Designing modern fire-safe timber structures – where does the responsibility lie?

José Torero, Katherine Cashell and Oliver Wilton summarise the key issues around fire safety of structural timber, and explore where responsibility for this lies under new regulations in the UK.

The use of timber as a structural material has been increasing rapidly in recent years, largely in response to demands for buildings to become more sustainable with lower carbon footprints compared with traditional methods. The current article focuses on the challenges of achieving a 'fire-safe' timber building, particularly for complex, open-plan or multistorey applications. Before going into detail on this, it is important first to provide some more general context in terms of fire-safe design and the recent changes to building regulations in the UK.

Competency gap

The Grenfell Tower fire of 2017 was a landmark event that changed the landscape of structural fire engineering. The tragedy highlighted the deficiencies that exist in building standards and regulations, common construction practices, and also engagement between building designers and other stakeholders such as building occupants. It was particularly striking that this event occurred in a recently renovated structure, newly clad, which of course turned out to be so costly for occupants.

Over the past 20 years, the construction industry has evolved significantly, with the development of new materials, innovative building solutions, lighter and leaner structural frames, and so on. This evolution has been largely motivated by the ever-growing need to improve the sustainability and performance of building structures, which has become all the more pressing with recognition of the climate emergency. Indeed, the Institution of Structural Engineers has been instrumental and even pioneering in this regard, within professional institutions of the built environment.

However, it has become clear, following the various analyses and reviews of the Grenfell tragedy, that the procedures in place to ensure that buildings offer an adequate level of fire safety have developed at a much slower pace. The UK building regulations, and in particular the methods and requirements for testing whether products perform satisfactorily in a fire, have been shown to be deficient and not necessarily fit for purpose.

Even more fundamentally, the question of competency among professionals in designing a fire-safe structure has been in sharp focus, as well as the lack of clarity on where exactly the responsibility for this lies, especially for newer materials and technologies. As Richard Millett KC, Lead Counsel to the Grenfell Tower Inquiry, indicated in his closing statements, 'inadequate standards of competency' were at the core of the Grenfell tragedy to the point where they reflected 'a concomitant failure to pay due respect to the idea of home as a physical aspect of human privacy, agency, safety and dignity'[1].

New responsibilities

Following on from the report produced by Dame Judith Hackitt in her 2018 review of fire safety and building regulations,[2] the Building Safety Act[3] was passed in April 2022 and came into force on 1 April 2023. In conjunction, The Fire Safety (England) Regulations 2022[4] introduce new duties for the management of fire and building safety in higher-risk buildings (HRBs). They apply to new or existing occupied buildings (including blocks of flats, hospitals and care homes) which are over 18m in height, or seven storeys or more, and contain at least two residential units. The aim is to create a universal change in responsibility and culture in the construction sector, giving new emphasis to fire safety and also the needs of the building occupants.

A key new responsibility defined in the Act in relation to fire safety for HRBs is that of the Accountable Person. The Accountable Person must have the required competency and skills to ensure that building regulations are adhered to, and therefore they require a thorough grasp of the regulations, including the fire safety requirements. This reinforces the role of the Principal Designer as established in the RIBA Plan of Work 2020[5].

Architects will largely hold this role, although it could feasibly be structural engineers also. Either way, it is important that all professionals involved in the design of buildings are acutely aware of the fire safety requirements, and moreover have the competence to ensure that any additional professionals brought into a project, such as a fire engineer, are also capable and competent.

The Engineering Council has also set out a series of competency requirements[6] for those working on HRBs in relation to fire safety. These include the ability to identify

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the characteristics and behaviour of a structural material or form of construction under a major fire and also to assess the impact of a fire on the structure.

Importantly for structural engineers, it is also stated that designers must understand the ways in which the structural design may affect the fire safety of the building, and how the fire engineering design might impact on the structural safety of the building. It is required that engineers working on HRBs have the skills to design structures that remain stable after a fire, without risk of sudden and/or catastrophic collapse.

Fire safety in timber

So, in light of the above discussion, what do these recent changes to building regulations and practices mean for the design of fire-safe timber buildings, including HRBs, and what knowledge, competency and experience is required by engineers/designers to build such a structure?

In parallel to this, how do we, as a group of engineering professionals, ensure that our industry continues to embrace modern methods of construction (MMC), such as those employing engineered timber, and does not move away from these novel products and systems owing to a lack of competency in terms of fire safety?

This would not only undermine efforts to build using more sustainable materials, but also removes the need for a rational analysis of fire safety, going directly against Dame Judith's post-Grenfell recommendations.

Some evidence for these concerns were presented in November 2022, when the National Fire Chiefs Council (NFCC)[7] indicated that it is 'concerned that MMC buildings are being designed, approved and built under a regulatory system that has been described and accepted by Government as 'not fit for purpose' even for traditional construction techniques.' Particular emphasis and concern was directed towards 'the use of engineered mass timber products e.g., Cross-Laminated Timber (CLT); Glue-Laminate Timber (Glulam).' This comes in addition to the government ban on the use of combustible materials in building envelopes.

In recent years, the structural fire engineering research community has focused considerable efforts towards providing performance information, design recommendations and behavioural analysis for timber structures in fire. Accordingly, there is sufficient technical knowledge and expertise, especially among structural engineers and fire engineers, to design fire-safe, complex, timber structures. However, the methodologies and tools are bespoke and complex and the use of standard performance tests requires complex interpretation. Furthermore, despite the significant work being done in this area, gaps of knowledge still remain, adding further complexity to the design process. As a result, the fire-safe design of timber buildings requires highly competent professionals that are in short supply.

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↑ Structural timber presents a unique risk in a fire scenario, with particular concern around the potential for delamination of engineered timber products

The development and popularity of engineered timber products has been driven largely by the many attributes that timber has as a construction material. However, it behaves quite differently in a fire compared with more traditional, non-combustible, building materials such as steel and concrete. In spite of this, the tools and performance criteria that were designed for non-combustible structural materials, interior wall linings and combustible facade systems have remained unchanged, with little to no developments in terms of a competency framework for professionals to use.

Challenges with timber

The fire research community, especially among structural engineers (e.g. articles published in *The Structural Engineer* in 2018[8] and 2020[9]), is clear on the challenges that exist for designers of high-rise timber structures, and has identified gaps in existing knowledge and performance information.

Wood is a combustible material and therefore ignites, burns and releases flammable vapours when subjected to fire (or heat). While all materials degrade at extreme temperatures, particularly in terms of their mechanical properties, the release of these flammable gases during pyrolysis in the wood is essentially adding further fuel to sustain the fire. This property immediately leads to a fire safety concern, which is essential for designers to understand.

For many timber structures, especially complex buildings with large open spaces and 'higher-risk' developments, it is likely to be necessary to engage with an expert fire engineer from the beginning of the design process, and also for the Principal Designer to be able to ascertain the competency of the fire engineer. This latter point will require significant upskilling in terms of fire safety.

When a material, product or system is known to represent a hazard, it is the designer's responsibility to design to mitigate against this risk. Recognised hazards are common in the built environment, but because they are recognised, effective mitigation strategies have generally been developed. For timber, it is

important to understand the risk that this brings to a building. A conservative estimate for the temperature at which timber ignites is 250°C[10]. Therefore, an appropriate fire safety strategy should enable the correct management of all occupants of a building before the timber ignites if they are to remain unharmed.

Structural timber will eventually ignite as the fire grows, and its mechanical properties then decay and the timber structural elements lose cross-sectional area as they burn and char. Char has no residual strength. Therefore, the unique risk introduced by structural timber relates to its structural function. By separating this risk from the rest of the fire-safe design, it is possible to focus the mitigation strategy where it is necessary, and this requires effective collaboration between the architect, fire safety engineer and structural engineer.

The char that develops during a fire can act as a barrier and prevent the timber behind it from continuing to pyrolyse. Further, if no additional external heat is supplied, it is possible that the char will thicken and cause the fire to self-extinguish.

If the timber structure self-extinguishes after the combustible furnishings are fully consumed, then it is possible to attain the performance requirements of compartmentation and structural stability. However, on the other hand, the char can also pyrolyse and sustain a flame, thereby worsening the fire.

The determination of the potential for a timber structure to self-extinguish is the professional domain of the fire safety engineer. And it is worth reiterating that, under the Building Safety Act, the Principal Designer must be able to ascertain the competency of the fire engineer.

Conclusions

So, in conclusion, it is accepted not only that timber is an essential structural material for a variety of reasons, but also that it can be specified and designed to provide a fire-safe solution. It is possible to make conservative assumptions which circumvent knowledge gaps (e.g. prevent delamination by introducing conservative critical temperatures as opposed to fully analysing the process of delamination), and conduct ad hoc testing to establish the performance of a specific product, although this requires a very high level of expertise and competency.

The core problem is not materials, products, tests or tools, which all have a readily available solution, but competency. Structural engineers clearly have an important role to play in the design of fire-safe structures, made from any material. Although this is not a new development, the responsibilities and regulations have changed, and require careful consideration for HRBs.

To fill this gap in knowledge and competency among all participants in the design process, it is essential to increase higher education provisions in the UK. Currently, few educational programmes exist, and only the University of Edinburgh offers a degree amenable to structural engineers.

The Institution of Structural Engineers is planning to offer CPD courses for its members and also to update guidance documents in this area. In the case of architects, i.e. Principal Designers, the Department of Civil Environmental and Geomatic Engineering at UCL will start a new MArch programme in Fire Safe Design in October 2023.

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> **“THERE IS SUFFICIENT TECHNICAL KNOWLEDGE AND EXPERTISE, ESPECIALLY AMONG STRUCTURAL ENGINEERS AND FIRE ENGINEERS, TO DESIGN FIRE-SAFE, COMPLEX, TIMBER STRUCTURES**

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