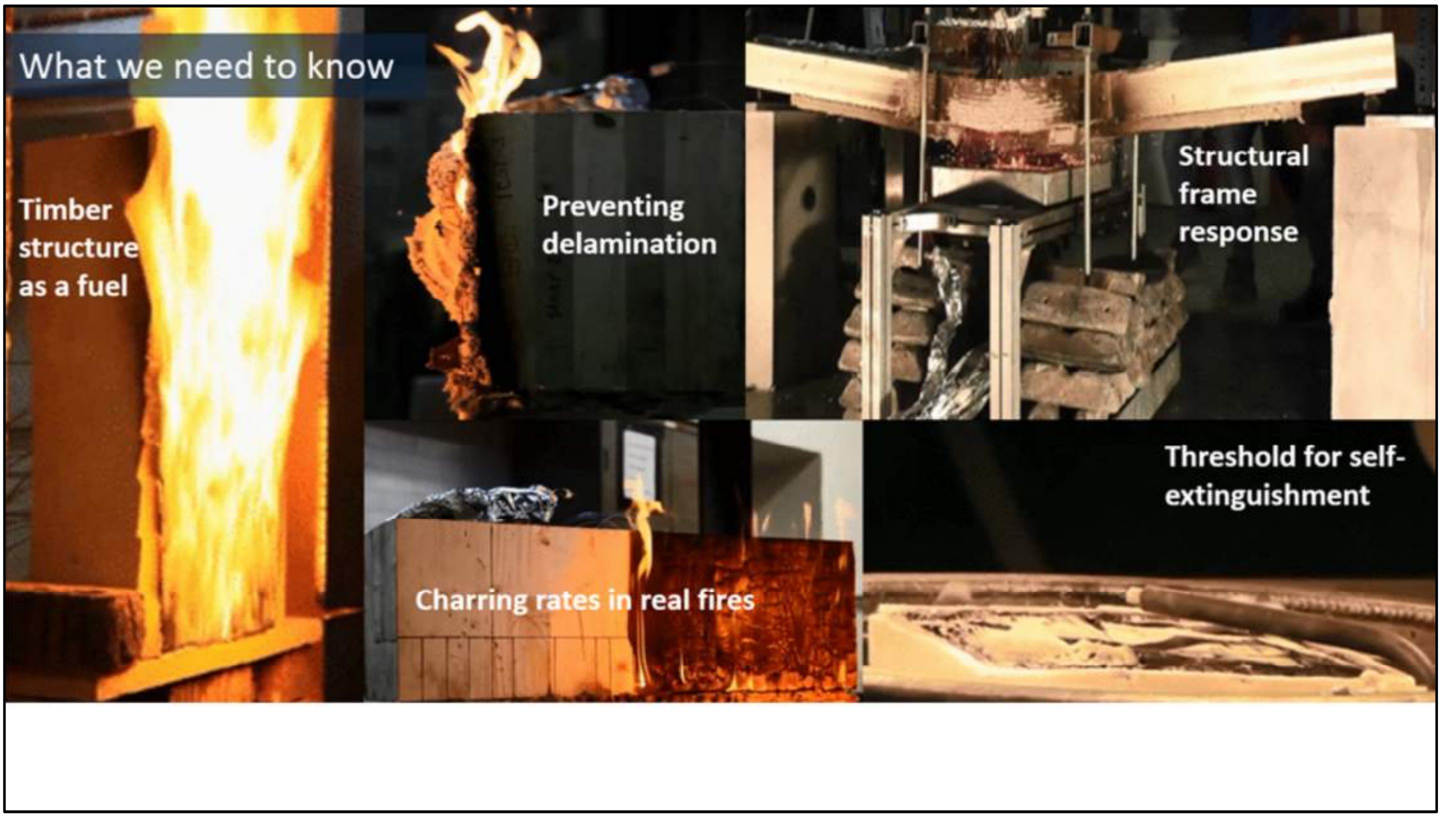
Specifically the HSE have made clear that this needs to be considered during the DESIGN phase of projects

And as a result the Structural Timber Association along with HSE have produced specific guidance on helping mitigating the risks of serious fires during the construction phase.

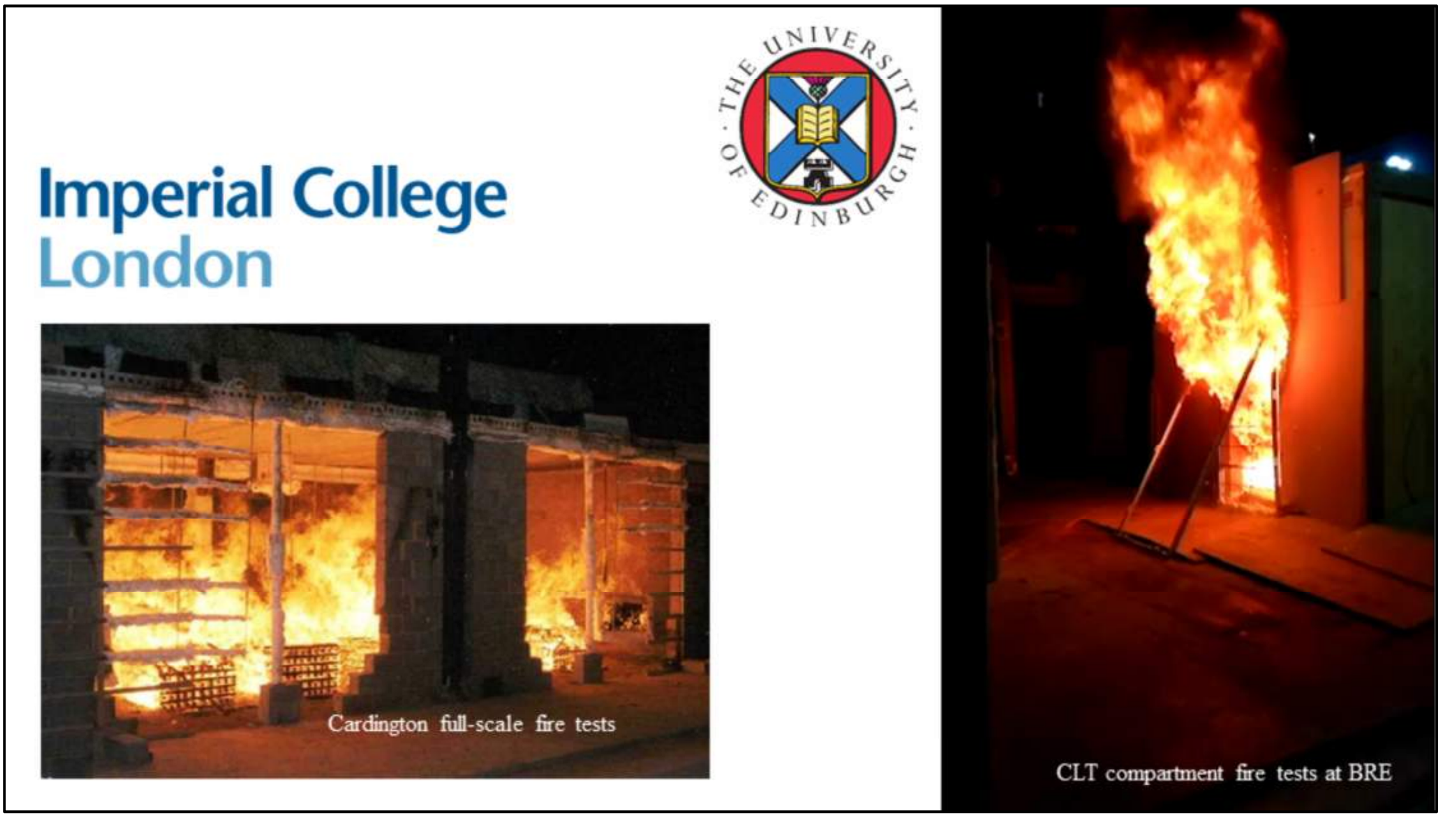
This is to be welcomed


But as well as the construction stage risks, there is also an increasing architectural desire to expose timber within the building
So to use timber for the internal walls, floors and ceilings, and to expose as much of the timber as possible.
And so with no applied fire protection.


The current understanding of safe timber performance in fire relies almost entirely on rules of thumb and outdated industry best practice.
This focuses mostly on the ability of timber to char and supposedly therefore protect itself from heat.
But this data is for solid timber elements
Not for more modern CLTs and glulam structures which make up a large part of the construction market
The fire performance of laminated timber can be significantly different to that of solid timber.
This is because timber elements are formed from multiple layers of timber that are glued together
And the fact this structural form is in itself fuel, changes the whole dynamic of how a fire behaves too.
It is fundamental basis of current fire codes (for example in the structural design standards) that a fire in a building involves the contents only
And when the contents have burnt out, the fire too should go out.
But when the walls, floors and ceilings are also potentially constructed of timber, this fundamental assumption may no longer be valid




We want to use timber in dynamic, imaginative, complex ways,
but this requires us to fill some of the information gaps we currently have
At Arup we are investing in research to enhance our understanding in five technical areas
that we have determined will enable us to make a fundamental change in the industry.




We are sponsoring PhDs at both Imperial College London and at Edinburgh
To conduct fire experiments at Cardington to create a data base of realistic responses so that we don’t need to rely on those out of date methods.
We are pioneering full scale experiments, currently in progress at the BRE, on spaces built in full with unprotected and partially protected CLT.
This should allow us to start using more unprotected timber on an evidenced basis.
This change is intended to allow not just us, but the wider profession,
to use timber safely with the imagination and complexity that is so desired on our projects.
With both timber and insulation, we don’t want to return to potentially disastrous City scale incidents
But equally we don’t want to stand in the way of modern methods of construction
We need to understand the information we currently have available
And to gain information where it doesn’t currently exit
So that we know how a material is likely to behave in a fire
And what impact this will have on how we plan for the response of the building, the occupants, the management team and the emergency services
So that we can decide how we can safely use it
To enable us to design knowingly

We Shape a Better World

Thank you

# References

General

- Approved Document B Fire safety
- BS 9999 Fire safety in the design, management and use of buildings
- BS 9991 Fire safety in the design, management and use of residential buildings
- BS 7974 Application of fire safety engineering principles to the design of buildings

Facades

- BR135 Fire performance of external thermal insulation for walls of multistorey buildings
- BS 8414 Fire performance of external cladding systems
- BCA Technical Guidance Note 18 Use of Combustible Cladding Materials on Buildings Exceeding 18m in Height
- BS 476 Part 11 Fire tests on building materials and structures. Method for assessing the heat emission from building materials
- BS EN 13501 Part 1 Fire classification of construction products and building elements. Classification using test data from reaction to fire tests

Timber

- Design guide to separating distances during construction for fire safety – Structural Timber Association
- Construction (Design and Management) Regulations 2015.