BUILT BY NATURE

TIMBER DEVELOPMENT UK

COMMERCIAL TIMBER GUIDEBOOK

INDUSTRY CONSENSUS GUIDANCE FOR GOOD PRACTICE MASS TIMBER OFFICE BUILDINGS

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EXECUTIVE SUMMARY

PURPOSE OF THE COMMERCIAL TIMBER GUIDEBOOK

The adoption of mass timber in large-scale commercial construction in the UK has been slower than anticipated, despite the increasing interest in mass timber as a sustainable building material.

This hesitancy stems from concerns about durability and moisture, fire safety, and as a result the challenge of obtaining sustainable property insurance. These issues are compounded by a lack of comprehensive guidance specific to mass timber construction.

The Commercial Timber Guidebook has been developed to address these challenges. It provides good practice technical guidance to demonstrate how mass timber buildings are designed and constructed to be robust, addressing key concerns about fire safety and durability risks.

The Guidebook sits alongside the Mass Timber Insurance Playbook (MTIP). While the MTIP provides a framework for understanding the risks perceived by insurers, the CTG offers the detailed technical information to mitigate these risks, with the aim of improving the insurability of mass timber buildings.

This coordinated effort fosters better communication between developers and insurers, promoting a shared understanding of mass timber's risks and benefits. An expert fire panel was also established to create consistent fire safety principles, which will further improve industry confidence in insuring mass timber structures.

GUIDANCE OVERVIEW

The main part of the Guidebook is divided into Mass Timber Background (chapters 2&3), Technical Guidance (chapters 4&5) and Illustrative Examples (chapter 6), offering context for mass timber and strategies for addressing key challenges. Each chapter starts with an executive summary to allow readers from different backgrounds to quickly understand the essential concepts. The mass timber background and technical guidance is summarised as follows:

Insurance
The Guidebook provides context of mass timber buildings in the UK from the perspective of the insurance sector. It summarises current available risk guidance documents, and how the construction and insurance sectors have learnt from experience when designing mass timber buildings.

Timber Offices
Mass timber buildings, especially office spaces, are gaining popularity due to environmental benefits like reduced carbon emissions and improved aesthetics. The Guidebook provides key design considerations for adaptable, sustainable offices using engineered timber, addressing challenges in architectural and structural design.

Moisture and durability
Timber's durability depends on how well it is protected from moisture. The Guidebook identifies moisture as a key risk and provides strategies to mitigate this risk throughout the building's lifecycle, ensuring long-term performance.

Moisture and Durability Principles - The Guidebook outlines principles relating to durability and moisture in mass timber buildings:

1. Specify appropriate materials
2. Risk identification
3. Consider repair and maintenance
4. Keep timber dry
5. Early intervention
6. Moisture management in assembly
7. Remove critical vulnerabilities
8. Durability risk analysis
9. Repair and remediation strategy

By following these principles, designers, contractors, and building operators can demonstrate to insurers that they have taken comprehensive measures to mitigate the risks associated with moisture.

Fire

Mass timber introduces unique challenges to fire safety due to its combustibility. The Guidebook outlines fire behaviour in mass timber buildings and offers strategies to manage these risks, acheiving life safety compliance and contributing to property protection.

Fire Safety Principles - A set of industry consensus principles for fire safety in mass timber buildings:

1. Comprehensive fire strategy
2. Adequate risk to health and safety
3. Assumed redundancies for life safety design
4. Impact on escape from area of fire origin
5. Mitigating internal (vertical) and external fire spread
6. Mitigating internal (horizontal) fire spread
7. Expected performance of structure and compartmentation
8. Survival of burnout with encapsulated mass timber
9. Survival of burnout with exposed mass timber
10. Smouldering Combustion

By following these Fire Safety Principles, designers, contractors, and building operators can significantly reduce the fire risk in mass timber buildings, making them safer and more attractive to insurers.

Illustrative Examples

The Guidebook provides four case studies of mass timber office buildings, illustrating how the durability and fire safety principles can be applied to different building heights and types:

1. Full timber offices below 18 meters, up to 4 storeys.
2. Full timber offices between 18 and 30 meters, up to 15 storeys.
3. Hybrid offices between 18 and 30 meters, up to 15 storeys .
4. Hybrid offices over 30 meters or over 15 storeys.

Each case study demonstrates how the durability and fire safety principles can be tailored to different types of buildings, providing real-world applications of the Guidebook's recommendations.


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FUNDERS' LETTER OF SUPPORT

As a group of developers, we are pleased to lend our collective support to the Commercial Timber Guidebook (CTG), a resource designed to advance the adoption of mass timber in commercial construction. Our commitment to sustainable building practices has driven us to co-fund this guidebook, recognising its role in shaping the future of construction in the UK.

The need for the CTG arises from the growing imperative to reduce the carbon footprint of the built environment and to unlock commercially sustainable insurance cover for commercial mass timber buildings.

This group of developers has a collective potential multibillion development pipeline value, along with the appetite for the adoption of mass timber construction. This presents an opportunity to achieve significant reductions in embodied carbon, supporting the global push towards net-zero emissions.

Although the environmental benefits of mass timber are well-recognised, its adoption in the UK has been limited by a lack of familiarity of the inherent risks and their mitigation. This unfamiliarity has created some challenges in obtaining the required coverage, which has slowed the broader use of mass timber on a wider scale. We support the development of technical reports, including this one, to increase the understanding and familiarity of the risks and benefits of timber construction. We look forward to engaging with the industry on how to put this guidance into practice.

Sincerely,

Built by Nature, BEAM, British Land, Derwent London, Hines, Landsec, Lendlease, MUSE, Related Argent, Stanhope

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1. INTRODUCTION

This chapter aims to establish the purpose of Commercial Timber Guidebook and set out how to use it.

Climate change is already affecting every inhabited region across the globe, with human influence contributing to many observed changes in weather and climate extremes. This climate change is caused by human activity, and with approximately 40% of global carbon emissions attributable to the built environment, we have the responsibility to act.

With the UK committed to bring all greenhouse gas emissions to net zero by 2050, mass timber construction will undoubtably play a major role in the reducing of carbon emissions.

Timber is a replenishable and sustainable material and if utilised correctly, mass timber construction offers several sustainable benefits compared with traditional building materials including, lower embodied carbon, carbon sequestration, circular economy benefits, and low waste to name a few. The using mass timber can reduce the embodied carbon emissions in a single building by 20%- 60%.

Despite the above, the increase in mass timber construction in the UK is relatively slow with designers and developers becoming increasingly frustrated with current obstacles to constructing mass timber buildings.

THE GUIDEBOOK KEY THEMES

Demonstrates consensus on fire safety and design principles
A panel of fire and design experts collaborated to address perceived inconsistencies in fire safety approaches to reach a consensus on a set of fire safety and design principles for mass timber buildings. For the first time, the Guidebook outlines an agreed upon approach followed by competent fire engineers designing in mass timber.

Establishes good practice principles for durability and fire
The Guidebook consolidates comprehensive good practice technical guidance on the key risk areas of durability from moisture and of fire.

Bridges the knowledge gap
The Guidebook will play a critical role in reducing the knowledge gap between the construction industry and the insurance industry regarding the use of mass timber by addressing key concerns around durability and fire.

KEY DEFINITION

Mass timber is the name given to types of engineered timber that can be used as structural building materials. Mass timber buildings can be **full timber** (entire structural frame comprises timber elements) or **hybrid** (combination of a steel/concrete frame with mass timber floor slabs).

WHAT IS THE COMMERCIAL TIMBER GUIDEBOOK?

The Commercial Timber Guidebook's (CTG) main purpose is to address the insurance sector's concerns about the risks associated with adopting mass timber in construction.

The CTG represents a consensus of current good practices in the design of mass timber buildings and provides technical guidance for risk mitigation, and remediation strategies in relation to durability due to moisture, and fire.

The Guidebook is not, and does not purport to be, a standard for mass timber construction and it does not intend to guarantee, to the user of the guidebook or its associates, the availability of insurance.

The authors, contributors and funders recognise the importance of available, affordable and long-term sustainable insurance to the successful development and continued innovation of sustainable construction.

The Guidebook is intended as a the beginning of an ongoing and developing dialogue with the insurance industry, its specialist advisers, and consultants in risk.

The aims of the Guidebook are as follows:

- To provide a consensus approach to design and construction of mass timber that assures the insurance industry of intended good practice.
- Inform the design, development, and construction community to advance the use of mass timber.
- To produce a guide to good practice risk mitigation for anyone engaged in mass timber construction.

CHALLENGES OF INSURING MASS TIMBER BUILDINGS

Currently it is proving challenging to obtain sustainable property insurance for mass timber commercial buildings. The insurance sector acknowledges the requirement for an increase in the adoption of mass timber to meet sustainability goals, however there are a number of concerns regarding the safety and resilience of mass timber buildings. They seek assurance that these concerns are fully considered, and design measures are put in place so that risks are satisfactorily mitigated.

REAL ESTATE SECTOR
RISK MANAGEMENT GUIDANCE

2017
- STA:16 Steps to fire safety

2019
- BMTrada: Learning resources, introduction to timber engineering design, moisture and humidity

2020
- STA: Structural timber buildings fire safety in use guidance Volume 6

2022
- STA: Moisture Management Strategy
- RDH Building Science: Moisture risk management strategies for mass timber buildings, 2022, Version 2.1
- STA: Technical Note 24 - Moisture protection during construction
- Swedish Wood: Moisture-proof CLT construction without a full temporary shelter

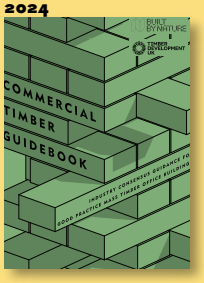
2023
- WTA: New Model Building (residential)

2024
- Arup: Fire Safe Design of Mass Timber Buildings
- TDUK: Moisture Management During Construction

BRIDGE DOCUMENTS
HELP CLOSE THE GAP

2023

2024



INSURANCE SECTOR
GUIDANCE TO COMMUNICATE INSURANCE SECTOR'S VIEW ON RISK

2022
- RISCAuthority: Insurance Challenges of Massive Timber Construction
- FPA: Joint Code of Practice: Fire Prevention on Construction Sites

2024
- Allianz: Emerging Risk Trend Talk 2
- Aviva: Mass Timber - Considerations for Planning & Design (RIBA Stages 0-4)

HOW CAN THE GUIDEBOOK HELP INSURANCE?

The Guidebook helps to enhance insurer confidence and promotes long-term property safety and durability by demonstrating good practice guidance for mitigation of moisture and fire risks in mass timber buildings. This will be viewed positively by the insurance sector.

The Guidebook aims to cover all the stages of a construction project from initial design through to post-occupancy, highlighting key risks and how these can be considered at the design stage, during construction, and during the use of mass timber buildings.

The CTG sits alongside the Mass Timber Insurance Playbook (MTIP). The MTIP provides a framework for understanding the perceived risk challenges that hinder developers acquiring an insurance provision for mass timber buildings. The CTG provides the technical guidance to address and mitigate against these durability and fire risks.

WHO PRODUCED THE GUIDEBOOK?

Core team

The Guidebook has been produced by a collaboration of leading industry experts from Waugh Thistleton Architects, Elliott Wood, OFR Consultants, and Lignum Risk Partners, combining their collective expertise in engineering, architecture, fire safety, and risk management to provide comprehensive guidance on mass timber construction. The core team has engaged with the insurance markets and the design and structural engineering experts and incorporated their feedback into the Guidebook. Refer to the appendix for more information on the core team.

Fire consensus

To develop this Guidebook, an expert fire panel consisting of leading academics and consultants was established. These experts, experienced in the development and review of fire safety designs, particularly in commercial mass timber buildings, worked together to reach a consensus on fundamental fire design principles. The aim of this panel was to address the perceived inconsistency in fire design across the industry, and to provide a unified approach that enhances trust and confidence in the fire safety and asset protection of mass timber buildings.

A series of fire workshops conducted between August 2023 and May 2024 facilitated iterative discussions among the expert fire panel, leading to a consensus on the 10 fire principles outlined in Section 5.4. The significant coordination and effort invested in this process were aimed at advancing industry standards and building insurer confidence in timber construction.

The expert fire consensus panel for the principles comprised of Design Fire Consultants, Hoare Lea, OFR Consultants, Semper, UCL (Jose Torero), and University of Edinburgh (Luke Bisby). Note that the 'fire consensus' relates to the 10 fire principles only.

WHO IS THE GUIDEBOOK FOR?

Insurers

The CTG serves as an aid to ongoing dialogue with the insurance industry. It is intended to reassure insurers that good mass timber design has properly considered the perceived risks of insurers and includes appropriate mitigation measures. It also covers the remediations (repairs and reinstatements) that could be required in a building's natural lifetime. The CTG responds to key design challenges and insurance considerations that are outlined in the MITP.

Developers and asset owners

The CTG can be used by developers and asset owners in discussions with insurers, as set out in the MTIP. There is guidance on in use and maintenance of mass timber buildings which serves to continually mitigate risks during the natural life of a building, together with remediation measures should they be required.

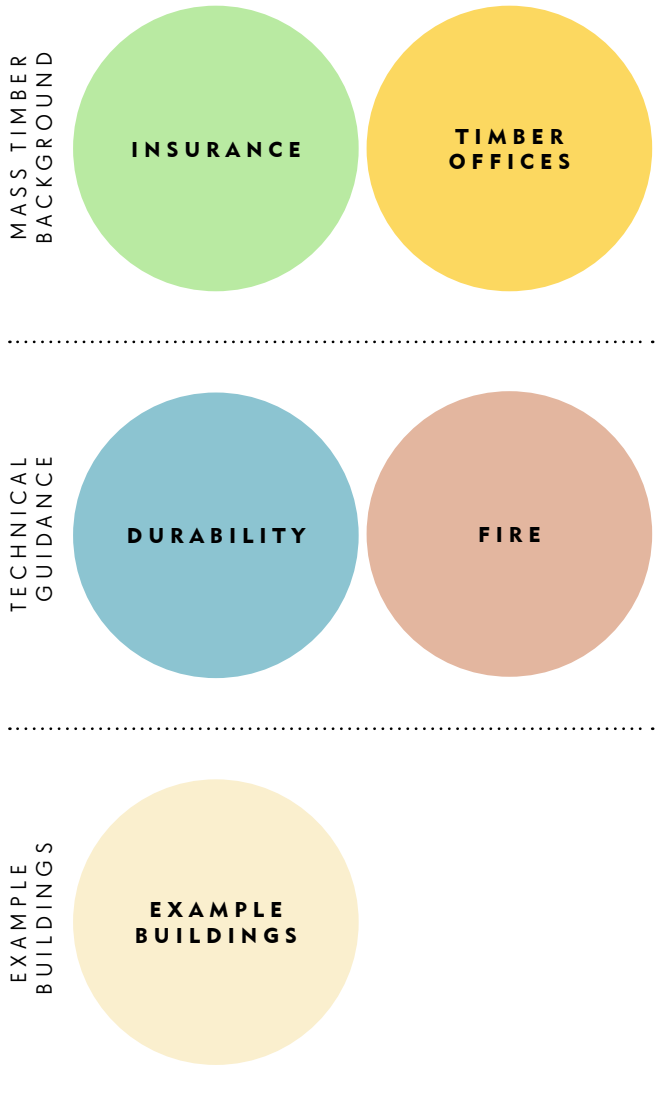
Designers

The CTG is written primarily for designers with the purpose of addressing specific concerns of the insurance industry in relation to mass timber constructions. The Guidebook provides technical guidance, a framework of design considerations and principles for different building typologies that can be applied by competent consultants to exercise good practice in design and risk mitigation.

THE GUIDEBOOK STRUCTURE

The Guidebook is aimed at and will solely focus on commercial (office) buildings where mass timber construction is used, to demonstrate to insurers good practice design and risk mitigation guidance.

It is not expected that the whole of the Guidebook will be relevant to all parties due to differences in expertise. The Guidebook is separated into three parts, Mass Timber Background, Technical Guidance and Example Building Typologies.



MASS TIMBER BACKGROUND

Insurance
This chapter provides context for mass timber buildings from the perspective of the insurance sector along with a summary of current risk guidance documents and where both the construction and insurance sectors have been able to learn from experience when designing mass timber buildings.

Timber Offices
This chapter provides a general overview of timber office buildings. The chapter discusses the types of engineered timber that are commonly used in mass timber buildings and outlines architectural and structural considerations that influence the design of large office buildings.

TECHNICAL GUIDANCE

The technical design guidance forms the majority of the guidebook and is written primarily for designers. The scope of the CTG has aimed to cover relevant information for mass timber buildings to address the significant risk areas for mass timber buildings.

Durability
This chapter focuses on how mass timber's durability is affected by moisture, outlining the risks associated with water damage and providing strategies for mitigating these risks to create robust, durable buildings.

This includes technical guidance on:

- The properties of timber relating to moisture and durability and specifying appropriate materials.
- Highlighting key risk areas and how these can be mitigated in the design phase, construction phase, and in use phase.
- Guidance on the remediation process if mass timber is damaged by water.
- A set of durability principles that can be adopted by designers to demonstrate good practice relating to identification of risks, risk mitigation measures and remediation strategy.

Fire

This chapter focuses on how the use of mass timber impacts fire safety requirements, the additional hazards that a combustible frame introduces and how these can be addressed.

This includes technical guidance on:

- The goals and objectives that may form part of a fire safety design, including the minimum statutory goal of life safety and how fulfilling this goal may contribute to property protection and business continuity goals.
- An overview of the burning of wood and its implications on the fire hazards within a building.
- A set of proposed principles that can be adopted by designers to demonstrate the adequacy of the fire safety design in a commercial timber building.
- Discussion on the anticipated implications of these principles in the fire safety design of a commercial building, and on the potential benefits for property protection and business continuity by addressing the proposed fire principles.

EXAMPLE BUILDINGS

The technical guidance in the Guidebook will allow design teams to establish good practice and appropriate durability and fire safety provisions for mass timber buildings they are designing.

This chapter presents an appraisal of four mass timber commercial building examples, highlighting fire safety and durability considerations for each, based on the principles established in the technical guidance in the Guidebook.

The following building typologies are considered:

1. Full timber offices below 18 meters, up to 4 storeys.
2. Full timber offices between 18 and 30 meters, up to 15 storeys.
3. Hybrid offices between 18 and 30 meters, up to 15 storeys .
4. Hybrid offices over 30 meters or over 15 storeys.

These examples serve as practical models to guide designers, developers, and insurers in applying good practice design and risk mitigation strategies in terms of fire safety and durability. The use of the guidelines provided do not replace the need for design and calculations by responsible and competent designers.

2. INSURANCE

Following the Guidebook will not guarantee the availability of any insurance or guarantee the treatment of any particular insurance claim. Rather, following the Guidebook's principles and recommendations is intended to improve the project's risk profile in the eyes of an insurance underwriter, and can help to reassure them that it is a more insurable risk. In turn, this is intended to lead to more sustainable terms and premium rates. Whilst the Guidebook is not intended to provide insurers, their loss adjusters and legal advisers with a benchmark against which any claims can be measured, it is possible that it may be consulted for its consensus of contemporaneous good practice.

Mass timber is a relatively new construction technology in a complex, regulation-driven industry. The primary risks associated with it are fire and water damage, which can impact safety and cause costly damage. While the insurance industry is still developing experience and data around these risks, efforts by the construction industry to reduce time and cost in mitigating fire and water damage will aid long-term sustainability.

This guidance aims to inform ordinary good practice according to the consensual opinions of the authors of the Guidebook. It promotes risk mitigation strategies for future mass timber construction, reinforcing the essential role of insurance in supporting innovation and sustainability.

FOCUS

This chapter discusses the relatively recent adoption of mass timber in UK construction and the associated risks, particularly fire and water. It also summarises the insurance industry's current position on the use of mass timber in the UK.

KEY THEMES

The insurance industry currently has insufficient access to loss data and technical development dialogues. This restricts the availability of and impacts the cost of insurance for mass timber buildings in the UK.

Following the Guidebook's principles and recommendations is intended to improve the project's risk profile in the eyes of an insurance underwriter and help to assure them that it is a more insurable risk.

The insurance industry wishes to support the UK construction sector in the use of mass timber and encourage continuing dialogue to mutual benefit.

CONCLUSIONS

The insurance industry encourages more collaboration between contractors, designers and insurers to share knowledge, data and experience.

The insurance industry welcomes all initiatives that help to increase adoption of ordinary good practice in the use of mass timber.

CHALLENGES OF INSURING MASS TIMBER BUILDINGS

Insurance is an economic necessity, without which innovation, development and progress in everything that supports society would be hampered by the inability of business or government to take the risk of doing anything new. Investors and developers wanting to promote and incorporate mass timber construction often find that the insurance sector is unable to offer insurance that meets their commercial requirements, partly due to insufficient statistical data and partly due to the use of timber being a comparatively new risk in the UK insurance market.

The insurance industry does acknowledge the requirement for an increase in the adoption of mass timber if environmental targets and net zero ambitions are to be met, however there are a number of concerns regarding the safety and resilience of mass timber buildings. They seek assurance that these concerns are fully considered, and design measures are put in place so that risks are satisfactorily mitigated.

Within the long history of construction, mass timber is a relatively young technology. In the UK, the 21st century building industry and insurance sector remains generally unfamiliar with the dynamics and properties of modern mass timber as an increasingly dominating feature of the modern built environment, which is a much more complex and regulation-driven environment than when timber was last the dominant building resource.

There are two primary risks deriving from mass timber construction; fire risk and water damage risk. There are two principal hazards deriving from fire and water risks: safety to human life and the costs resulting from the loss of amenity of a property damaged by fire or water and the reinstatement or remedial cost of the property itself. The insurance industry is required to bear the majority of the burden of these risks and in the early 21st century the insurers do not yet have the reliable long term statistical evidence of the ultimate cost of loss and damage from this source, nor do they have an experienced resource for the remedial works necessary to put the property back into its pre loss condition.

The UK insurance sector's brokers and insurers are generally supportive of the use of mass timber in the UK. They recognise that increased use of mass timber across the world is an imperative and an enabler to support the construction industry to meet – and to continue to meet - its required net zero commitments. They also recognise the need to meet their own net zero commitments and agree that deploying underwriting capital into mass timber supports their and the construction sectors' needs. With that comes an appreciation that the use of mass timber will increase. The biggest challenge the insurance sector faces is their own nascent knowledge and the small amount of data available to them compared with more well-known building materials. The comparative lack of data makes it harder for insurers to assess, quantify and underwrite the risk, hence the higher premium rates and less commercially sustainable terms that they currently require. They therefore would welcome more collaboration between contractors, developers, insurers, brokers and risk advisers to share new learning possibilities, acquired knowledge and even to create an industry wide knowledge database for the benefit of all those involved in the use of mass timber. The insurance industry's view of the use of mass timber in commercial buildings has evolved over the last two years from slightly anti/neutral to neutral/positive. There is more work to be done by all parties but it would appear that there is now a desire to support greater adoption of the use of mass timber in the UK from the insurance sector.

Everything that the construction and property investment community can do to contribute to the reduction in time and cost of remediating reinstating and mitigating the losses, deriving mainly from fire and water perils, will contribute to the long-term sustainability of insurance products and services to support the continued innovation in the mass timber sector. Insurance is essential in the continued innovation and development of the future built environment.

RISK AND RISK GUIDANCE DOCUMENTS

Driven by the necessity to rapidly decarbonise the built environment, over the past few years a sector of the

industry has prioritised learning and swiftly enhanced its knowledge and expertise in mass timber, and also its understanding about the potential design, construction and use pitfalls.

This growing expertise in the construction industry is evidenced by collectively produced guidance: documents such as 16 Steps To Fire Safety (2017)[1], Structural timber buildings fire safety in use guidance, Volume 6 (2020)[2], Moisture management strategy (2022)[3], all by the STA, and the Mass Timber Insurance Playbook (2023)[4]. Signposts to key documents are given in Section 7.3. This Guidebook is the latest collective industry guidance document representing the consensus of the mass timber buildings design experts. Some companies have also published individual company guidance documents such as Arup's Fire Safe Design of Mass Timber Buildings (2024)[5], which is a useful document sitting along this Guidebook and allows designers to make more informed decisions based on risk and a useful summary of relevant research and the 'New Model Building' (2023)[6] design guide for residential buildings by WTA.

The insurance industry itself has also recently produced documents such as The Insurance Challenges of Massive Timber Construction (2022)[7] and Joint Code of Practice: Fire Prevention on Construction Sites (2022)[8], both authored by the RISCAuthority / FPA, as well as guidance documents drafted by individual companies such as Allianz's Emerging Risk Trend Talk 2 (2024)[9]. Signposts to key documents are given in Section 7.3.

This Guidebook is the latest collective industry guidance document representing the consensus of the mass timber buildings design experts in what constitutes ordinary good practice.

LEARNING FROM EXPERIENCE

The sector has learnt from the relatively small number of loss events, many of which the Guidebook's authors have been able to closely study. The Guidebook's content reflects this built-up knowledge.

Of the comparatively few loss events specifically associated with mass timber construction, even fewer have been publicised, with only one notable loss involving an impact to the mass timber structure. In 2014 the University of Nottingham's GSK Laboratory was destroyed during construction from a fire caused by an electrical fault. Guidance documents that cover the risks exposed by this event include the STA's 16 Steps to fire safety Promoting good practice on construction sites (2017) and the Fire Protection Association's Fire Prevention on Construction Sites (2023). Relevant risk-mitigation measures, during construction, in this case include prioritising the completion of fire compartments including fire doors and fire stopping and installing sprinklers if and where required.

Although moisture-related losses are more frequent and make up the bulk of insurance payouts, these tend not to be publicised, and we are unable to list these here.

In two recent high-profile loss events involving moisture and fire respectively, the mass timber structure played neither a role in, nor was it impacted by, the loss. The first example is at Sky Central in London, from 2014 onwards. The building suffered moisture ingress during construction which resulted in damage to the timber cassettes set in the glulam roof (not the glulam itself). The STA's Moisture management strategy, Process guidance for structural timber buildings (2022) covers this risk. The second example is the Wood Innovation Design Centre in Prince George, Canada, which suffered a loss in 2024. The building's timber cladding was damaged by a fire caused by a blast following a ruptured gas line in an adjacent building. The extent of the subsequent fire was limited by the building's non-flammable insulation-filled external wall void and its sprinkler system. In fact, the damage was mitigated by the flexible glulam structure which allowed the building to bend and absorb the shock of the blast, preventing potentially even greater damage.

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3. TIMBER OFFICES

Despite the difficulties outlined in the introductory chapter, during the past two decades, the timber construction sector has seen a steady increase in the number of commercial buildings being built around the world.

Timber offices have been proven to generate significant environmental and financial benefits throughout their life cycle and have become symbols of environmental awareness in architecture.

Beyond the environmental benefits of timber, mass timber buildings are valued for their attractive aesthetics and the biophilic benefits they provide. These have been shown to enhance creativity, productivity, and employee satisfaction—particularly important in the post-pandemic workplace.

While timber buildings are perceived as more expensive than traditional concrete or steel structures, a recent study found the cost difference can be minimal. When factors like faster construction, lighter materials, and high prefabrication are considered, timber could become the more cost-effective choice.

FOCUS

This chapter outlines key architectural and structural factors that influence the design of mass timber office buildings, such as the choice of structural system, materials, and the organisation of core and service areas. Careful consideration of these factors can influence the resilience and robustness of the completed building.

KEY THEMES

- Types of engineered timber
- Key general design aspects

CONCLUSIONS

This chapter offers guidance on mass timber office buildings and the general design considerations that need to be considered. A building that is designed with the aim of maximising adaptability and space efficiency should consider the following design aspects.

- Building form
- Structural system
- Materials
- Structural grid
- Service distribution
- Core design

3.1 TYPES OF MASS TIMBER

Mass timber is the name given to types of engineered timber that can be used as structural building materials. Mass timber components are made from small planks or layers of timber bonded together to increase their strength and form load-bearing components such as panels, beams and columns. This Guidebook focuses on three most commonly used types of mass timber.

Cross laminated timber

Cross laminated timber (CLT) is manufactured by combining multiple layers, or lamella, of timber with abutting layers stacked such that the grain orientation alternates 90°. CLT is commonly used for floor structures and walls.

Glulam

Glulam, also referred to as GLT, is similar to CLT in that layers of timber are combined; however glulam differs from CLT in that all layers have the same grain orientation. Glulam is commonly used in applications where a large span is required, such as roof joists, beams, and columns.

Laminated veneer lumber

Laminated veneer lumber (LVL) is again constructed similarly to the aforementioned types of engineered timber, being made up of multiple layers. However, LVL is manufactured from considerably thinner layers frequently under 3mm in thickness. LVL is commonly used for similar applications as Glulam.

Types of adhesive

Typically melamine or polyurethane based adhesives are used in the manufacture of engineered timber products, which may lose adhesion at different temperatures. Non heat-resistant adhesives are common for low risk buildings where fire will not affect the bond line. Heat-resistant adhesives maintain bond integrity during fire and are best suited for higher-risk buildings where auto-extinction is necessary.

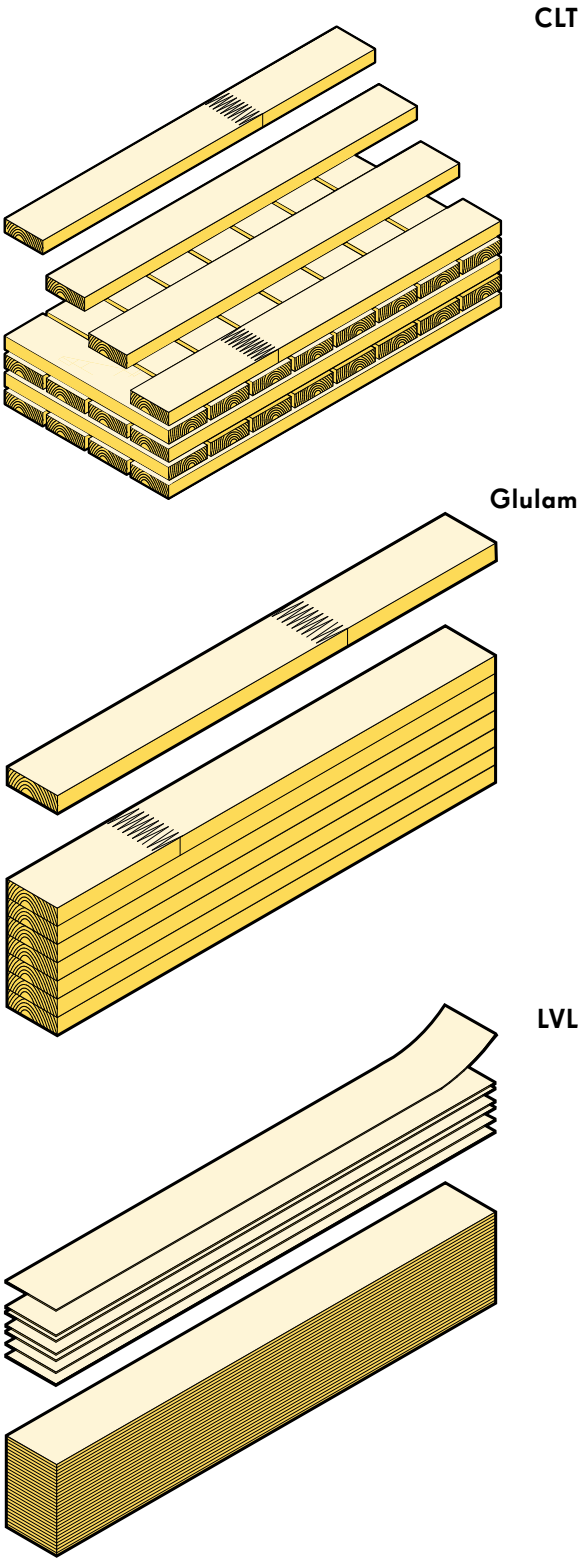


Figure: The three main types of mass timber

3.2 KEY GENERAL DESIGN ASPECTS

This section outlines architectural and structural considerations that influence the design of large office buildings (eg choice of structural system, materials, core and service distribution design), with the aim of maximising:

Adaptability: the ability to change functional and spatial arrangements to suit changing circumstances, thereby increasing the financial resilience of an asset.

Space efficiency: maximising usable space, a parameter that is particularly important in buildings seeking to increase their financial value through the quantity and quality of space they are able to offer.

These key design aspects are then used to inform the examples provided within Section 6 example buildings.

BUILDING FORM

With regards to massing, prismatic, regular building shapes are widely used because they are both simple and suited to maximise space efficiency, structural stability and adaptability.

Prismatically shaped office buildings offer:

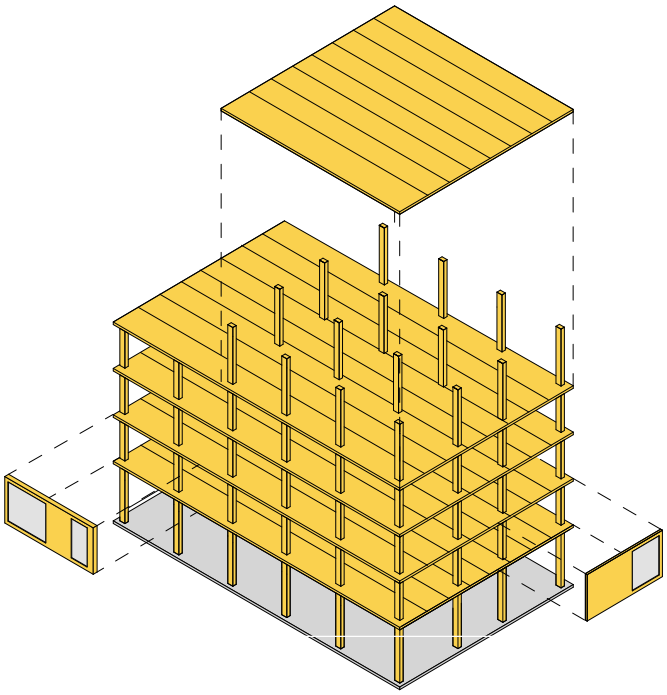
- Uniformity and repetition of internal spaces (structural bays) simplifies the organisation of open plan work-spaces.
- Maximised natural light and ventilation for work-areas.
- Uniform escape distances to lifts/cores, especially if these are positioned centrally.
- Simple form that mitigate complexities in a building's design and assembly, lowering the potential for errors and delays and allowing for compatibility with existing off-the shelf products and construction techniques (eg non-structural prefabricated, façade materials or internal separation walls etc).
- The opportunity for repetition and modularity: design approaches that both optimise the use of building components.

STRUCTURAL SYSTEM

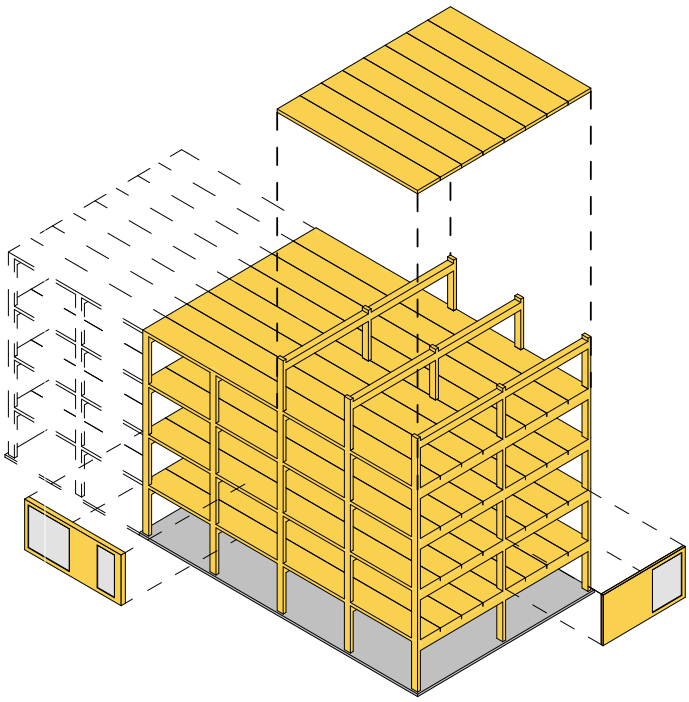
Mass timber buildings can be formed by one-dimensional (post and beam or post and slab type), two-dimensional (platform type) structural elements, or by three-dimensional components (volumetric modular) which are composed of off-site, pre-fabricated walls and floors, plus a series of combinations of these three basic configurations.

Although contemporary multi-storey timber construction presents a variety of forms and spatial configurations to meet different contextual, regulatory and design requirements, a common thread seems to be the choice of structural system which maximises the adaptability of internal spaces to meet tenants needs.

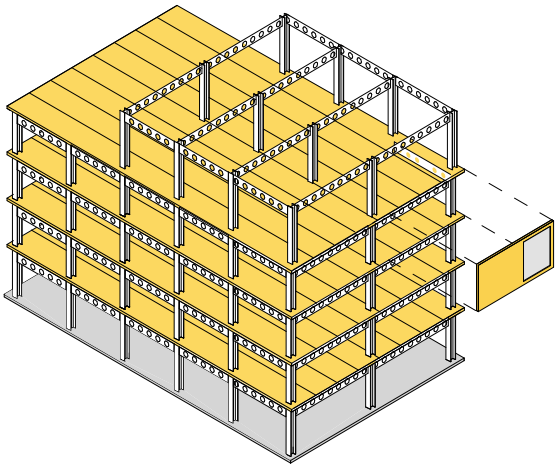
Like steel and concrete, large timber office buildings are typically frame structures which are defined as post and beam structural systems. These one-dimensional, column-based structures allow for adaptable, open-plan layouts that are easy to organise and reconfigure, with the only permanent obstacles being the load-bearing structure, cores (with their vertical and horizontal circulation and service distribution routes) and possibly some functional areas (wet and high load areas). Furthermore, in post and beam structures, the building envelope has no structural function and can therefore be dismantled and replaced as required.



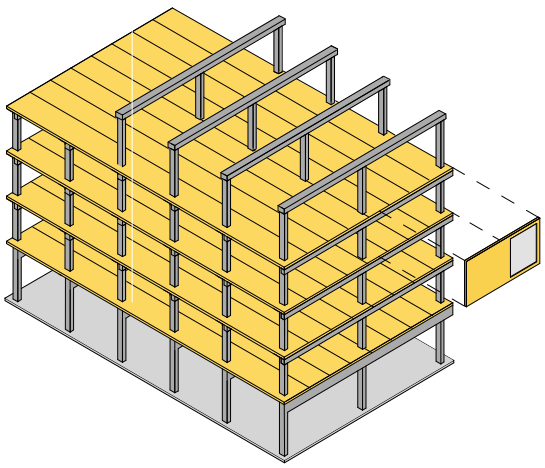
POST AND SLAB
with Prefabricated Façades



POST AND BEAM
with Prefabricated Façades



HYBRID
with Steel Primary Structure



HYBRID
with RC Primary Structure

Figure: Mass timber building systems

MATERIALS

The structural design commonly used in mass timber office buildings fall into two categories: full timber and hybrid (concrete/timber or steel/timber).

In full timber structures the entire superstructure including the building's core/s are exclusively made of engineered timber; materials other than timber are used only in the substructure and in the ground floor slab.

In hybrid structures large part of the superstructure is made of materials other than timber, such as steel, reinforced concrete, or a mix of both. This type of structure generally makes use of concrete or steel both for columns, beams and core/s, with the use of timber confined to floor plates (made of CLT, composite RC/CLT or RC/GLT) and separating walls.

The hybridisation of timber with other materials can enhance its structural, acoustic and vibrational performance, particularly in larger structures with longer spans.

STRUCTURAL GRIDS

Property agents, building owners and investors expect office spaces to have a good spatial efficiency and large, adaptable column free spaces that can easily be reconfigured. These expectations emphasise the importance of selecting an optimal structural grid. For mass timber buildings, it is crucial to design the most efficient span for the structural timber frame from the beginning of the project to meet these requirements effectively. Trying to force timber into structural grids originally conceived for traditional building materials such as steel and concrete can lead to material inefficiencies.

The structural grid dimensions (together with building height and structural material choice) influence the number and size of every system component. Considerations such as standard product sizes, transport, site logistics, construction speed, and material efficiency should be integrated with the overall spacial design.

This Guidebook assumes a 9x6 metre grid for the office buildings in the Illustrative Examples in Section 6. This grid has been chosen for material optimisation and embodied carbon reduction, making it an efficient and sustainable choice. It is worth noting in this context that the 2023 update of the British Council for Offices (BCO) Key Design Criteria, has acknowledged the benefits of using 6-7m structural grids, balancing carbon reduction with the desire for efficient, column-free spaces. This approach prioritises sustainability alongside spatial efficiency.

Structural grid sizes and layouts must be planned alongside services distribution from the early stages of the project. This coordination is vital for achieving a holistic design approach in mass timber construction.

CORE DESIGN

A core is a vertical distribution space for the circulation of building users and services, containing stairs, lifts, services risers, bathrooms or WC's.

In typical post and beam type mass timber structures, the core often also fulfils a structural function, providing lateral stability to the entire structure. The location, number, size and material (CLT or LVL, concrete or steel framed) of these cores is primarily determined by a building's use, height, occupancy and the consequent fire escape distances.

Cores can be classified into two main categories: in-grid and site-adaptive. In-grid cores are aligned with the building grid and occupy one or more structural bays (central, atrium and peripheral cores). In contrast, side-adaptive cores function outside of the structural grid, enabling a regularly shaped building to adapt to the irregularities of a real-world site. This is achieved by connecting or infilling the irregular shape between regular forms.

Recent research has highlighted the prevalence of central core configurations in timber office buildings: a strategy that maximises both structural robustness and space efficiency. This allows a large number of users to be accommodated along a building's perimeter, increasing

access to natural light and views. In addition, central cores facilitate fire evacuation procedures and logistics.

By centralising the core, designers consolidate load-bearing elements and streamline vertical circulation; this approach also ensures optimum use of materials and overall structural stability and safety. This optimisation is not just about structural and spatial efficiency, but also about a more adaptable environment capable of accommodating a wide/changing range of functions.

SERVICES DISTRIBUTION

Proper coordination of mechanical, electrical and plumbing (MEP) services with the building structure is essential, particularly in mass timber office buildings. Avoiding MEP routing holes improves the structural performance of building components and ensures flexibility for future service modifications.

Service design is influenced by building occupancy, layout and bay depth and height targets. For this reason, many early design decisions deeply influence the MEP strategy. For example, the choice between natural and mechanical ventilation has a significant impact on massing height, core layout roof and façade design. This is why the early appointment of a services engineer is essential. It is beneficial if they have a clear understanding of 'plug and play' systems and can provide detailed construction information rather than performance specifications.

Most mass timber office buildings use cores for vertical distribution while the soffit of service and distribution corridors surrounding the core accommodate their horizontal distribution without compromising the clear heights of workspaces. These distribution corridors present a relatively short span (approximately. 3 to 4.5 m grid depth), and consequently a shallow structural beam depth (potentially even a localised post and slab arrangement) that creates a deeper service zone containing primary service distributions such as ventilation ductwork and electrical cabling.

Experience shows that this ceiling zone requires a free depth of approximately. 500 mm and that horizontal service runs each serve a zone of a maximum of six bays each without relying on additional vertical risers. This services distribution strategy facilitates future adaptation as office-bays can easily be upgraded or downgraded should heating or ventilation requirements change, furthermore, it is compatible with all office typologies.

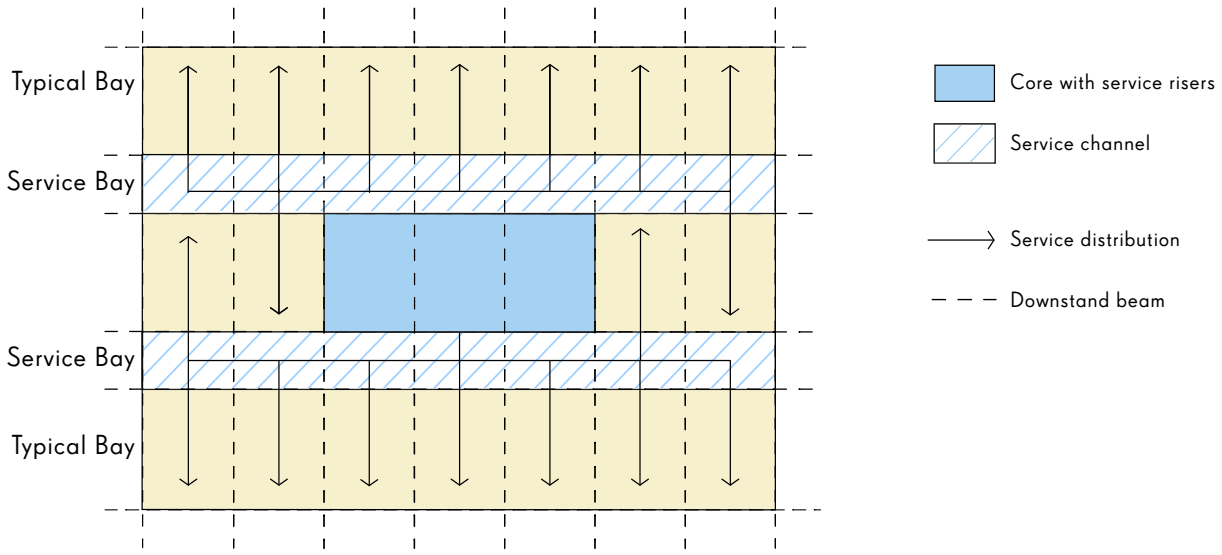


Figure: Services distribution in different core arrangements

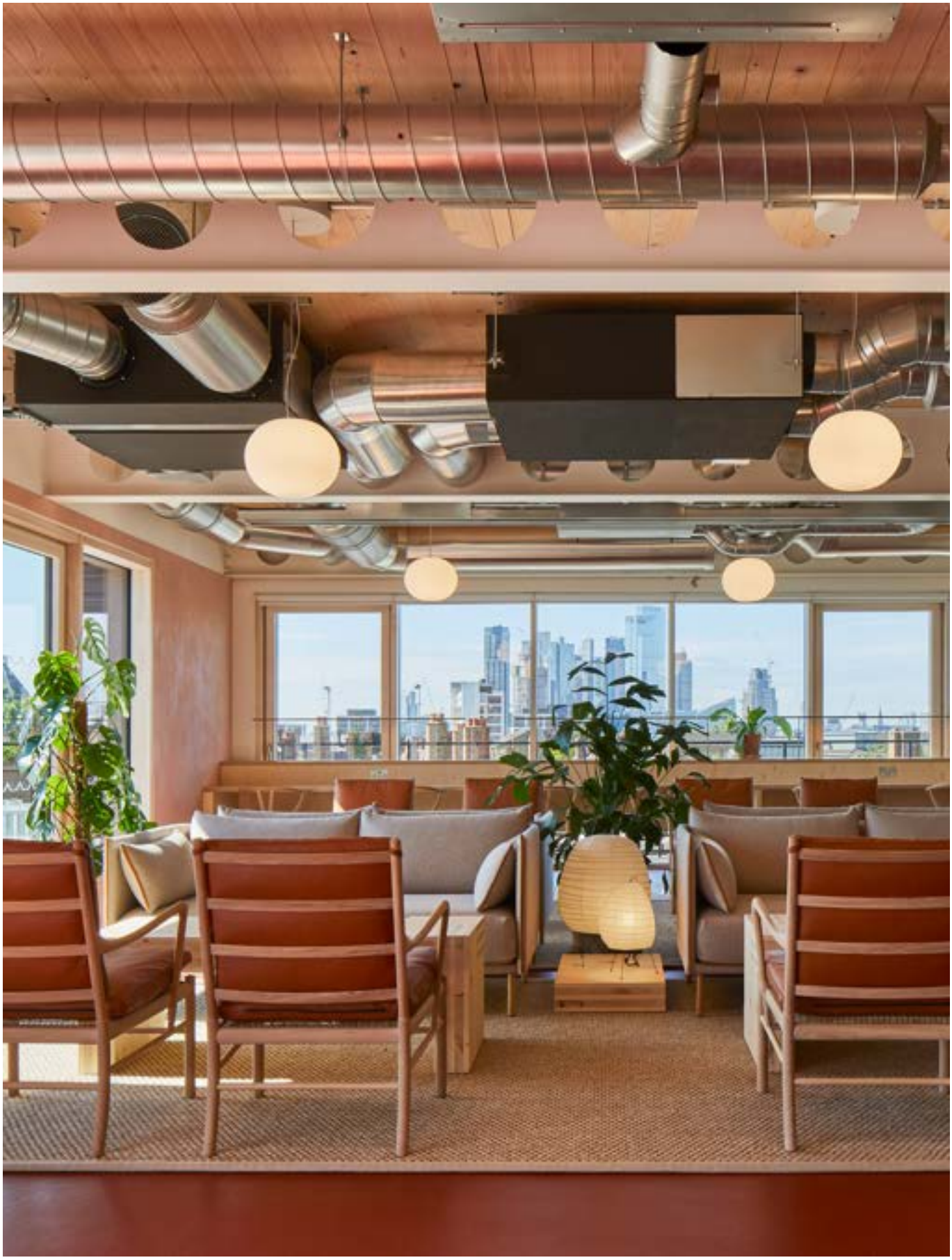
A top-down service distribution delivering ventilation and lighting is usually supported by raised access floors of at least 150mm deep, allowing underfloor bottom-up service distribution for low voltage power and data cabling as wireless technology improves the depth of the service void will likely decrease.

Ceiling mounted services are often left exposed, affecting their specification (aesthetic appearance should be considered) and layout within the ceiling space. However, their installation is easier in 'soft' timber substrates compared to concrete. Prefabricating service distribution runs potentially combined with timber or hybrid floor slabs can streamline installation by enabling them to be installed as single elements.

ADAPTABILITY

The adaptability of a building refers to its capacity to adjust to changing spatial, functional, and financial needs, thereby maximising its value during its intended lifespan and potentially beyond. Adaptability can delay, if not eliminate, obsolescence and the resulting demolition of a built asset. The key factors that enable adaptability in office buildings are:

- Minimising the structure and separating it from the building envelope and internal layouts allows for a flexible design. This loose fit approach supports adaptable and spatial partition systems, enhancing future reconfigurability and functionality of the space.
- A kit of parts design strategy enables buildings to be expanded or modified over time, with standardised, repeatable components. This approach supports flexibility, allowing for changes in the main structure (eg creating double height spaces or new floor connections) and simplifies repairs through the easy replacement of standardised parts.
- A well thought out structure-service coordination that enhances spatial adaptability by optimising floor to floor heights in critical areas and allowing for potential future spatial re-configurations
- The choice of materials - such as timber - which are left exposed for their aesthetics, durability and sustainability credentials, not only enhance the value of the space but also help to reduce the environmental impact of the building
- Overall simplicity, achieved by reducing the number and variety of building components while increasing the repetition of grids and layouts, creating easily understood, interchangeable and adaptable structures and spaces.



4. DURABILITY

Timber is unique among mainstream building materials as it can be completely renewable. Sourced from well-managed forests, it can be replenished, making it a sustainable choice for modern construction. Alongside its renewability, timber offers several other key benefits. It is safe to handle, visually appealing, and provides excellent thermal insulation. With a high strength-to-weight ratio, it is both strong and lightweight. When properly specified, detailed, assembled, and maintained, timber can also be extremely durable.

However, the durability of timber largely depends on how it is used and protected, particularly from moisture. Through proper design, detailing, and maintenance, timber structures can stand the test of time, combining sustainability with long term durability.

FOCUS

This chapter focuses on how mass timber's durability is affected by moisture, outlining the risks associated with water damage and providing strategies for mitigating these risks to ensure long-term performance.This chapter will set out the following:

- The properties of timber relating to moisture and durability and specifying appropriate materials.
- Highlighting key risk areas and how these can be mitigated in the design, construction, and in use phases.
- Guidance on the remediation process if mass timber is damaged by water/moisture.
- A set of durability principles that can be adopted by designers to demonstrate good practice relating to identification of risks, risk mitigation measures and remediation strategy.

KEY THEMES

- Timber Properties: Moisture and Durability
- Risk Mitigation Guidance
- Water Damage Remediation Guidance
- Durability Principles

CONCLUSIONS

This chapter offers detailed and comprehensive guidance about the challenges, mitigation, and remediation strategies for designing durable and robust mass timber buildings. This is summarised in the following key principles:

- Understand material properties
- Specify appropriate materials
- Risk identification
- Consider repair and maintenance
- Keep timber dry
- Early intervention
- Moisture management in assembly
- Remove critical vulnerabilities
- Durability risk analysis
- Repair and remediation strategy

4.1 MOISTURE AND DURABILITY

Durability is generically defined in ISO Standards as "the ability of a constructed asset or any of its components to perform its required functions over a specified period of time without unforeseen maintenance or repairs" [1].

In simple terms, durability defines the longevity of a material or product. Any material used in a building should ideally be as durable as the building itself, typically 50 years, which is the medium working life of a typical structure (as defined in Eurocode EN 1990). Most timber products refer to working and service life in their European Technical Assessment (ETAs) and Environmental Product Declaration (EPDs).

In the context of timber and engineered timber products, durability also pertains to their resistance to moisture induced mould or fungi, specifically in regions of temperate climate.

Overall, the durability of a timber building is most affected by:

- Moisture (in its various forms).
- Incorrect specification of the material for its given environment.
- Incorrect detailing, installation and maintenance procedures.

Long-lasting durability is a function of:

- An environment where temperature and humidity, the main variables of timber's moisture content, are given proper recognition (Service and Use Classes).
- A correctly specified material.
- Correctly carried out design, installation, maintenance (and possibly replacement procedures).

A typical design team should keep account of buildability, cost and time/programme implications but also adopt the following durability measures:

- Identify areas of risk and predict potential weak points and damage level.
- Mitigate damage with a coordinated risk management plan.
- Be aware of damage repair measures (remediation).

As further discussed by the STA: "the industry does not establish roles and responsibility for durability, leading to confusion and ignorance of moisture management in the process of commissioning a new building"[2]. It is imperative for these responsibilities to be clearly defined for each project workstage to preempt any potential durability related issues. There are other durability concerns for timber, such as insect infestation, but this piece of research focuses solely on issues related to water and moisture, as these pose the most significant risk to timber buildings.

Other than structural errors, approximately 90% of all building construction problems are associated with water in some way[3].

Common Perception:
Timber buildings will always decay and so have a short useful life.

Reality:
Properly designed, constructed, and maintained timber buildings can be just as durable as those made from steel or concrete. When moisture is managed effectively, timber can last indefinitely.

All buildings, regardless of material used, will develop moisture or water related issues at some point in their life. This can include the corrosion of metals, loss of bonding between the steel and concrete in reinforced concrete, damage to plasterboard through dissolution, cracking of masonry and concrete caused by freeze-thaw cycles, and the decay of wood-based materials[4].However, timber is more susceptible to this type of damage because it is both hygroscopic (porous) and anisotropic, meaning it has different material properties in different loading directions. Regardless, a properly designed, constructed and maintained timber building will last a long time.

Moisture is not a risk to timber so long as it can dryout, however timber tends to get wet faster than it can dry. If it is exposed to water for a long time, it will absorb it and become saturated, leading to issues including staining, mould growth, dimensional changes, and eventually decay; the severity of which is proportional to the duration of exposure and the moisture content[5].

This is important for designers, contractors and insurers because in modern timber structures, particularly office buildings, timber is often left exposed, making even minor imperfections in the timber unacceptable.

These issues can be prevented by understanding the properties of wood and implementing a comprehensive moisture management strategy throughout the entire lifespan of a timber building. While it is widely recognised that the construction phase carries a high risk of water damage, the occupation phase—where water leaks or ingress can also cause significant damage—is often overlooked. To increase a building's resistance to moisture damage and extend its lifespan, it is important to consider durability from the early stages of design through construction and handover. This includes implementing risk mitigation strategies as well as planning for repair and maintenance.

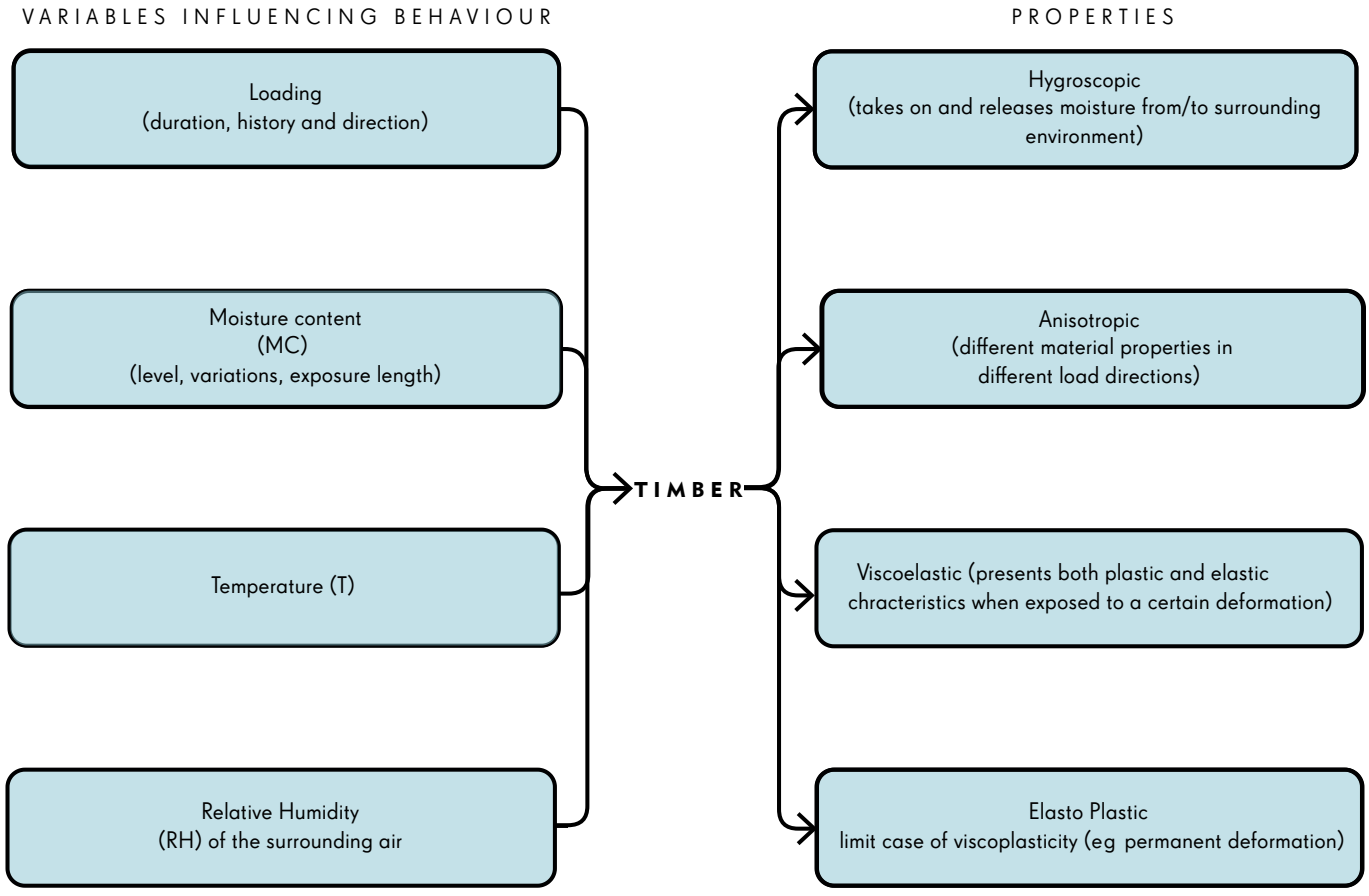


Figure: The effect of environmental variables on timber

SERVICE, USE CLASSES AND TIMBER DURABILITY

When specifying wood components, it is vital to understand their durability characteristics, service, and use classes: key indicators of the correct use and expected service life of engineered wood products.

Service classes

Service classes (SC) describe the environmental conditions (temperature and relative humidity expected to prevail in service) affecting the moisture content in timber products exposed to them (see relevant table adapted from EN 1995-1-1 Eurocode 5).

- SC_1 covers timber products situated within the building envelope in spaces that are generally heated, and not exposed to external moisture and temperatures, a space where the timber is kept at a moisture content of 12% or less.
- SC_2 timber is expected to be exposed to external moisture and temperatures, but not wetting.
- SC_3 portrays a condition where timber is external, fully exposed to large variations of moisture and temperature.

During the design process, the service classes for different structural components should be identified. This will then inform the material specification; materials chosen must be suitable for use within the relevant service class, and appropriate durability strategies and details should be provided.

Use classes

Use classes (UC according to BS EN 335:2013) are conceptually similar to service classes but fulfil a different function; they offer a guide to the vulnerability and decay risk of timber products.

BS EN 335:2013 defines five use classes for different environmental exposures for solid wood and wood-based products. For each use class, the standard indicates the biological agents relevant to each instance of exposure. The use class describes the fitness for purpose of a product for a particular environment that can be achieved either through natural durability or through a preservative treatment, or a combination of both.

Timber durability

Every timber species can be classified based on its natural durability (according to EN 350-2) on a scale from 1 to 5 (1 being very durable and 5 non-durable). Larch, Pine, and other species commonly used for mass timber are all class 4: slightly durable[6].

SERVICE CLASSES INFORMATION

Service Class	Temperature	Approx RH*	EMC**	Example from the UK National Annex to Eurocode 5
1	20 ° C	65%	12%	Warm roofs, intermediate floors, timber-frame walls - internal and party walls.
2	20 ° C	85%	20%	Cold roofs, ground floors, timber-frame wall - exterior uses where member is practiced from direct wetting
3	Conditions leading to higher moisture contents than service Class 2		>20%	Exterior uses - fully exposed

* RH relative humidity: level not to be exceeded for more than a few weeks each year

** EMC: Max equilibrium moisture content for most softwoods. In similar conditions the EMC of panel products will be typically lower

USE CLASSES INFORMATION

Use Class	Service Situation	Principal Biological Agent	Typical Service Situation	Examples
1	Above ground, covered, permanently dry	Insects	Internal, with no risk of wetting	All timbers in normal pitched roofs except tiling battens and valley gutter members. Floor boards, architraves, internal joinery, skirtings. All timbers in upper floors not built into solid external walls.
2	Above ground, covered (ie by a roof or other building component). Occasional risk of wetting	Fungi/insects	Internal, with risk of wetting	Tiling battens, frame timbers in timber frame houses, timber in pitched roofs with high condensation risk, timbers in flat roofs, ground floor joists, sole plates (above DPC), timber joists in upper floors built into external walls.
3	Coated above ground, protected eg by a coating. Exposed to frequent wetting. If wood becomes wet, drying out may be delayed by a coating	Fungi	External, above damp proof course DPC coated	External joinery including roof soffits and fascias, bargeboards, cladding, valley gutter timbers, external load bearing timbers.
	Uncoated above ground not protected. Exposed to frequent wetting	Fungi	External, above DPC uncoated	Fence rails, gates, fence boards, agricultural timbers not in soil/manure contact and garden decking timbers that are not in contact with the ground.
4	In contact with ground or fresh water. Permanently exposed to wetting	Fungi	Timbers in permanent contact with the ground or below DPC. Timbers in permanent contact with fresh water. Cooling tower packing. Timber exposed to the particularly hazardous environment of cooling towers.	Fence posts, gravel boards, agricultural timbers in soil/manure, earth-retaining wals, poles, sleepers, playground equipment, motorway & highway fencing and garden decking timbers that are in contact with the ground. Lock gates and revetments. Cooling tower pacing (fresh water).
5	Permanently exposed to wetting by salt water	Marine borers, fungi	All components in permanent contact with sea water	Marine piling, piers and jetties, dock gates, and cooling tower packing (sea water)

SOURCES AND EFFECTS OF WATER AND MOISTURE DAMAGE

A timber structure can become wet by four main mechanisms:

- Infiltration: the development of a gravity fed water path arising from infiltration of water. This typically originates from the roof or foundation of the building, from cladding panels on the façade, from leaks (escape of water) in the plumbing system or from the activation of a sprinkler system.
- Capillarity: movement of water within the wood itself. This occurs mainly where the wood touches the ground or is wet from precipitation, especially in the end-grain areas of columns or wall panels.
- Condensation: occurs when moist indoor air meets a cold surface and condenses into droplets (thermal bridging); poor building envelope (airtightness) is also a potential cause of condensation.
- Moisture trapping: usually the consequence of poorly planned site moisture management or poor workmanship (eg installation of impervious membranes onto wet timber substrates).

These wetting mechanisms can be triggered by a variety of sources at different times during the life of a timber building[7]. In terms of the consequences of water exposure, different timber products and assemblies absorb and dry at different rates; wood species, end-grain exposure, surface treatment and the presence of hidden voids have a huge impact on the overall behaviour of a timber structure[8].

Exposure to high levels of moisture during construction can cause delays to follow on works and problems later down the line, from localised surface discolouration, corrosion of metal fasteners and dimensional changes (eg shrinkage/swelling) to fungal decay (in a trapped water scenario). However, most of the issues that arise during construction are short term and can be easily avoided with a comprehensive moisture management strategy and

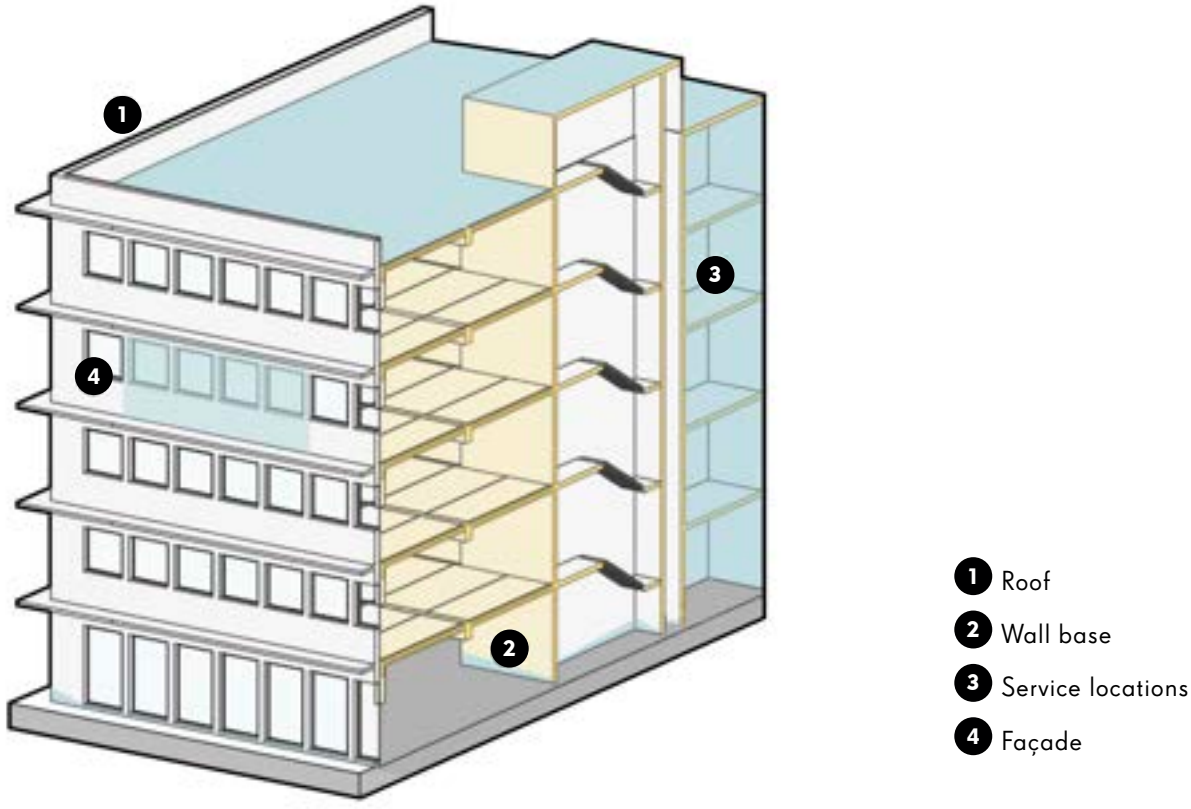


Figure: Main risk areas in a timber building

relatively light remedial works when damage occurs. More serious problems can, however, arise from water leakage through the roof, façade, or water/heating systems; in such cases, the damage is proportional to the time taken to discover the leaks.

PREDICTING RISK AREAS

In all buildings, there are areas that may be more susceptible to moisture damage, in particular:

- Roofs and terraces, which should be designed to prevent water sitting on the wood either during construction or in the event of a membrane failure, ie the structure itself should be sloped (the greater the slope, the less risk of water accumulation).
- Interfaces between walls/columns bases and ground floor slabs, where infiltration, capillarity rise or even interstitial condensation could cause damage. This can generally be avoided by raising the timber above the finished floor level.
- Façade panels, and particularly the interfaces between panels, should be made accessible by positioning them away from the main structure (eg columns, perimeter beams).
- Areas around water pipes and wet service routes, which should be monitored by leak and moisture sensors.
- Wet areas (eg kitchens, showers, and bathrooms) where there is a risk of leakage and/or malfunction of equipment. This risk that can be mitigated using moisture sensors above protective membranes and in some cases with less sensitive materials than CLT or as floor slabs eg traditional joisted floors, precast concrete planks or steel profiled deck.

In all these areas, careful attention must be given to the design of the timber structure to ensure it is well-detailed and allows for easy access, repair, and partial disassembly if moisture-related issues occur. While these problems can arise at any stage of a building's life, they can be anticipated and addressed effectively during the design and construction phases at various scales.

Effective moisture management is achieved by protecting the structure and envelope using multiple, combined defensive strategies that need to be applied at different stages of the building's life, including:

- Design phase: design for durability (eg raising timber from ground level, fall to roof panels etc)
- Design phase: Provision of potential water drainage paths (eg roof falls, outlets)
- Construction phase: Moisture management strategy
- Operation phase: Water/moisture detection (as early as possible through low and hi-tech means)
- Geneal: Forsee ways to promote drying of wet timber through drainage, ventilation, evaporation, and diffusion

Common Perception:
Timber can not be exposed to water without sustaining damage.

Reality:
Timber can handle water exposure as long as it is allowed to dry out properly. With the right design and construction techniques, such as using protective coatings and ensuring proper drainage and ventilation, timber can resist water damage effectively. It is prolonged exposure to moisture without drying that poses a risk, not short-term contact with water.

4.2 RISK MITIGATION

To minimise the risk of moisture damage in timber buildings, it is essential to follow key risk mitigation principles throughout the building's lifecycle. This begins with design phase considerations such as careful material specification, detailing to avoid water pooling and providing protective secondary materials such as membranes and sealants. Construction phase considerations include providing proper protection during transportation and construction to prevent moisture exposure[9]. Once the building is in use, regular monitoring of moisture levels and implementing effective maintenance strategies are necessary to prevent long-term damage. By addressing these aspects, the building's durability and resilience against moisture can be significantly enhanced.

Risk mitigation strategies differ in their scale, cost, and complexity to implement, depending on the specifics of each project. Therefore, these strategies should be tailored to each project individually. It is also important to weigh the cost of mitigation against the potential cost of repairing damage, considering the likelihood of such damage occurring.

Risk mitigation strategies should be designed with the understanding that some may not work as intended. Therefore, it is advisable to implement multiple layers of protection for each building element. For instance, a waterproof membrane might prevent moisture from penetrating the roof, while pitching the roof will allow water to run off the timber structure should the membrane fail. As a backup measure, a moisture monitor could alert the owner if the structure becomes wet. This multi-layered approach should be applied to all building components to ensure a thorough and reliable protection strategy.

These measures are explained in more detail in the following section, focussing on risk mitigation in relation to the phases of a building's life.

A-DESIGN PHASE

Material/component specification

When specifying timber components, it is important to know their durability, service and use classes. See section 4.1 for further information. These factors help determine the right application and expected lifespan of engineered wood products.

Building envelope water ingress - roof

Roofs and terraces are particularly vulnerable to water ingress. To reduce the risk of building envelope failure, the following risk mitigation measures can be incorporated when designing roofs.

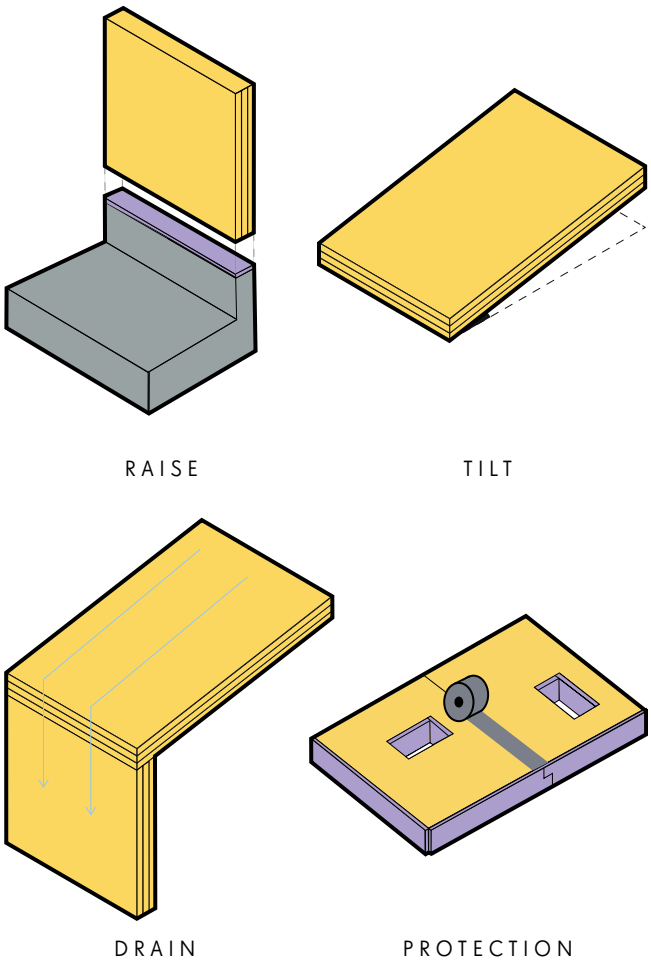


Figure: Designing to prevent moisture build up

- Pitching of roof panels: All flat roofs should be installed with a minimum pitch of 1:50. This accounts for the deflection of large roofing panels, helping to prevent water pooling. Pitched panels also facilitate roof drainage in the event of waterproofing membrane failures, minimising damage during installation or repair.
- Focus on temporary and permanent rainwater outlets (RWO) design: Rainwater outlets (RWOs) and downpipes may be part of the permanent rainwater system or serve as temporary solutions. If RWOs are positioned above the roof insulation in the final design, they may sit too high to drain water during construction. For flat CLT roof terraces and floor slabs, rainwater can track across the surface, pool, and seep through slab joints unless the joints are extensively taped.
- Focus on roof panels service penetration design: Service penetrations should generally be minimised and located in designated areas treated with end-grain sealer at the factory. Even small holes and cut-outs, whether temporary or permanent, require attention. For instance, lifting holes must be sealed with wood plugs or taped immediately after assembly. Temporary holes used only during installation can be sealed with breathable tape, while larger holes can be covered with a breathable membrane and tape, temporarily closed with plywood sheets, or used as temporary rainwater outlets.
- Focus on identifying system failures to ensure prompt remediation: Install tell-tale drainage points (small holes in the timber roof structure) that allow water to drain through to the ceiling's internal face, making water ingress clearly visible to occupants. Place leak detection systems at the roof's lowest points, which will notify building management if water starts to pool. Install moisture sensors at the lowest edges of roof panels to alert the building management system if timber moisture levels exceed 14%.

Common Perception:
Timber structures are too susceptible to water damage, making them a risky choice for long-term use.

Reality:
While timber is more sensitive to moisture than some other materials, this risk can be mitigated with proper design, installation, and maintenance. Effective moisture management strategies ensure timber structures remain robust and durable.

Capillary action – wall bases

Wall bases are vulnerable to deterioration from capillarity action when in contact with a wet substrate, especially at the ground floor level where they may be exposed to severe wetting from standing water and groundwater pooling. This risk should be addressed during the design phase, with the following mitigation measures incorporated into the design.

- Specify a DPC to the underside of timber wall panels where these are in contact with grout, screed or concrete to prevent moisture rising via capillary action through wall panels. However, relying on damp or water proofing membranes is not enough as most of them have a shorter lifespan than the structure itself and may not be capable of fulfilling their function once they deteriorate. A secondary mitigation measure should also be employed.
- Apply end-grain protection to wall panels in contact with the ground.
- Raise timber components from the external ground and finished floor level where water could potentially accumulate and trigger a localised wood decay process over time. In the UK, there is no specific regulatory guidance on how or by how much the timber should be raised. Documents such as STA good practice and the BM Trada technical sheets propose the minimum support height of timber (or any other degradable material) is 150 mm.

Escape of water - leaks

In timber buildings, special consideration must be given to the design and monitoring of water carrying systems such as heating, cooling, fresh or wastewater and sprinkler systems. These are the main sources of leakage, causing localised but significant durability problems to the timber structure.

Some water leaks can remain undiscovered for substantial amounts of time, leading to consistently high levels of moisture (moisture content >20%) and the consequential degradation of timber. This can occur in floor build-ups or behind plasterboard sheets forming encapsulation layers and may be due to the routing or dimensioning of pipework, installation, or material choice errors.

Office buildings typically group and stack bathroom areas together, and can therefore be easily supplied through common risers, isolated, and monitored.

The following measures must be taken to prevent damage from leaking water in heating and water-carrying systems:

- Apply design for disassembly principles to allow easy access, maintenance, and replacement in wet areas.
- Keep water pipes away from the timber structure to reduce the risk of water damage.
- Ensure pipework is easily accessible and inspectable, and position it in purpose-made ducts or chases
- If pipes are hidden behind boards, choose materials that allow water stains to become visible (avoid tiles as surface finishes).
- Utilise shared service risers for the vertical distribution of all water-carrying pipes.
- Where possible, use ceiling distribution for routing water pipes horizontally.
- Install leak detection sensors near components that might prevent water from draining, such as fire breaks or collars where fire compartments are bridged.

Additional measures should be included in areas of the building where wet services are concentrated, such as WCs, kitchens, utility spaces etc. These include:

- Tanking of wet areas to protect timber against water leaks.
- Waterproof surfaces (entire floor and walls up to at least 150 mm, especially in areas exposed to water, such as showers) with careful attention to vertical and horizontal penetrations.
- Slope floors towards floor drains to facilitate water drainage.
- Consider alternative materials for wet area floor structures, which are less sensitive to moisture.
- Install leak detection systems and/or moisture sensors to monitor for potential water leaks.

These principles constitute timber specific preventive measures to avoid water pooling and moisture trapping.

Flooding

Due to climate change, flooding is becoming more common in Europe and will likely be a major concern in the future. Buildings are at risk, especially when located at the bottom of slopes or on low terrain, and in areas with low infiltration rates. During a flood, basements, ground floors, and even entire buildings are at risk of serious damage. Flood risk assessments should account for the possibility of future flooding due to climate change. When necessary, appropriate flood protection measures should be implemented, based on the level and duration of potential flooding. These measures may include elevating the timber using a concrete upstand or, in higher risk situations, using reinforced concrete or steel for ground floors or podiums.

Common Perception:

Timber structures must be completely covered at all times during construction to prevent water damage.

Reality:

While covering timber during construction is beneficial, it is not always necessary to keep it fully covered. Protective measures like factory-applied membranes and sealants can safeguard timber components from moisture exposure. When combined with proper detailing, positioning of components, and effective site management practices, these strategies ensure the structure remains durable even without full coverage during construction.

B-CONSTRUCTION PHASE (MANUFACTURE, ASSEMBLY)

Manufacturing and transportation

In this document, we assume the manufacturer uses proper protection during the production and transport of components and is responsible for delivering them in perfect condition. If not, the components will be returned for replacement.

Storage and assembly

The construction and logistics of constructing a timber building is the responsibility of the Contractor, but designers need to understand the risks during this phase and moisture should be a priority point on the agenda. As with all forms of construction, communication is key, and mistakes generally happen in between phases. A Design Responsibility Matrix should be produced to highlight responsibilities. The design team should establish a project specific Moisture Management Strategy prior to the involvement of the specialist subcontractor, this is a live document that sets out responsibilities and discusses design and mitigation measures to be implemented through-out the build phase of the project[10].

Mass timber components will be delivered to site with a low moisture content, generally around 12%, which allows for the timber to be immediately enclosed during construction without the need for allowing for drying out in situ. Unfortunately, most construction sites and programmes do not allow for immediate installation and enclosing of the timber from the elements and the material will likely need to be stored on site or be installed and left exposed for a time. This does not have to be a problem and with careful management and planning should have little impact on the timber.

Once delivered, on-site wood-based materials and components must be fully protected from rain, snow and wet ground. If the timber needs to be stored on-site prior to installation, this should ideally only be for short periods of time, and they must be adequately protected from standing water and be ventilated to allow for drying, making sure any sheeting used for damp proofing Is breathable.

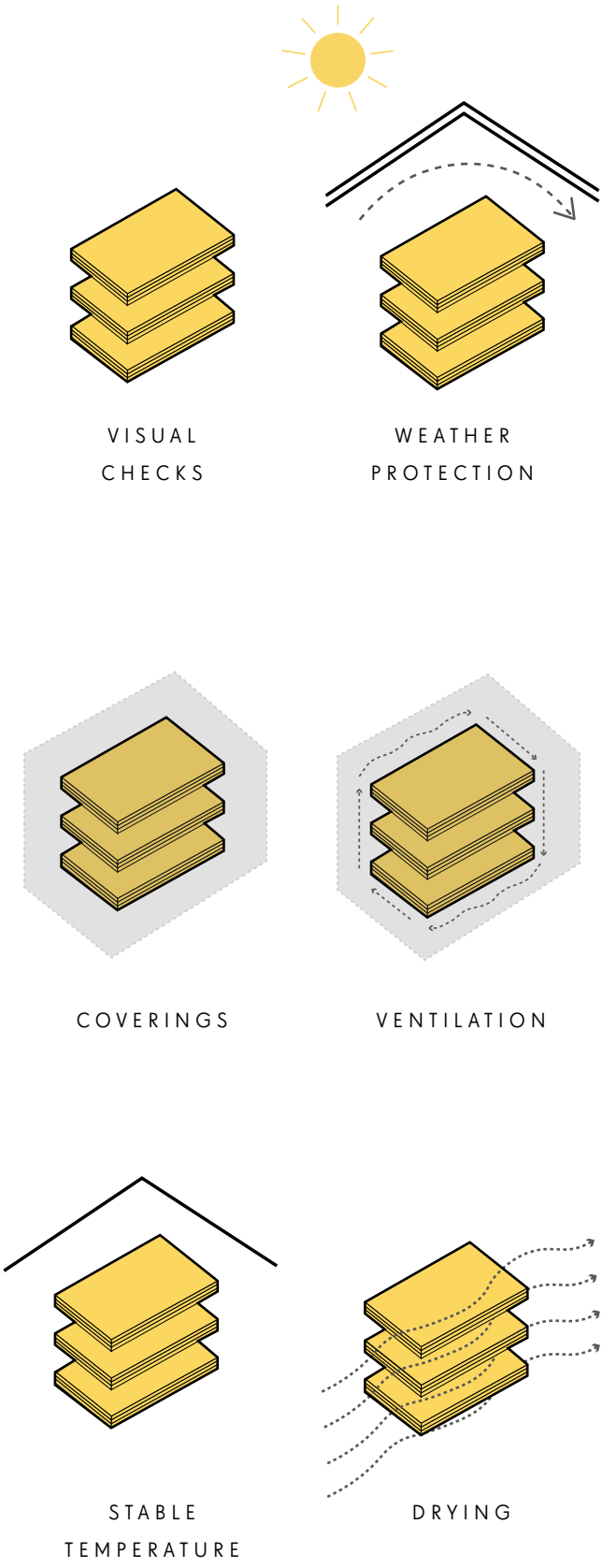


Figure: Proper storage of timber during construction phase

During construction, a cover (temporary scaffold tent) is often the safest choice to protect the timber structure, but there are many logistical and financial reasons why this strategy cannot always be implemented. If a cover is not suitable for the structure, moisture risks should be managed through design, detailing, and partial protection measures[11].

Pre-application of sealants to the end grains of CLT panels to prevent water absorption is recommended. Many CLT producers are now able to pre-install (on demand) weather protection membranes to enhance water protection of CLT slab panels during assembly, this is also recommended for floor and roof panels. Joints between panels and panel interfaces can be vulnerable to moisture and it is recommended that all joints are taped. The Contractor should also employ active measures where necessary to avoid ponding such as sweeping surface water from CLT panels.

It is worth noting that timber takes longer to dry out than it does to get wet, and certain elements are more susceptible and subject to weather, such as roofs and exposed floor panels compared with vertical components. Care will need to be taken on site to properly dry out any timber to avoid the trapping of water during the construction phase. A moisture management strategy by the Contractor should be in place to consistently monitor the timber components and component interfaces, with moisture readings carried out prior to enclosure of any timber structure to ensure that moisture content is no more than 18%.

C - IN USE PHASE

An overlooked aspect of moisture management planning involves the occupancy/in use phase of a building. Considerations for a typical office building include:

Escape of water – fire suppression

Sprinklers are a common fire safety tool in buildings, but the water they release can cause damage, particularly to timber structures

Sprinkler systems operate using a water supply connected to a network of hydraulic pipes and sprinkler heads, which are spaced at standardised intervals. These pipes are installed below the ceiling and are typically more accessible than other systems like mechanical or electrical installations. Wet systems, which remain filled with water, are most commonly used in commercial buildings.Sprinklers work by activating when they detect heat, allowing fires to be suppressed locally, which helps contain both the fire and potential water damage. A German survey in 2015 found that about 70% of fires were extinguished with only one or two sprinklers, indicating that moisture damage from these systems is usually limited.

The risk of moisture damage from sprinklers is well understood and can be managed effectively by building owners and operators. When sprinklers are activated, the building's management system typically alerts occupants and owners, allowing for immediate remediation. This includes removing accumulated water through temporary drainage or wet/dry vacuums. Careful inspection of structural connections, such as slabs, columns, beams, and vertical service connections, is essential to prevent long-term water entrapment. Additionally, walls and ceilings around the sprinkler activation area should be checked for water infiltration or marks indicating damage. Any water damage from these single events is normally easily dealt with by passive drying out measures.

Plumbing and appliance leaks

Plumbing and appliance leaks can be difficult to detect, however risks can easily be mitigated through careful detailing and design strategies, such as locating services in easily accessible locations, tanking of wet areas to protect timber against escape of water and using leak detection and moisture monitoring systems. This is described in more detail in the above section A - DESIGN PHASE.

Monitoring and maintenance strategy

A robust and comprehensive maintenance strategy is essential for long term durability of any building. For timber buildings, it is particularly important that occupants understand the risks of moisture damage and know to seek help if they notice any leaks or signs of moisture related issues. This information should be included in the Operation and Maintenance Manual and form part of the handover documentation.

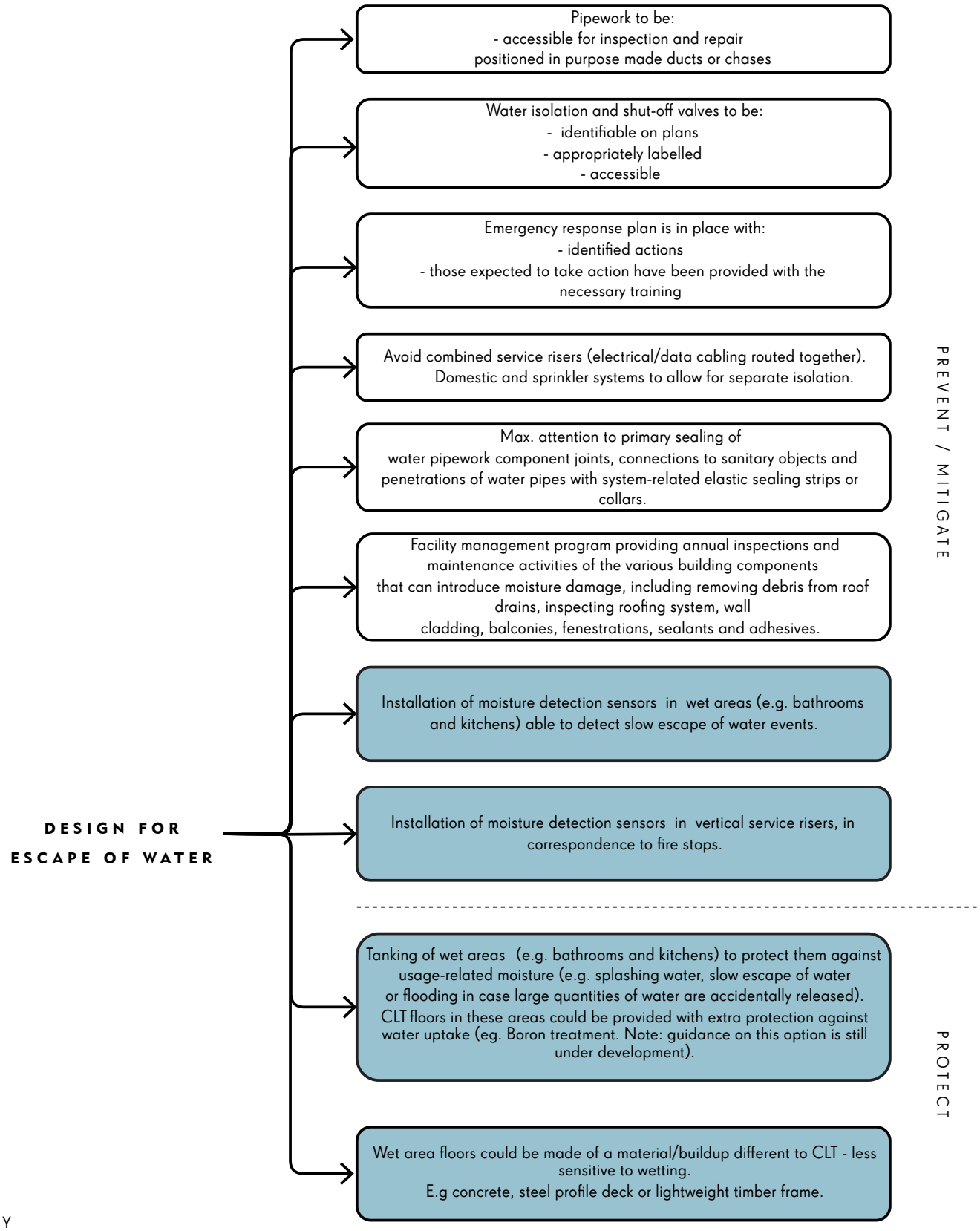


Figure: In use protection measures for timber buildings

A facility management program should be in place to conduct annual inspections and maintenance of components vulnerable to moisture, such as clearing roof drains, inspecting the roof, wall cladding, balconies, windows, and checking sealants and adhesives. This can be enhanced with the use of moisture monitors and leak detection systems, which can set off a physical alarm or trigger an alert sent via WiFi to the building management system.

The Operation and Maintenance Manual should also include a post-completion checklist for inspecting and repairing the building after occupancy, along with a detailed methodology for carrying out repairs.

Reparability is crucial for durability, as it outlines how to fix or replace damaged components efficiently. By applying design for disassembly principles, disassembly sequences and component interdependencies can be clearly explained, aiding in the development of both general and specific repair strategies. A building should be properly maintained if insurance is not to rise with building age.

RISK MITIGATION TABLE

The Risk Mitigation Table provides an overview of interventions that the design and construction team can make to reduce the risk of moisture damage to a building. Some measures are essential for all projects to ensure the building's durability, while others depend on the specific details of the project, such as cost, programme, building type and use.

Primary mitigations: Must be applied on every project to prevent moisture damage and ensure durability.

Secondary mitigations: These should be considered based on:

- Building location
- Project budget
- Construction timeline
- Type and use of the building
- Building management and maintenance approach
- Any other specific moisture risks to the building

Each project should assess which interventions are most appropriate based on its unique risks and constraints.

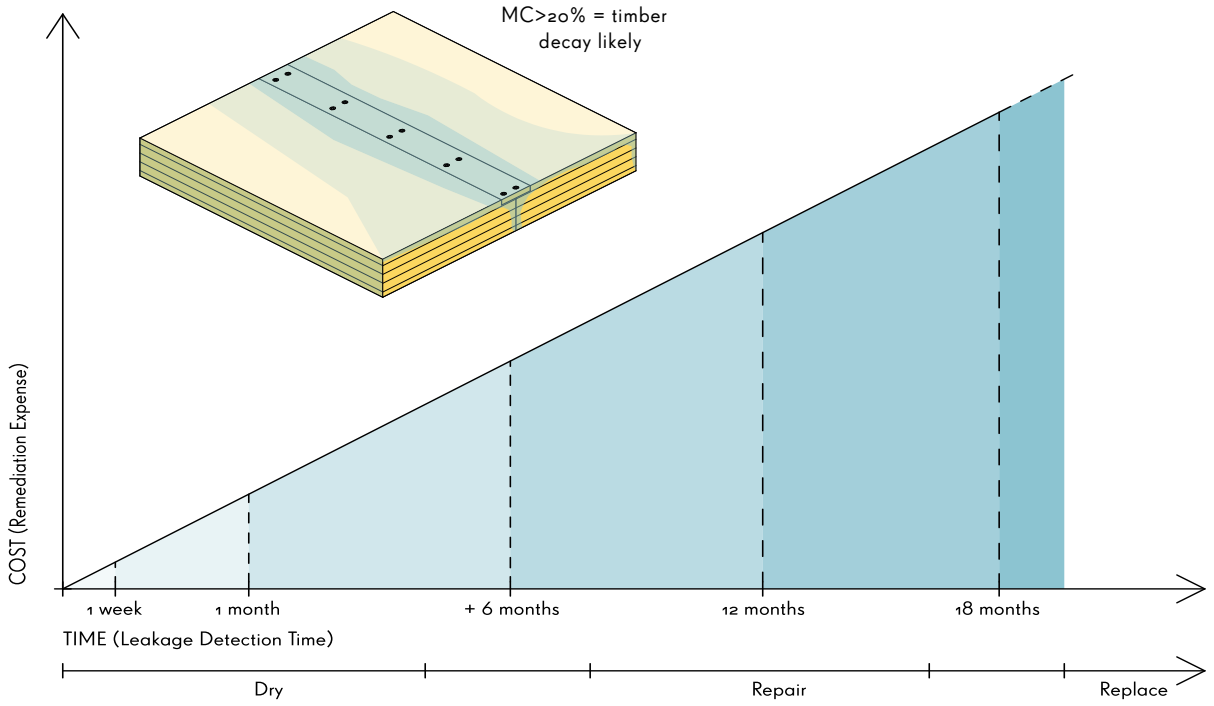


Figure: Risk of moisture damage increases over time

INTERVENTION		REASON	CONSIDERATION
Roof to minimum 1:40 falls	●	Aids water run off to prevent ponding on timber surface	
End grain sealant applied post machining of panels	●	Barrier applied to edges where timber absorbs water more readily	
Taped joints	●	Prevents moisture reaching edges at joints between components	
GF timber min. 150mm from FFL to external walls. Above FFL to internal walls	●	Prevents components contact with ground level moisture from pooling, splashing etc. Also from being buried in floor build-ups where moisture can be trapped.	
Construction phase moisture management strategy	●	Ensures site staff understand and implement measures required to protect and remove water during construction	
Install membrane to top face of CLT floors	○	Protects CLT surface from moisture ponding during construction (when floor slabs below roof level may be exposed)	Cost
System leak detection (water mains pressure)	○	Aids quick detection of a leak in the whole building system that could damage the timber	Cost / Maintenance
Localised moisture detectors near timber structure in high risk areas	○	Aids quick detection of any water sources which could damage the timber in areas where this is of greater probability (eg bathrooms, concealed voids with piped services)	Maintenance. Can be installed during fitout and owned by freeholder or Tennent.
Localised moisture detectors in timber	○	Aids quick detection of timber moisture content to quickly identify and rectify issues	More onerous installation, management system and cost
Ground level concrete/steel podium	○	Provides additional protection against contact with ground level moisture (including flooding)	Exposed timber structure at ground level not possible
Change to lightweight timber frame in high risk areas	○	Aids quick detection of water sources which could damage the timber and ensures timber in high-risk areas is not part of primary structure	Location of high-risk areas limited and fixed
External down pipes or down pipes in concrete structure	○	Positions key source of water away from structural timber	Potentially visible downpipes
Services in higher durability zones	○	Positions services which could be a source of water away from structural timber	Only viable in large projects which necessitate core of different material
Alternative material to roof slabs	○	Positions structural timber away from area prone to moisture ingress (roofing membrane failure etc.)	Exposed timber soffit at upper level not possible

KEY

● Primary mitigations. Must be applied on every project.

○ Secondary mitigations. Project specific, dependant on building characteristics and risk profile.

4.3 WATER DAMAGE REMEDIATION GUIDANCE

Timber can withstand getting wet providing it dries out quickly. However, prolonged exposure to water causes it to absorb moisture, leading to problems such as staining, mould growth, warping, and decay. The severity of these issues depends on how long the timber is exposed to water and the amount of moisture it absorbs. Minor damage, like superficial staining and minor decay, can be addressed locally with minimal impact on the building's functionality whereas more severe damage may require replacing entire timber components. Therefore, detecting and addressing water exposure promptly is crucial to minimising damage[12].

The orientation and position of components within a structure affect their durability. Vertically orientated elements, like wall panels and columns, are generally more durable but can be damaged through capillary action. Horizontal elements, such as floor panels and beams, are more susceptible to damage from ponding and trapped water. Due to their location, roof panels are more vulnerable to damage than floor panels.

If the moisture content of timber exceeds 20%, there is a risk of fungal decay developing. This risk increases if high moisture levels persist for over a year. If decay is found, a professional assessment is needed to determine its extent. Minor decay may not require replacement if the timber is still structurally sound and does not affect building performance. Prompt action is essential, as delays between detecting high moisture levels and starting repairs can allow damage to progress.

REMEDIATION PROCESS

When trapped water is suspected, a moisture content survey should be conducted to identify affected areas and assess the damage. Moisture readings should focus on high risk areas such as the lower edges of pitched roof panels, the perimeter of panels and at their lowest deflection points. For roof panels these readings can be taken from within the building, from the underside of panels up to the top lamella. A qualified professional must conduct the moisture content survey, and a remediation strategy should be developed with an experienced structural engineer, ideally in collaboration with the panel manufacturer and installer. Surveys should be supported by BIM data, calculations, construction information, O&M manuals and H&S files, all of which should be included in a digital manual.

Once high moisture levels are detected, all surface finishes must be locally removed to expose the timber structure. This includes any internal or external finishes, cladding, covering membranes, insulation, raised access floor systems, and acoustic build-ups on floor slabs. Concrete toppings or screeds should be removed in key areas, such as deflection low points and column to beam connections, to check if water has penetrated to the timber substrate. For external areas, the affected site should be temporarily covered with an enclosure, and upstands should be installed around the cutout to prevent further wetting.

The remediation strategy for timber components depends on the length of water exposure that the timber has endured and the extent and depth of damage.

Common Perception:
Timber structures are impossible to repair effectively after water damage.

Reality:
Timber buildings are highly repairable. If water damage occurs, timely detection and appropriate remediation strategies can restore the structural integrity without requiring complete replacement.

Timber with low moisture content, where only the surface of the panel is affected, can often be dried passively by exposing it to air. This method is cost effective and does not require specialised equipment, but it is slow. Alternatively, active drying, where heated, desiccated air is blown onto the panel surfaces, is a faster and more commonly used method. However, it must be done carefully as forced drying too quickly can lead to further damage, such as cupping and gaps opening up between boards as the timber shrinks. Depending on the location, level of decay, and drying method, drying timber can take several months, as noted in the drying table by BMTRADA & Stora Enso[13]. After drying, shear tests should be conducted on small samples to ensure the panels retain their structural performance. If cracks have formed from moisture induced swelling or shrinking, repairs may be needed.

Long-term exposure to moisture can lead to serious issues such as fungal decay and may require more complex and costly remediation. Four repair options are available

- Dryout the affected area.
- Replace one or more lamellas in a structural component.
- Local repair where a localised section of a CLT structural component is removed and replaced.
- Partial repair, where a structural component, such as a CLT floor or wall panel, is partially removed and replaced.
- Full scale repair, where the affected component is completely removed and replaced.

The approach needed will depend on the location and extent of the damage, as well as the type and orientation of affected structural components. A structural engineer should be consulted to assess the impact on structural performance, the design requirements for the connections and the need for any temporary works and propping. The repair strategy must address structural, fire, and acoustic performance requirements.

For local and partial repairs to horizontal elements, the process typically involves removing the damaged CLT lamellas or sections, installing replacement lamellas, which are likely to be LVL or CLT sections, and then reinstalling any coverings or finishes. For vertical elements, water damage typically occurs at the base where the wall is working in bearing. Repairs usually require cutting off the wall base (minimum 150mm) and forming a concrete or steel upstand to replace it.

For full scale repairs of horizontal timber elements, ensuring proper access for the installation and manoeuvrability of new slab sections is key. This often involves temporarily removing glazing or façade panels to facilitate site access. To improve flexibility, it is recommended to use smaller CLT sections, such as 1-meter-wide strips. If a vertical element is extensively damaged and the damage is widespread, a full replacement of wall sections is necessary. Temporary propping will likely be required to support the structure during the repair.

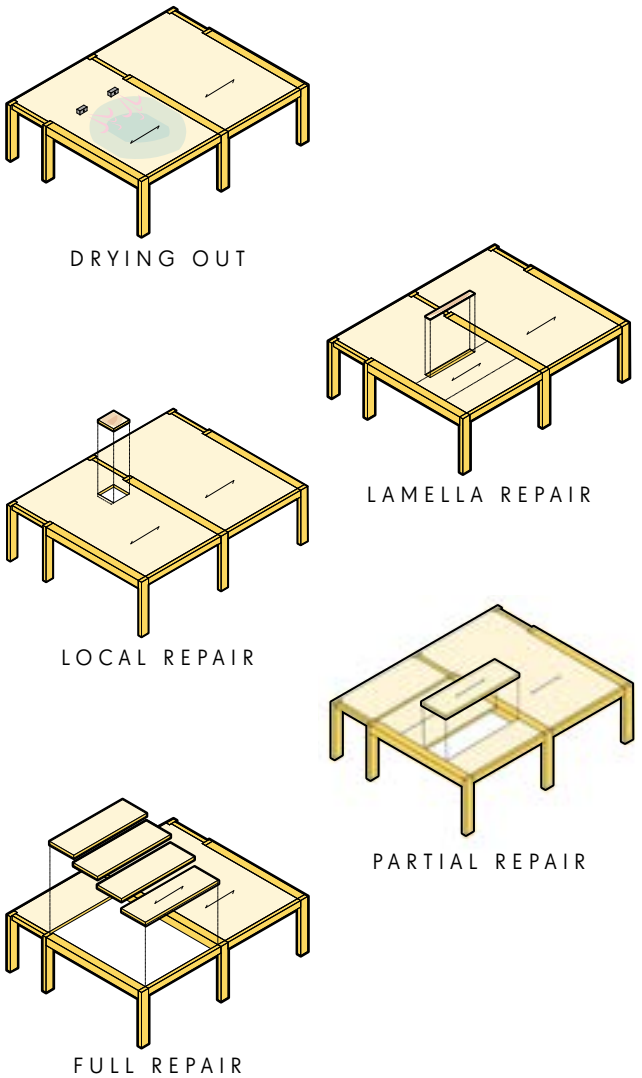


Figure: Repair strategies for moisture contaminated timber

4.4 PRINCIPLES FOR DURABILITY

The ten principles presented here are designed to guide designers and contractors in creating durable, long-lasting timber buildings. By focusing on selecting appropriate materials, identifying high-risk areas, and integrating strategies for maintenance and repair from the outset, these guidelines help ensure that timber structures remain resilient over time.

Rooted in current industry standards, best practices, and the collective expertise of professionals with extensive experience in mass timber construction, these guidelines offer practical insights for building durable structures.

Offering a framework that can be applied from the early design stages through to the building's operation, these principles help guide decision-making throughout the project. However, it is essential that the design and construction of timber buildings are overseen by qualified professionals and competent contractors with the necessary expertise. While these principles offer valuable guidance, they should complement, not replace, project-specific risk assessments and moisture management plans tailored to the unique conditions of each project.

DURABILITY PRINCIPLES

	Principle
1	**Understand material properties** The designer must understand the properties of the materials they are specifying, and how these affect the building's durability.
2	**Specify appropriate materials** Understand the durability characteristics and select materials based on Service and Use classes.
3	**Risk identification** Identify high-risk areas (eg roofs, wall bases, wet areas) early in the design process and choose appropriate protection strategies.
4	**Consider repair and maintenance** Incorporate methods for inspection and repair during design stages, particularly in high risk areas. For example, use design for disassembly principles.
5	**Keep timber dry** Mass timber can last indefinitely if kept dry. Ensure water can escape and dry quickly in case of exposure. Water detection methods need to be considered and assessed together with mitigation strategies.
6	**Early Intervention** Act promptly if timber is exposed to water. Moisture sensors may provide early detection, but these should not be solely relied upon.
7	**Moisture management in assembly** Contractors must implement a moisture management strategy during the building assembly. This should be include industry guidance and checklists. Special consideration must be given to the design of wet areas, which are often potential sources of long lasting damage.
8	**Remove critical vulnerabilities** Use redundancy-based water-damage mitigation strategies to ensure durability even if one defence layer fails.
9	**Durability risk analysis** Every building should have a durability risk analysis that quantifies the impact of water-related damage in terms of exposure time and remediation cost.
10	**Repair and remediation strategy** Develop a repair and remediation strategy for each new building, outlining specific risks, mitigation strategies, and remediation plans.

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5. FIRE

Mass timber stands out among structural materials for commercial buildings due to its many advantages, including sustainability and aesthetic appeal. However, when left exposed, it introduces new considerations for fire safety design. Unlike traditional materials, mass timber changes the fundamental assumption that the structure itself will not contribute to the fuel load in the event of a fire.

FOCUS

This chapter focuses on how the use of mass timber impacts fire safety requirements, the additional hazards that a combustible frame introduces and how these can be addressed. This chapter will set out the following:

- The goals and objectives that may form part of a fire safety design, including the minimum statutory goal of life safety and how fulfilling this goal may contribute to property protection and business continuity goals.
- An overview of the burning of wood and its implications on the fire hazards within a building.
- A set of proposed principles that can be adopted by designers to demonstrate the adequacy of the fire safety design in a commercial timber building.
- Discussion on the anticipated implications of these principles in the fire safety design of a commercial building, and on the potential benefits for property protection and business continuity by addressing the proposed fire principles.

KEY THEMES

- Compliance, Stakeholder Goals and Fire Safety Objectives
- Alternative Fire Engineering Approaches and the Qualitative Design Review
- Thermal response of engineered timber, self-extinguishment of flaming combustion, smouldering, heat-induced delamination
- Fire hazards induced by the presence of mass timber
- Principles to Demonstrate Adequacy of Fire Safety Design

CONCLUSIONS

This chapter offers detailed and comprehensive guidance about the use of mass timber and its impact on fire safety requirements and design. The following fire principles will need to be considered to demonstrate the adequacy of the fire safety design in a commercial timber building.

- Comprehensive fire strategy
- Adequate risk to health and safety
- Assumed redundancies for life safety design
- Impact on escape from area of fire origin
- Mitigating internal (vertical) and external fire spread
- Mitigating internal (horizontal) fire spread
- Expected performance of structure and compartmentation
- Survival of burnout with encapsulated mass timber
- Survival of burnout with exposed mass timber
- Sensitivity/consequence analysis
- Smouldering combustion

Mass timber commercial buildings that follow the fire principles will be designed to withstand a reasonable worst-case fire scenario (e.g. subject to an uncontrolled fire), which will typically be conservative and add significant robustness regarding property protection and business disruption.

5.1 COMPLIANCE, STAKEHOLDER GOALS AND FIRE SAFETY OBJECTIVES

The fire safety design of a building should be developed following a clear identification of the fire safety goals applicable to it. This is relevant to buildings of all uses and construction types, regardless of their form of construction, with the goals typically established at the outset of a project either through a formal or informal qualitative design review (QDR) process (see Section 5.2).

The Society of Fire Protection Engineers (SFPE) Handbook[1] defines fire safety objectives as falling under five core themes: life safety, property protection, continuity of operations, environmental protection and historic preservation. Typically, only life safety is associated with statutory requirements. Whilst statutory objectives associated with life safety offer minimum legal requirements during the design, construction and operation of a building, other stakeholder goals can exist that should be interrogated and, where relevant, incorporated into the fire safety design. Each of these themes ar

Life safety
Life safety concerns the health and safety of those in or around a building, ie occupants within a building, fire-fighters attending a fire in a building and public in the vicinity of a building.

To achieve an adequate level of life safety, BS 7974[2] identifies the following design objectives:

a) the occupants are ultimately able to leave the building in reasonable safety or the risk to occupants is acceptably low.

b) fire-fighters can operate without undue risk to:

- Assist evacuation when necessary.
- Effect rescue when necessary.
- Prevent conflagration.

c) collapse does not endanger people (including fire-fighters) who are likely to be in or near the building.

The Building Regulations 2010[3] incorporate statutory requirements within Schedule 1, Part B, which align with the objectives above and must be satisfied when undertaking building work. These are set out as a collection of performance-based requirements under Regulations B1 to B5, as below:

- B1: Means of warning and escape.
- B2: Internal fire spread (linings).
- B3: Internal fire spread (structure).
- B4: External fire spread.
- B5: Access and facilities for the fire service.

Property protection
Protection of specific property (eg equipment, valuables) within the building, or of the building itself as an asset, can be identified by the client, insurer or another project stakeholder as a goal. Property protection is not specifically addressed by the Building Regulations, with building owners and operators generally free to decide on what level of protection against fire they wish to provide in cognisance of the financial consequences.

These financial consequences could arise through damage or destruction of a building, damage or destruction of building contents, loss of productivity, or loss of reputation. However, fire precautions implemented in a building for the purpose of satisfying the life safety requirements of the Building Regulations typically contribute to an extent to the protection of the building asset. Further, some provisions implemented under the guise of life safety have their genesis in property protection, eg the inclusion of sprinkler protection and the limiting of compartment sizes.

Business continuity
Business continuity is a business's level of readiness to maintain critical functions after an emergency or

disruption. Where the continuity of business has been identified as a goal by the client or another project stakeholder, as per BS 7974 there normally needs to be some form of business impact assessment which aims to elucidate the client's / operator's objectives, stakeholder obligations, statutory duties and the environment in which the organisation operates. Ultimately, this leads to tangible design objectives that inform the organisation's continuity and recovery strategy. Like property protection, business continuity goals are 'private', with the end-user free to invest in a level of protection that they feel is proportionate to their potential future losses, should a fire occur.

Environmental impact

Another specific goal that can be identified by project stakeholders is the protection of the environment in the event of a fire. Whilst fires are accidental events and providing additional measures in fire safety design to specifically address environmental protection is not common, as per BS 7974 such measures can be developed, to limit the impact on the environment from a conflagration involving several buildings or the release of quantities of hazardous materials. These may limit:

- The effects of fire on adjacent buildings or facilities.
- The release of hazardous materials into the environment.
- The unintended effects of methods of fire-fighting (eg avoidance of river pollution).

Historic preservation

As previously mentioned property protection goals can include the protection of the building itself as an asset. For listed buildings or other historic buildings, stakeholders may also identify specific goals related to historic preservation, where the whole building or specific areas of the building are of historical importance. Historic preservation goals are of key consideration during refurbishment/construction works, addressing fire risks within this period. Recent examples of damages/losses to buildings of historic buildings, highlighting the risks to historic preservation during refurbishment works are the fire in Notre Dame Cathedral in Paris in 2019 and the Copenhagen Stock Exchange fire in 2024.

THE BUILDING REGULATIONS 2010 AND COMPLIANCE ROUTES

The Building Regulations 2010 are intended to ensure a reasonable standard of health and safety for people in and around buildings in a fire. The Building Regulations are secondary legislation facilitated by the Building Act (primary legislation), which empowers the appropriate national authority to make regulations for several purposes, most notably for "securing the health, safety, welfare and convenience of persons in or about buildings and of others who may be affected by buildings or matters connected with buildings". The Building Act also facilitates the approval and issue of documents for the purpose of "providing practical guidance with respect to the requirements of any provision of building regulations". For Part B (Fire Safety), this is Approved Document B, Volumes 1[4] and 2[5].

It is a misconception that the guidance in Approved Document B (sometimes incorrectly referred to as 'Part B') constitutes the law or that it must be followed in all instances. What must be complied with are the requirements of Part B of Schedule 1 to the Building Regulations 2010. To demonstrate compliance with these, there are different routes that fire safety designs can follow, as detailed below.

Common Perception:

Life safety protections do not contribute to property protection.

Reality:

Life safety measures, such as automatic fire detection systems, sprinkler systems and compartmentation, and structural fire protection contribute to property protection by providing an early alert to the fire, controlling and containing the fire, and protecting the structure. These measures not only provide reasonable standards of health and safety to those in or around a building but can also limit fire spread, reducing potential damage to the building and its contents.

Whichever route is chosen, compliance with the Building Regulations, including the requirements in Part B, is a legal requirement. It is therefore key to identify a robust and defensible route to compliance from early stages of a project.

ADOPTING DESIGN GUIDANCE

For common building situations, the fire safety requirements of the Building Regulations can be satisfied by following the relevant guidance in Approved Documents or similar standards – for commercial buildings this is typically through Approved Document B or BS 9999[6].

Approved Document B and BS 9999 contain a collection of recommendations that, if applied in their entirety and adopted in the design of common building situations, result in a building design that can satisfy Part B of Schedule 1 of the Building Regulations. The restriction in scope of applicability, ie to common building situations, intends to ensure that the series of recommendations align with the implicit assumptions regarding how fires may develop, how elements of construction might perform, how occupants might react, etc.

In facilitating the issue of Approved Documents, the Building Act states that, where applied within their intended remits, proof of compliance with such a document may be relied on as tending towards negative liability. Conversely, a failure to comply with a relevant approved document may be relied upon as tending to establish liability. The Approved Documents do not define what constitutes a common building situation. However, some indications are given in the introduction of Approved Document B as to situations that might be uncommon. These include:

- Difficult ground conditions.
- Buildings with unusual occupancies or high levels of complexity.
- Very large or very tall buildings.
- Large timber buildings.
- Some buildings that incorporate modern construction methods.

Therefore, in a recent publication[7] the Collaborative Reporting for Safer Structures (CROSS) expert panel has reinforced that:

"Those with responsibility for meeting the requirements of the regulations will need to consider for themselves whether following the guidance in the Approved Documents is likely to meet those requirements in the particular circumstances of their case."

Further, the expert panel goes on to conclude that:

"….the use of CLT in multi-storey buildings is not a "common building situation" as defined in the Approved Documents as they are currently published."

The conclusion by CROSS primarily relates to concerns about the implications of the structure's involvement as a source of fuel and how this could lead to incompatibilities with underlying assumptions made in arriving at the recommendations in Approved Document B. This has subsequently been supported by specific FAQ[8] guidance being published by the Department for Levelling Up, Housing and Communities, on the topic of combustible structures, which states:

"Following the guidance in Approved Document B, including the minimum fire resistance periods and the standard test methods, may not be sufficient to meet the requirements of the building regulations, particularly in cases where the consequences of fire spread, and fire induced structural failure are more significant."

In extension, the same conclusion would hold for all forms of combustible structural solution and is not limited to mass timber. Furthermore, similar compliance tools, such as BS 9999 could also be considered subject to the same limitations / scope of applicability.

5.2 ALTERNATIVE FIRE ENGINEERING APPROACHES AND QDR

Within Approved Document B, it is acknowledged that alternative routes to compliance may be necessary for cases falling outside of its scope, ie uncommon building situations. For those cases, it is said that the functional requirements B1 to B5 may be satisfied via alternative methods or evidence.

Herein, these are generally referred to as alternative fire engineering approaches, which could involve one of three possible methods as defined in BS 7974:

- Quantitative methods.
- Probabilistic methods.
- Qualitative methods.

The most appropriate route to compliance for any project (including commercial buildings with mass timber structures) should be discussed and agreed at the inception stage.

For small buildings, adopting design guidance (often referred to as a prescriptive-based approach) may be suitable. However, for taller buildings and thus with higher failure consequences in the event of fire, an alternative fire engineering approach is likely to be required.

Figure: Hybrid timber structure in construction

Where an alternative fire engineering approach is considered necessary/appropriate to meet the project goals and demonstrate compliance with the Building Regulations 2010, it is expected that any such solution will be developed following the guidance in BS 7974. This will include the completion of a qualitative design review (QDR) in consultation with all relevant stakeholders. BS 7974 provides a structured process for highlighting and determining fire hazards, fire risks, design actions and mitigation measures and will typically involve the following main stages:

- Review architectural design and selection of materials, including their suitability and fire properties, occupant characteristics and client requirements.
- Establish functional objectives for fire.
- Identify fire hazards and possible consequences.
- Establish trial fire safety engineering designs.
- Set acceptance criteria for the designs.
- Identify the method of analysis.
- Where identified, establish fire scenarios for analysis.
- Document outputs of the QDR.

The QDR for each project can be different depending on project specifics, complexity, goals and challenges of the building in question; accordingly, the level of detail of the QDR may vary between projects.

SUPPORT IN THE CHOICE OF COMPLIANCE ROUTE

Acknowledging the uncertainty in the relationship between mass timber and conventional routes to fire safety compliance using Approved Documents, the Structural Timber Association (STA) have published the structural timber buildings fire safety in use guidance, Volume 6[9]. This document intends to clarify the appropriate route to compliance for a mass timber structure in function of its height and use, with emphasis on Regulation B3(1) which concerns structural stability in the event of fire. The

document has been the standard source of reference for compliance with Regulation B3(1), achieving support from organisations, such as CROSS[7,10].

Within Volume 6, it is posited that two differing structural performance objectives exist for a structure depending upon the failure consequences. For low consequence cases, the structure should remain stable long enough to facilitate the evacuation of occupants and fire service activities. For high consequences of failure, the structure should have a reasonable likelihood of surviving the full duration of a fire event. The distinction between these two objectives is made through a combination of consequence classes and consideration of building height.

SUPPORT IN PROPERTY PROTECTION & BUSINESS CONTINUITY

It cannot be assumed that designing for life safety automatically addresses property protection or business continuity goals as these objectives depend on the goals of the stakeholders of each project and are therefore project specific. Nevertheless, some fire precautions aimed at complying with the requirements of Part B of the Building Regulations 2010 contribute to property protection and business continuity objectives in some manner.

As previously mentioned, precautions currently provided as life safety measures like sprinklers and compartmentation have their origins in property protection.

Whilst the specific property protection or business continuity objectives will depend on the project, these are typically aimed at:

- Reliably detecting fires.
- Limiting the extent of fire spread and thus damage within a building.
- Mitigating against the risk of building collapse.

In fire safety designs aimed only at Building Regulations compliance, the following are examples of provisions and systems that are likely to be in place and contribute to property protection and business continuity goals.

Automatic detection

Not every building designed for life safety will necessarily have an automatic detection system, as there are some small buildings which may achieve reasonable standards of health and safety with a fire alarm system based on manual call points. Nevertheless, it is common for fire safety designs to incorporate automatic fire detection to life safety categories (L1 / L2) which are comparable to property protection ones (P1 / P2) to BS 5839-1[11]. Such provisions are particularly common in mass timber buildings.

Fire separation and compartmentation

Fire safety designs seek to mitigate the extent of fire spread within a building through the provision of fire separation and compartmentation – which is also a provision often identified for property protection. Either informed by the evacuation strategy for the building, or by the height or floor area of the building, sub-division of buildings into multiple fire enclosures or compartments is a typical provision in designs for life safety.

Common Perception:

Approved Document B is not applicable for mass timber buildings, but the document is law and must be complied with.

Reality:

While Approved Document B is tailored for "common building situations" e.g. traditional construction methods, it still provides a framework for fire safety that may apply to mass timber buildings of low to medium consequences of structural failure. Approved Document B is not the law but contains practical guidance about how to meet the Requirements of Part B of Schedule 1 to the Building Regulations 2010 (as amended) in buildings within its scope. The Requirements of Part B are what constitute law and must be complied with. Compliance can be demonstrated by adopting design guidance where applicable or through alternative fire engineering approaches.

Automatic suppression

Whilst not every fire safety design for life safety will incorporate automatic fire suppression, eg a sprinkler system, there are height thresholds at which guidance recommends the provision of automatic suppression. Regardless of the selected route to compliance, these thresholds triggering the need for sprinkler systems are typically followed in fire safety designs. Sprinklers intend to mitigate uncontrolled fires by limiting their growth and, in many cases, supressing the fire. They are often identified as a measure for property protection as they are effective in mitigating the extent of fire involvement and thus fire damage. Sprinklers are also a common provision in a mass timber building.

Structural fire performance

There is a misconception that every building designed for life safety will have its structural fire provisions designed such that, in the event of a fire, the building will enable a safe evacuation and it may then collapse. This goes in hand with the misconception that a structure that is afforded a given period of structural fire resistance, for example R60, will fail once this time has elapsed during a real fire.

For smaller buildings, where the consequences of building collapse are lesser, the structural fire provisions may indeed not mitigate the prospect of collapse from an uncontrolled, fully developed fire. However, for tall buildings with high consequences of building collapse the fire safety design for life safety is typically premised on the structure withstanding intense uncontrolled fires and remaining stable both during and beyond such a fire event. This is through the provision of high fire resistance periods that historically have been premised on the structure surviving burn-out[12].

Firefighting provisions

A key objective of fire safety designs for life safety is the adequate provision of access and facilities for firefighting. Except for small buildings, these normally include dry or wet fire mains, and protected routes to enable the fire service to tackle fire within buildings

There is a misconception that the role of the fire service is only aimed at the protection of life and rescue. However, as per the Fire and Rescue Services Act 2004[13] protecting both life and property in the event of fires is the duty of all fire and rescue authorities, with it stating that they must make provision for the purpose of (a) extinguishing fires in their area, and (b) protecting life and property in the event of fires in their area.

Common Perception:

The fire service is only focused on the protection of life and rescue operations.

Reality:

While life safety and rescue are the primary goals of the fire service, they also work to protect property in the event of fire. Fire and rescue authorities, by law, make provisions for extinguishing fires in their area and protecting life and property, which contributes to the mitigation of damage to the building and its surroundings and the potential reduction of economic losses.


ALTRAD GENERATI

5.3 ENGINEERED TIMBER THERMAL RESPONSE AND FIRE SAFETY IMPLICATIONS

To ensure the safety of commercial timber buildings, designers must address the fire hazards associated with timber structures if they contribute as a source of fuel. Identifying and understanding these hazards is crucial, as this informs the development of fire strategies to mitigate them effectively and thus what evidence should be developed to support compliance with the Building Regulations and the attainment of other stakeholder goals.

THERMAL RESPONSE OF ENGINEERED MASS TIMBER

Engineered timber elements undergo distinct changes when exposed to heat, leading to physical, chemical, and structural alterations, as per Figure on facing page:

1. At the very initial stages of a fire, the cross-section of the timber element is still close to ambient temperature and its mechanical properties are preserved.
2. As the temperature rises to circa 100 °C, the timber element starts losing mass as per page 69 figure, due to dehydration. At this temperature, timber loses between 50% and 65% of its strength[14] depending upon the nature of the action (compression, tension and shear).
3. Between 200°C and 350°C pyrolysis occurs. This is a thermal decomposition of timber resulting in the release of pyrolysis gases and the formation of a char layer. At this stage, at approx. 300°C, timber loses 100% of its strength and stiffness[14,15].
4. Pyrolysis gases are combustible volatiles, which are released out of the timber and mix with air at the surface. If the conditions are appropriate, ignition of the pyrolysis gases can occur and flaming combustion starts. This stage is characterised by a rapid loss of mass as indicated in page 69 figure.
5. As the pyrolysis front progresses deeper into the timber, it leaves behind a char layer. This char layer has insulating properties. The thicker it is, the less heat from the surface will reach the pyrolysis front, slowing down the thermal decomposition and the mass loss rate of the wood below. Thus, the burning of timber is a time-dependent process as presented in page 69 figure, with the charring rate and thickness of the char layer evolving with time.
6. Above 350 °C char oxidation occurs and the surface starts to regress initiating a steady-burning phase. The rate of charring will depend on the external heat flux and the heat from the flame.

At the point where steady combustion has been established, different scenarios are possible. Depending on the amount of external heat flux and the design of the engineered timber product (ie type of glue, lamella thickness, etc) the timber can continue burning, self-extinguish or smoulder.

Self extinguishment of flaming combustion

Small-scale experimental studies have shown that to sustain continuous flaming combustion it is required to have a critical mass loss rate between 3.0 and 4.0 g/s.m^2 [15,16] is required. Otherwise, insufficient pyrolysis gases are generated to feed the flame at the surface and the timber undergoes self-extinguishment of flaming combustion[17].

To achieve this critical mass loss rate, small-scale studies indicate that the external heat source should be in the range of 30-45 kW/m^2 [16,17]. Additionally, medium and large-scale experiment compartments presented in [14,18,19] that indicated where the external heat flux to the timber boundaries dropped below 45 kW/m^2 self-extinguishment was achieved. Thus, this compartment research indicates that the threshold values established in small-scale tests provide an acceptable starting point to create design tools with conservative acceptance criteria that will help to predict whether self-extinguishment will happen or not in a given scenario.

After self-extinguishment, the heat accumulated at different depths of the timber will dissipate in all directions. This

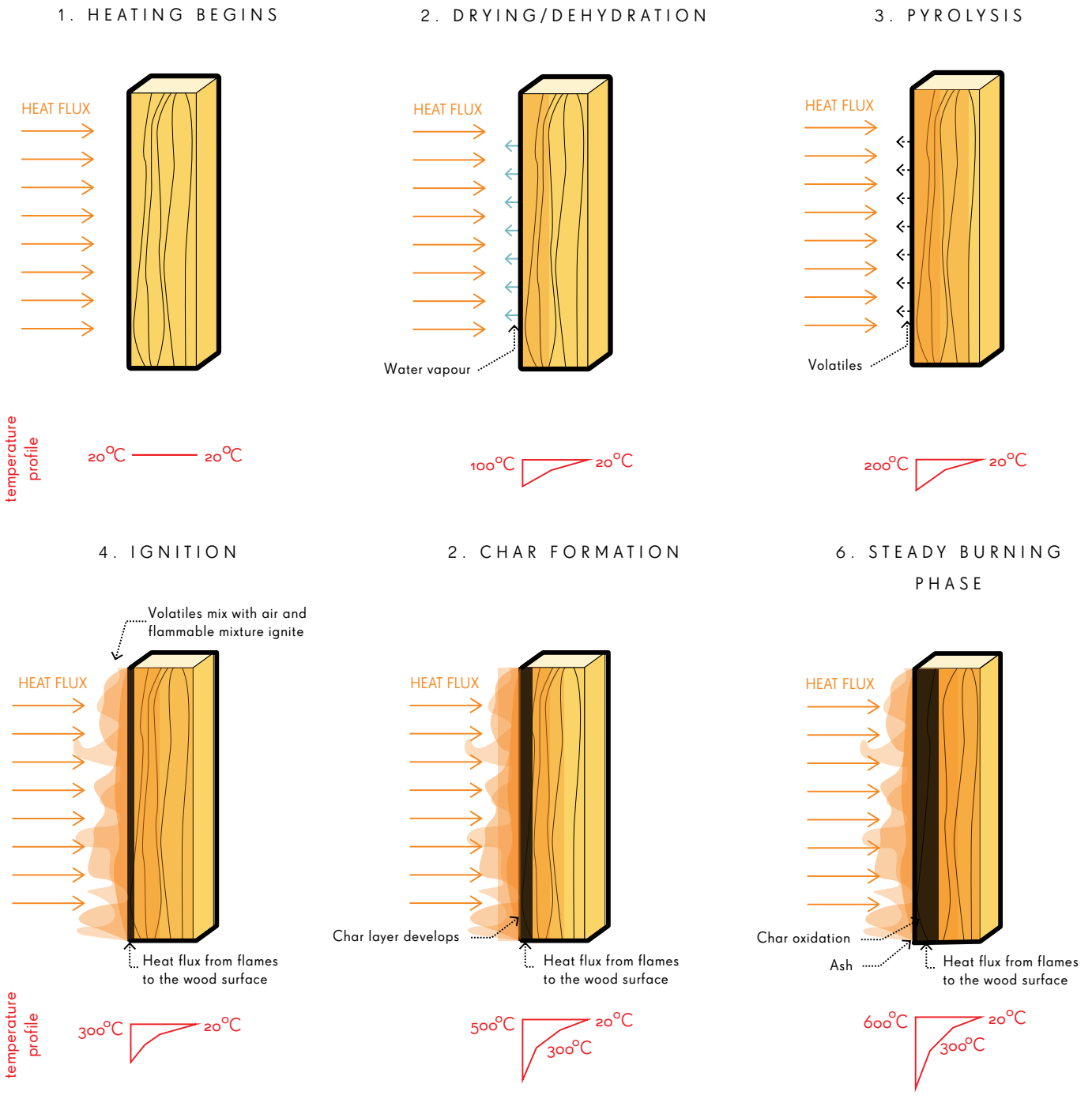

Figure: The stages of timber burning

means that deep sections of the timber element can still increase their temperature as the thermal wave continues progressing after self-extinguishment. Consequently, mechanical properties and structural stability can change after the flame has extinguished, with timber elements often most vulnerable to structural failure in the decay phase and beyond into the cooling phase of fires.

Smouldering combustion

Smouldering is a slow, low heat release rate and low-temperature type of combustion, where oxygen reacts with a solid, eg wood[20]. The reaction of oxygen with the solid matrix of the smouldering timber produces the characteristic glowing in the char. Smouldering usually appears at corners, connections, interfaces, fissures and similar localised areas.

Recent research conducted at Imperial College[21], has focused on the smouldering phenomenon happening on large timber structures after flaming combustion has been extinguished. This degradation process took place for several hours and days after flaming combustion had stopped. In consequence, localised smouldering penetrated through the CLT soffit, and on some occasions, it created the right condition for the re-ignition of local flaming combustion. On other occasions the smouldering self-extinguished.

The work conducted by Crielaard[22] indicates that self-extinguishment of smouldering combustion in timber elements will happen below certain threshold values of external heat flux and airflow. These thresholds are orders of magnitude lower than for flaming combustion. Given the complexities associated with the construction of modern buildings, eg tolerances, installation of services, etc, conditions can exist that support continued smouldering in mass timber buildings. Therefore, designing on the basis of smouldering self-extinguishment is often impractical and challenging to evidence.

Heat induced delamination (HID)

During a fire, heat may propagate deeper into a timber member, such as cross laminated timber (CLT), and heat a glue-line. At this point, delamination at the glue line is possible. This is a phenomenon that consists of the mechanical failure in the glue line of an engineered timber product like CLT, where the external lamella detaches and exposes preheated virgin timber to the fire. It is very likely that the newly exposed surface will ignite and burn at a faster rate as there is no longer a char layer to regulate the energy reaching the pyrolysis front. Its occurrence increases the average charring rate of timber elements and may challenge self-extinguishment. It also reduces the timber cross section faster, affecting its ability to support loads.

Although, large-scale experiments representing commercial enclosures have demonstrated that self-extinguishment is possible despite delamination for the tested configurations[23,24] averting delamination is often imposed as a limitation on the design of CLT elements, especially where interactions between combustible elements can occur.

Delamination is a complex phenomenon, and to date, it is known that several variables will affect its occurrence. These variables are the type of glue, lamella thickness, heating conditions, moisture content and imposed loads on the elements [25,26,27,28].

Currently, the most typical glues used in Europe are polyurethane (PUR) glues and modified PUR glues (ie with added fire retardant). Microscale experiments showed that the commonly used polyurethane adhesive experiences softening at 220-240^{0}C which is not the case for modified

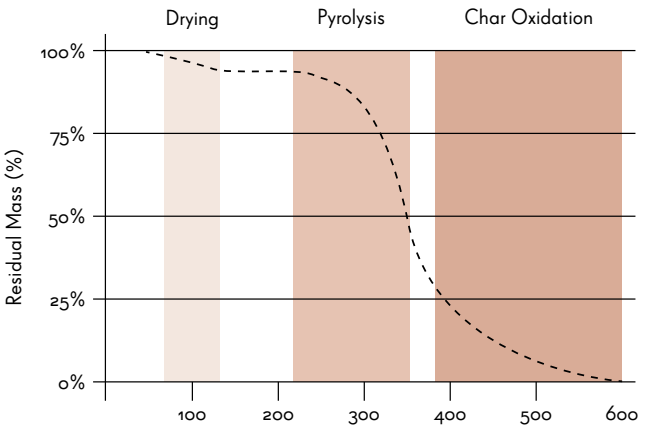

Figure: Thermal decomposition of timber as a function of temperature

polyurethane[29]. Several small and large-scale experiments indicate that CLT manufactured with modified PUR glues undergo less delamination[23,30]. However, delamination in modified PUR can still occur if the load is sufficiently high[28]. At a high temperature gradients, the moisture front moves faster and creates pressure on the bond line. When this is combined with a high load, the bond line can fail at lower temperatures (eg 100-120^{0}C). If the gradient is lower, the moisture front traverses through the bond line and the failure occurs at higher temperatures (ie >160^{0}C)[28].

Since the application of structural load, moisture conditions, and heating condition, all influence the bond line temperature at which HID occurs, a consistent critical temperature for delamination across different adhesives is not evident, making it difficult to be modelled and predicted.

Common Perception:
Heat-induced delamination is fully prevented by applying modified PUR glues (ie with added fire retardants).

Reality:
There is experimental evidence that heat-induced delamination in modified PUR can still occur, for example when the structural load is sufficiently high. The application of structural load, moisture conditions, and heating conditions, all influence the bond line temperature at which heat-induced delamination can occur. Hence, delamination across different adhesives is a complex phenomenon, difficult to model and predict.

Nevertheless, it is noted that preventing heat-induced delamination is not always a pre-requisite for self-extinguishment of flaming combustion, as it depends on the configuration of which surfaces are exposed.

FIRE HAZARDS INDUCED BY STRUCTURAL TIMBER

The fire hazards outlined below have been identified by understanding the burning behaviour of timber and by conducting large-scale experiments representing commercial and residential enclosures.

To date, several large-scale experiments representing commercial enclosures have been conducted [16,17,21,23,24,31,32]. These experiments usually consist of large open floor spaces, with high ventilation factors (ie large openings), and typically an exposed CLT ceiling is present. Although each experiment is different, the list of identified hazards presented below has, to varying extents, been reflected in these experiments.

Different hazards appear at different stages of the fire. Therefore, they challenge different parts of a fire safety strategy. The following list of hazards is organised following the timeline of development of a typical fire: ignition, fire spread, fully developed fire, decay stage and post-fire stage.

Internal fire spread and change in fire dynamics
In several large-scale experiments, like in [23,24] it has been noted that in the initial growing phase of the fire, the spread rates of the fire are comparable to those within non-combustible compartments. However, this research concludes that as soon as the fire ignites a large exposed timber area, like an exposed CLT ceiling, a quick change in the fire dynamic occurs. It drastically increases the fire spread rate within a compartment. This phenomenon can challenge the early stages of horizontal evacuation, while occupants are evacuating the compartment of fire origin.

To mitigate this, the flame spread over the combustible timber surface must be considered. This can be controlled by applying different treatments and coatings, the inclusion of automatic suppression systems or by breaking the continuity of the timber surface with beams or other elements.

Additionally, the ignition of the ceiling usually accelerates the ignition of the fuel located on the floor. This often leads

to a post-flashover fire, even in larger compartments. Therefore, the internal heat release rate and heat imposed on the structure will be significantly larger for exposed timber enclosures[23,24].

Fire spread due to a larger external flame

External flaming is a physical phenomenon that can occur in combustible and non-combustible structures. It consists of a flame emerging from openings in a building and it is most pronounced during the fully developed fire stage. In ventilation-controlled compartments (ie the openings are relatively small and the fire is limited by oxygen) the unburned gaseous fuels flow through the opening to react with the oxygen available outside the compartment. In fuel-controlled compartments (ie the openings are large, and the fire is not limited by the amount of oxygen) it is also possible to have external flaming due to flow dynamics.

Common Perception:

In a fire, the entire timber structure of any mass timber building will be consumed, leading to total building collapse.

Reality:

As is also the case for buildings with non-combustible structures, mass timber buildings with higher consequences of structural failure are typically / should be designed (by competent engineers) to survive burnout, i.e. to maintain their structural integrity during and beyond a fire event; they are not designed to collapse. In buildings with exposed mass timber structural elements, in the event of fire, the structure may ignite. However, depending upon the configuration of the fire enclosure, the amount of exposed surface area, the ventilation conditions and the mass timber specification (inclusive of the adhesive), burning can stop without third-party intervention and the structure continue to support the load. Additionally, fire safety measures like spandrels, compartmentation and sprinklers are used to control and contain the fire, lessening the prospect of fire spread to multiple floors.

In several large-scale experimental campaigns, representing different types of timber compartments, the exposed timber structure has been observed to have a significant influence on the size of the external flame[19,32]. The larger the area of the exposed timber inside a compartment, the higher the production of flammable pyrolysis gases. Thus, it is reasonable to expect that in ventilation-controlled compartments, the excess of unburned pyrolysis gases flows out of the compartment and combusts outside, triggering a much larger external flame. In fuel-controlled compartments, the increased amount of pyrolysis gases can increase the forces driving the flow dynamics or transition the fire from a fuel-controlled to a ventilation-controlled regime. In either case, it should be foreseen that greater external flaming is likely to be present and that this should be adequately addressed by the fire strategy as this has the potential to facilitate vertical fire spread (envelopment) and fire spread across boundaries (building-to-building).

Envelopment: Envelopment is usually addressed through a combination of external wall materials that do not readily support fire spread and internal fire separations, eg vertical compartmentation. If external flaming occurs, it has the potential to ignite external wall combustible materials should they be present, and / or circumvent compartmentation by heating openings on the storey above, facilitating re-entry of the fire. The envelopment hazard should be mitigated through appropriate consideration of the external wall design.

Building-to-building fire spread: In the case of mass timber buildings, a larger external flame can result in higher heat fluxes to the neighbouring buildings. This needs to be considered when establishing safety distances between buildings to mitigate the risk of fire propagation to other buildings.

STRUCTURAL STABILITY DURING AND AFTER A FIRE

As discussed on page 64, timber will dry, pyrolyse, combust, and char when exposed to heat. Therefore, the effective cross-section of the structural elements will keep

reducing during a fire and potentially beyond. Currently, there are available models to estimate charring rates and effective cross-sections due to the changes in the mechanical properties, like the models in Eurocode 5[31]. However, these models are simplified and only applicable to certain conditions. Designers must understand the tools they use and ensure that the load-bearing capacity of the timber structure will be able to withstand the imposed loads for the required time.

Additionally, temperatures deep within the cross-section of the timber elements will continue to rise as the thermal wave progresses after the fire. Consequently, the mechanical properties of deeper sections of the element will change since timber loses its strength at relatively low temperatures. This should be considered to ensure adequate stability after the fire has been extinguished[14], with glulam columns particularly vulnerable to strength loss during the cooling phase of a fire and beyond.

Design for burnout

Higher consequence of failure buildings are generally afforded structural fire provisions with the expectation of maintaining their structural integrity during and beyond a fire event. For buildings with a non-combustible structure, this is often achieved with structural elements that achieve high levels of fire resistance when subject to standard testing that translates to often indefinite survivability when subject to a real fire.

For a non-combustible structure to survive the full duration of a fire, it must withstand the thermal assault from the movable and permanent fire load in a building, eg furniture, linings, fixtures and fittings. However, in the case of a timber structure, the structural elements can continue burning after the movable and permanent fire load burns out and until the whole timber structure is consumed. Therefore, the only way to design for burnout (ie surviving the full duration of a fire) for these structures is by demonstrating self-extinguishment of flaming combustion of the timber elements on a case-by-case basis. Currently, simple models and experimental work exists[15,16,17,18,24] to help designers estimate the potential for self-extinguishment of timber in different configurations.

Smouldering combustion after the fire

Smouldering usually appears as a local effect, and although it is much slower than flaming combustion, it can be harder to detect and extinguish and its effects cannot be neglected. Studies conducted by Imperial College[21], showing that smouldering can persist for several hours or days after flaming combustion has been extinguished, and although it can extinguish, it may also transition to flaming combustion. Thus, smouldering is a phenomenon that needs to be addressed to demonstrate safety in the hours and days after the fire. This is likely to require some form of intervention by the fire and rescue services.

Common Perception:

An R60 fire rating means that the building will fail after 60 minutes.

Reality:

The time in minutes used to express fire resistance ratings, for example R60 (60 minutes loadbearing capacity), relates to the time taken for an element to fail to fulfil one or more classification criteria under standardised furnace conditions . It is not the same as time elapsed during a real fire. For instance, in the fire test the isolated construction element is subjected to elevated temperatures that follow an indefinitely growing time-temperature curve which has been standardised for classification purposes, and broadly reflects the fully developed phase of a fire; whereas a real fire behaves differently, with growth, fully developed and decay phases, and does not grow indefinitely. Furthermore, by testing isolated construction elements both positive and negative behaviours associated with system performance in a real fire are not addressed.

5.4 PRINCIPLES TO DEMONSTRATE ADEQUACY OF FIRE SAFETY DESIGN

Exposed mass timber structures introduce fire hazards to a building that are not explicitly addressed by traditional design routes involving the application of guidance or design codes. In many cases, a performance-based route will be necessary to demonstrate compliance with the Building Regulations. This will necessitate a Qualitative Design Review (QDR), where the goals are identified with all relevant stakeholders from the outset. The fire safety design of the building should, as a minimum, evidence that reasonable standards of health and safety are achieved for those in or around a building, as per the requirements of the Building Regulations.

For the purpose of life safety compliance, this Guidebook presents the following list of 10 Fire Principles, proposed to enable the demonstration that reasonable standards of health and safety can be achieved in the event of a fire in a commercial mass timber building. The fire safety design should always be undertaken by competent professionals with relevant experience. The principles provide a template – they may be adopted by designers in the absence of project-specific alternatives that might otherwise be determined through the QDR process, in dialogue with relevant stakeholders. For this reason, they are necessarily conservative and may not apply in all cases.

The principles and approach within the table have been through an iterative process of discussions and consensus within a panel of academics and consultants who are experienced in the development or review of fire safety designs from first principles, including for commercial mass timber buildings. The fire panel was formed from academics/consultants from Design Fire Consultants, Hoare Lea, OFR Consultants, Semper, The University of Edinburgh and University College London. The principles primarily address life safety, but provide potential benefits for business continuity and property protection.

POTENTIAL BENEFITS

The 10 Fire Principles, which address life safety compliance, are presented on the following page.

Even though it cannot be assumed that designing for life safety automatically addresses property protection or business continuity goals, through addressing the 10 Fire Principles there are potential benefits to these goals as follows:

- The development of a comprehensive fire strategy, and undertaking of a Qualitative Design Review, from the onset ensures that stakeholders' objectives are elicited at the outset of a project. Where appropriate / relevant, this includes insurers' objectives.
- The assured competency of those involved in the design and approval process reduces exposure to risk in the event of a future fire.
- A transparent and clear fire safety strategy reduces the prospect of mismanagement and misunderstanding whilst the building is in service. Thus, increasing the effectiveness of the prevention fire safety layer.
- The communicated extent or increase in potential fire damage from the choice of structural framing material informs potential implications for property protection, asset protection and insurability.
- Potential vulnerabilities and failure modes in the fire safety strategy are explicitly identified and mitigated.
- Demonstrating comparable and adequate risk to buildings with non-combustible structures will likely require more widespread use of compartmentation and automatic fire suppression systems. This will likely reduce the extent of fire damage.

FIRE SAFETY PRINCIPLES

	Principle	Fire Engineering Approach To Meet Intent of Principle
0	**Fundamental Principle - Comprehensive Fire Strategy** A comprehensive fire safety strategy should be developed by someone with relevant competency and experience for each building that follows the below principles. Furthermore, the strategy should establish and clearly articulate maintenance and management plans, as well as a clear and explicit definition of all dependencies, conflicts, and redundancies between the different protection strategies used.	– Development of the fire strategy to be an iterative process, live throughout the design and construction stages of the project, whereby the end product is to meet this fundamental principle. – Competent professional to decide the approach to address the principles below and develop the comprehensive fire strategy. – Professional to demonstrate their competency and relevant experience.
1(A)	**Adequate Risk to Health and Safety** All buildings, independent of what materials are used and their combustibility, shall be demonstrated to have an equal and adequate risk to the health and safety of people (including fire brigades) in or around a building in the event of a fire.	Demonstrate the adequate risk to health and safety through either of: – Responding to the principles within this table, where a comparative approach is embedded (the proposed acceptance criteria being with reference to a non-combustible building). – Approaching from first principles (ie without following the comparative approach in this table).
1(B)	**Adequate Risk to Health and Safety** No greater reliance should be placed on fire safety measures in a combustible structure than would be expected for a non-combustible structure unless they have an demonstratably higher reliability.	– Consider the reliability of the fire safety measures proposed within the fire strategy. – Ensure these are not elevated or relied upon more so than for a non-combustible building, unless a higher reliability can be evidenced for the specific case of a mass timber building.
2(A)	**Assumed Redundancies for Life Safety Design** Sprinklers are to be treated as a redundancy in the fire safety strategy, and therefore should not be included in the assessment of adequacy of a fire safety strategy. The fire safety strategy must provide an adequate level of safety independent of the presence of sprinklers.	– Quantify consequences of sprinkler failure, by undertaking an analysis that doesn't include the benefit of sprinklers. – Make design decisions based on the outcomes of the analysis and the acceptable risk.

2(B)	**Assumed Redundancies for Life Safety Design** Fire brigades are to be treated as a redundancy in the fire safety strategy, and therefore should not be included in the assessment of adequacy of a fire safety strategy. The fire safety strategy has to provide an adequate level of safety independent of presumed fire brigade intervention.	– Quantify consequences of no fire brigade intervention, by undertaking an analysis that doesn't include this. – Make design decisions based on the outcomes of the analysis and the acceptable risk.
3	**Impact on Escape from Area of Fire Origin** The contribution of the combustible structure to fire growth should be demonstrated to be negligible in the enclosure of fire origin during the escape of occupants from within. Alternatively, provisions will have to be included that consider such contribution in a manner that does not adversely affect the available safe escape time from the enclosure of fire origin.	Demonstrate that structural timber doesn't affect the available safe egress time (ASET) by either: – Applying ADB/BS 9999 recommendations, ie. reaction to fire of exposed surfaces, or – Ensure there is no ignition of the surface linings (including the timber) prior to the last person leaving the compartment of fire origin, or – Demonstrate through a full assessment that flame spread over the surface linings (including the timber) will not happen at a stage that adversely affects evacuation from the compartment of fire origin.
4(A)	**Mitigating Internal (Vertical) and External Fire Spread** In all but the lowest consequence class, if the structure is allowed to contribute as a source of fuel, it should be explicitly demonstrated that the fire will not spread beyond the storey of origin. This should include an explicit demonstration that internal and external detailing is sufficient to achieve this outcome.	Addressing internal spread: – Retain appropriate levels of compartmentation. – Decide appropriately challenging design fire scenarios. – Characterise internal fire. – Assess capacity of compartmentation to mitigate internal fire spread. Addressing external spread: – Decide appropriately challenging design fire scenarios. – Characterise external flame. – Determine heat flux from characterisation of external flame. – Identify threshold to evaluate against. – Include appropriate design provisions to mitigate circumvention of compartmentation.

4(B)	**Mitigating Internal (Vertical) and External Fire Spread** In all cases it should be explicitly demonstrated that the fire will not spread to neighbouring buildings.	Assess the prospect of external fire spread to neighbouring buildings, through either of: – Applying the principles of BR187 (but capturing the increased fire load due to the combustible structure and increased external flaming). – Undertaking full first principles external fire spread assessment, where the external flaming is characterised.
5	**Mitigating Internal (Horizontal) Fire Spread** Compartmentation should be such that all occupants have an adequate opportunity to remain safe. This includes all occupants with limitations that might complicate or limit their capacity to reach a place of safety. If a Personal Emergency Evacuation Plan (PEEP) is required, this will have to be constructed in a manner that suitably accounts for the use of structural timber.	Similar procedure to 4(a) (internal), but applied horizontally: – Retain appropriate levels of horizontal compartmentation. – Decide appropriately challenging design fire scenarios. – Characterise internal fire. – Assess capacity of compartmentation to mitigate internal fire spread during the required safe egress time (RSET).
6	**Expected Performance of Structure and Compartmentation** The construction should deliver its expected mechanical functionality as regards compartmentation and structural performance until the combustion of the contents and combustible structure has stopped (and accounting for the decay and cooling phases of the fire, where necessary).	– Define expected mechanical functionality. – Define performance threshold. – Decide appropriately challenging design fire scenarios. – Carry out analysis to quantify mechanical behaviour under those scenarios. – Assess performance relative to threshold. – For encapsulated structure see Principle 7, for exposed mass timber see Principle 8.
7	**Survival of Burnout with Encapsulated Mass Timber** For cases where the structure is intended to survive burnout and the structural protection strategy used is encapsulation, it should be explicitly demonstrated that the encapsulation will prevent the ignition of the timber structural elements being encapsulated for the duration of the expected fire scenarios. Given the natural performance uncertainties of encapsulation, explicit safety factors and redundancies will need to be included.	Within the process of qualifying principle 6, the following would apply: – Decide appropriately challenging design fire scenarios. – Define performance threshold for ignition. – Carry out analysis for the identified scenarios. – Assess criteria relative to the threshold.

8	**Survival of Burnout with Exposed Mass Timber** For cases where the structure is intended to survive burnout, if timber structural elements are left exposed (ie unprotected), then it is acceptable for the structural timber to ignite; nevertheless it should be explicitly demonstrated that the structural timber will extinguish (flaming combustion) after the consumption of the moveable fuel load and other internal linings. Given the natural performance uncertainties introduced by the timber products, explicit conservativeness will need to be included in the assessment of the conditions that lead to extinguishment of exposed structural timber.	Within the process of qualifying principle 6, the following two would apply: – Define a threshold for extinguishment of flaming combustion. – Carry out analysis to evaluate if the threshold is met.
9	**Sensitivity/Consequence Analysis** A sensitivity/consequence analysis that focuses on damage potential should be conducted for reasonably foreseeable failure modes, and the impacts of a fire on the timber structure, on all surrounding buildings and on fire brigade interventions.	– Identify variables and their uncertainty. – Evaluate consequences through the identified range of uncertainty. – Identify credible scenarios requiring failure analysis. – Carry out the associated failure analysis.
10	**Smouldering Combustion** Smouldering combustion is a secondary hazard that, if allowed to develop and left unattended, can challenge the integrity of the structure. The fire safety strategy for a building should explicitly acknowledge this hazard noting that the fire brigade will have a role in ensuring smouldering is addressed. These fire brigade activities should be aligned to conventional practices for more traditional forms of construction.	– Provide explicit communication to the fire brigade, articulating smouldering risk and consequences as situations that the fire brigade will encounter in a building with mass timber structures.

IMPLICATIONS OF 10 FIRE SAFETY PRINCIPLES

The proposed 10 Fire Principles have set a framework to enable the demonstration that reasonable standards of health and safety can be achieved in the event of a fire in commercial buildings with mass timber structures. The table on the following page sets out many of the likely implications of following the principles herein.

INSURANCE CONSIDERATIONS OF FIRE PRECAUTIONS

The competent designer of a commercial mass timber building should demonstrate that, in the event of fire, reasonable standards of health and safety are achieved. For higher consequence classes, this will likely be through a performance-based approach, which may follow the principles proposed within this Guidebook (as applicable), or by defining project-specific principles as part of the QDR process. It is noted that designing for life safety may not directly address project-specific property protection or business continuity goals, but fire precautions that are included in the fire strategy of commercial timber buildings introduce robustness to the building would be considered by insurers and underwriters.

A key precaution is the provision of sprinklers. Sprinkler protection is adopted in fire strategies of commercial timber buildings to mitigate the prospect of uncontrolled fires, with the expected outcome being control/suppression of the fire by the sprinkler system, possibly without ignition of the exposed timber structural elements. Nevertheless, it is expected that the competent designer charged with developing the fire strategy will assess the design and demonstrate adequate safety if fire precautions (such as sprinklers) fail. Designers should consider 'what if?' scenarios. That generally means mass timber commercial buildings will be designed not to withstand a realistic fire scenario (ie one controlled by sprinklers), but will instead be designed to withstand a reasonable worst-case scenario (when subject to an uncontrolled fire). The resulting design will typically be more conservative and add significant robustness regarding property protection and business disruption.

Sprinklers present a significant benefit for property protection, and in accordance with the 10 Fire Safety Principles, a competent fire engineer will have considered what happens were they not to activate or fail to control the fire for any reason, and incorporated mitigations against such an event in their design. The same applies for any other fire precautions, safety systems or aspects which the designers have disregarded as part of their due diligence, including fire service intervention, etc. It is anticipated that insurers and underwriters will view this positively.

FIRE SAFETY PRINCIPLES IMPLICATIONS

Principle	Implication
0	Only those who can evidence relevant education, knowledge and experience should be instructed to develop the fire safety strategy for a mass timber building. The resulting strategy may impose constraints on how the building is used and operated throughout its life.
1(A)	There can be no reduction in the level of safety achieved by a mass timber building to facilitate its construction.
1(B)	Provisions such as sprinklers, automatic fire detection and passive fire protection should not generally be assumed to be more reliable or more effective in a mass timber building relative to a non-combustible building. If an argument is to be made in support of greater reliability or effectiveness, specific evidence for a mass timber building should be developed and should be demonstrated as compatible with the case in hand.
2(A)	Sprinklers should not be considered in the fire safety strategy for the purpose of, eg increasing travel distances, reducing exit widths, increasing compartment sizes, increasing the amount of permissible unprotected area, reducing separating distances between buildings or permitting reductions in structural fire performance.
2(B)	As above, but in the case of fire brigade intervention.
3	It should be demonstrated that the timber structure does not reduce the ASET for occupants in the enclosure of fire origin. If this cannot be demonstrated, reaction-to-fire treatments or encapsulation are likely to be required to the combustible structural elements.
4(A)	Non-fire protected openings between floors, eg atria, are unlikely to be permitted. The external wall must be detailed in a manner so as to prevent vertical fire spread. This will likely require a combination of fire resisting spandrels, projections and glazing owing to the likely flame heights.
4(B)	As sprinklers must be considered as a redundancy measure, this will likely affect the permissible unprotected area to the external wall or the proximity of a mass timber building to the relevant boundary. Alternatively, greater internal compartmentation may be required.
5	The fire resistance required of fire separations, compartmentation and fire stopping may need to be greater to compensate for the potential increase in fire severity. Specific provisions, such as evacuation lifts, will likely need to be included for those who might require assistance.

6	The fire resistance required of fire separations, compartmentation and fire stopping may need to be greater to compensate for the potential increase in fire severity. The fire resistance / protection of non-combustible elements, eg steel and concrete in hybrid construction, may need to be greater to compensate for the potential increase in fire severity. Mass timber elements may require oversizing above and beyond that set out in EN 1995-1-2 for standard fire exposure to account for strength loss during the decay and cooling phases.
7	It is not sufficient to specify a lining that achieves a classification established under furnace conditions, eg $k_2$60. A separate dedicated analysis must be undertaken to quantify the performance of linings under realistic fire exposure conditions.
8	Self-extinguishment is only likely in compartments with a limited area of exposed timber structure. Therefore, the amount of visible timber may be constrained in instances where surviving burn-out is an objective. Self-extinguishment can be hampered by heat induced delamination, particularly in situations where multiple combustible surfaces can interact. This may affect adhesive choice and, thus, the supplier of cross-laminated timber (CLT).
9	The analysis scope of the fire consultant is likely to be increased as a detailed sensitivity / consequence analysis should be undertaken for all building types. Common failure modes might be identified, leading to a need to increase the redundancy of some fire strategy features.
10	Either smouldering combustion should be prevented or, through the QDR process and in the fire strategy, there must be an explicit communication with the fire brigade that intervention to stop smouldering may be a prerequisite of long- term stability. Detailing should seek to mitigate smouldering as far as practicable, eg it may be desirable to avoid exposed timber in cavities and/or to avoid penetrations through timber construction.

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6. EXAMPLE BUILDINGS

This chapter focuses on illustrative examples of different types of mass timber commercial buildings, demonstrating how the design principles and risk mitigation strategies discussed earlier in the Guidebook can be applied in practice. It explores how the use of mass timber affects overall risk profiles, helping design teams determine the appropriate fire and durability measures for each building. The example fire measures have been developed by the authors of the Guidebook, based on the 10 Fire Principles, after the conclusion of the workshops held with the fire panel of consultants and academics. To illustrate the interventions required as risk profiles increase, we have provided examples for four building types at different scales:

1. Full timber offices below 18 meters, up to 4 storeys.
2. Full timber offices between 18 and 30 meters, up to 15 storeys.
3. Hybrid offices between 18 and 30 meters, up to 15 storeys .
4. Hybrid offices over 30 meters or over 15 storeys.

The example buildings considered are based on Approved Document A disproportionate collapse consequence classes and consequence-based guidance for mass timber buildings from STA guidance document Structural timber buildings fire safety in use guidance, Volume 6 – Mass timber structures; Building Regulation compliance B3(1).

Each example building appraisal assumes a competent and qualified design team has implemented all mandatory fire and durability risk mitigation measures, including:

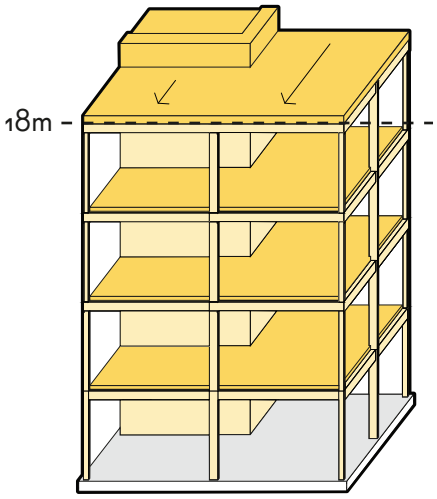
– Undertaking a Qualitative Design Review (QDR) from early design stages, identifying stakeholders' goals and fire hazards specific to the project. A QDR is needed for buildings falling outside the remit of prescriptive guidance, as is the case for mass timber buildings where the structure is exposed and contributes as a source of fuel.
– Comprehensive fire strategy by competent professional following the 10 Fire Principles. By addressing these 10 principles, it is proposed that the adequacy of the fire safety design of a mass timber building can be demonstrated

Each example building outlines potential risk mitigation interventions, but these are not exhaustive. Each building will require appropriate measures which may differ from those listed. All risk mitigation guidance provided here should be reviewed, verified and approved by the designers responsible for the project.

The example buildings are assessed using the FPA RICS Authority Building Risk Evaluation Tool (FPA RICSA BRET), which includes 26 parameters to help define the insurance risk profile of a project. If new features not included in the examples, like balconies or electric vehicle (EV) charging points, are added to a design, the designers must specifically address and plan for the specific challenges these features present.

This Guidebook is intended for the preliminary design of buildings and structures. The use of the guidelines provided in the example building appraisal does not replace the need for design and calculations by responsible designers (including, but not limited to, structural, fire or building physics experts).

6.1 EXAMPLE BUILDING - TYPOLOGY 1



STRUCTURAL MATERIAL
Full timber

HEIGHT
4 storeys and <18 metres

BUILDING NIA
2,000 m²

MAX. FLOOR CAPACITY
1 in 12 m² NIA (60 people/floor)

CONSTRUCTION
Offsite Category 3 and 5

EXPOSED SURFACES
Glulam columns and beams
CLT soffits

COST
<£25 million

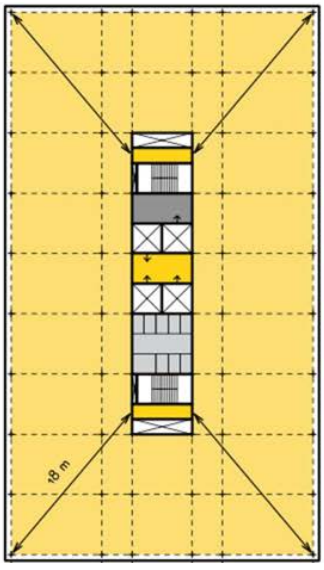
CONSEQUENCE CLASS
Class 2A

BUILDING DESCRIPTION

Illustrative example Type 1 is a 4 storey **commercial office building**

It is made from a **full timber construction**, using mass timber floor slabs and mass timber columns and beams. The core is also constructed to from CLT.

The building has a **timber roof** installed to falls and uses lightweight timber frame construction within the toilets and service areas.



An example plan of the illustrative building

	FPA RICSA BRET PARAMETER	OUTCOME
1	**Building Use and Occupancy**	Commercial
2	**Building Height and Storeys**	4 storeys, <18 metres
3	**Building Footprint**	<5,000 m²
4	**Size of Compartment (% Area)**	Single floor, <20% of total area
5	**Size of Compartment (% Volume)**	<25% total volume
6	**Structural Material**	Full Timber (CLT & Glulam)
7	**Ground Floor Structure**	Concrete GF slab. Timber above +150mm
8	**Construction Method**	Offsite Category 3 and 5
9	**Core Structure**	CLT
10	**Floor Structure**	CLT
11	**Façade System**	Non-combustible
12	**Interior Surfaces**	CLT
13	**Atria**	None
14	**Internal Car Parking**	None
15	**Balconies**	None
16	**Swimming Pool/Spa/Sauna**	None
17	**Hazardous Materials**	None
18	**Eco Surfaces**	None
19	**Renewable Energy Systems**	PV panels installed to roof
20	**Combustible Void Protection**	Dry lined with sprinkler protection and fire detection
21	**Detection/Suppression**	Early detection
22	**Separation**	Assessed to provide correct fire resistance from boundary
23	**Firefighter Provisions**	Dry risers provided
24	**Stairwells**	2 no. stairwells
25	**Flood Risk and Resilience**	Considered a low flood risk zone.
26	**EOW Risk and Resilience**	Lightweight timber frame and sensors to high risk areas.

FIRE RISK MITIGATIONS FOR EXAMPLE BUILDING 1		
Intervention		**Reason for inclusion**
Sprinklers		Not required unless identified through the QDR and development of the fire strategy as a requirement.
Non-combustible core		Not required unless identified through the QDR and development of the fire strategy as a requirement.
Minimum two staircases	○	To satisfy Principle 1(a) providing alternative means of vertical escape. May not be required for buildings <11m.
Compartmentation between floors	○	To satisfy Principle 4(a) demonstrating fire does not spread beyond the story of origin (unless concluded through the QDR and agreed with approving authorities, insurers and other stakeholders as not being required).
Façade design to prevent floor to floor fire spread	○	To satisfy Principle 4(a) demonstrating fire does not spread beyond the story of origin (unless concluded through the QDR and agreed with approving authorities, insurers and other stakeholders as not being required).
Demonstration of auto-extinction		Not required unless identified through the QDR and development of the fire strategy as a requirement.
Heat-resistant adhesives		Not required unless identified through the QDR and development of the fire strategy as a requirement.
Protection to top of mass timber slab	○	To satisfy Principle 6, preventing simultaneous ignition on the top and bottom of the mass timber slab (unless concluded through the QDR and agreed with approving authorities, insurers and other stakeholders as not being required).
Non-combustible façade construction	○	To satisfy Principle 4(a) and 4(b), mitigating internal (vertical) and external fire spread (unless concluded through the QDR and agreed with approving authorities, insurers and other stakeholders as not being required).
Fire and Rescue Service required to tackle smouldering fire		Not required unless identified through the QDR and development of the fire strategy as a requirement.
Connections between floors enclosed in fire resisting construction	○	To satisfy Principle 4(a), mitigating internal (vertical) fire spread (unless concluded through the QDR and agreed with approving authorities, insurers and other stakeholders as not being required).

KEY

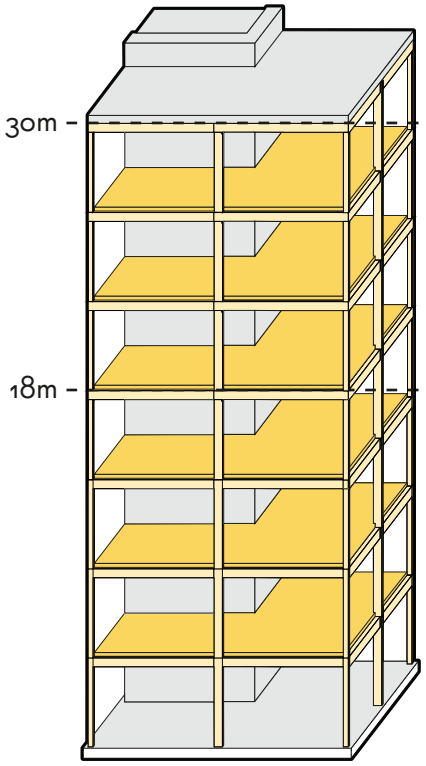
● Intervention required ○ Possible intervention required

DURABILITY RISK MITIGATIONS FOR EXAMPLE BUILDING 1		
Intervention		**Reason for inclusion**
Roof to minimum 1:40 falls	●	To satisfy Principle 3 - Risk identification; Principle 5 - Keep timber dry; Principle 8 - Remove critical vulnerabilities
End grain sealant applied post machining of panels	●	To satisfy Principle 3 - Risk identification; Principle 5 - Keep timber dry; Principle 8 - Remove critical vulnerabilities
Taped joints	●	To satisfy Principle 3 - Risk identification; Principle 5 - Keep timber dry; Principle 8 - Remove critical vulnerabilities
GF timber min. 150mm from FFL to external walls. Above FFL to internal walls	●	To satisfy Principle 1 - Understand material properties; Principle 2 - Specify appropriate materials; Principle 3 - Risk identification; Principle 5 - Keep timber dry; Principle 8 - Remove critical vulnerabilities
Construction phase moisture management strategy	●	To satisfy Principle 7 - Moisture management in assembly
Install membrane to top face of CLT floors	●	To satisfy Principle 7 - Moisture management in assembly
System leak detection (water mains pressure)	●	To satisfy Principle 6 - Early intervention
Localised moisture detectors near timber structure in high risk areas.	●	To satisfy Principle 6 - Early intervention
Localised moisture detectors in timber	●	To satisfy Principle 6 - Early intervention
Ground level concrete/steel podium		No high risk areas at ground floor.
Change to lightweight timber frame in high risk areas	●	To satisfy Principle 6 - Early intervention
External down pipes or down pipes in concrete structure		No concrete structure
Services in higher durability zones		No higher durability zones. Sensors installed in place
Alternative material to roof slabs	●	To satisfy Principle 1 - Understand material properties; Principle 2 - Specify appropriate materials; Principle 3 - Risk identification; Principle 5 - Keep timber dry; Principle 8 - Remove critical vulnerabilities

KEY

● Intervention required

6.2 EXAMPLE BUILDING - TYPOLOGY 2



STRUCTURAL MATERIAL
Full timber with concrete core

HEIGHT
10 storeys and <30m

BUILDING FOOTPRINT
>1,000m² <20,000 m²

MAX. FLOOR CAPACITY
1 in 12 m²

CONSTRUCTION
Offsite Category 3 and 5

EXPOSED SURFACES
CLT/Glulam and Concrete

COST
£40 million

CONSEQUENCE CLASS
Class 2B

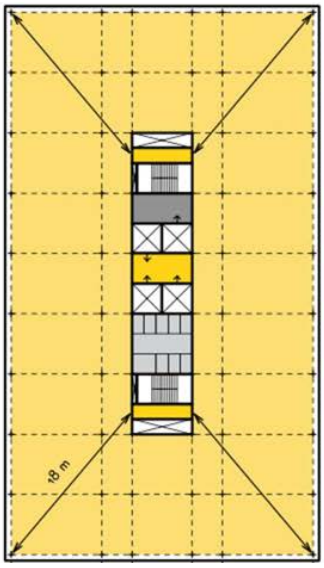
BUILDING DESCRIPTION

Illustrative example Type 2 is a 10 storey **commercial office building** under 30 meters.

It is made from a **full timber construction**, using mass timber floor slabs and mass timber columns and beams however the core is constructed from **concrete**.

The building has a **non combustible roof** installed to falls. The toilets and service areas are considered to be within the concrete core.

It is clad in a **non-combustible rainscreen cladding system**, with provisions to prevent fire spread between floors



An example plan of the illustrative building

	FPA RICSA BRET PARAMETER	OUTCOME
1	**Building Use and Occupancy**	Commercial
2	**Building Height and Storeys**	10 storeys <30 metres
3	**Building Footprint**	<20,000 m²
4	**Size of Compartment (% Area)**	Single floor, <15% of total area
5	**Size of Compartment (% Volume)**	<15% total volume
6	**Structural Material**	Full Timber (CLT & Glulam) ex. core and roof
7	**Ground Floor Structure**	Concrete GF slab. Timber above +150mm
8	**Construction Method**	Offsite Category 3 and 5
9	**Core Structure**	Concrete
10	**Floor Structure**	CLT
11	**Façade System**	Non-combustible, fire spread prevention between floors
12	**Interior Surfaces**	CLT + Concrete
13	**Atria**	None
14	**Internal Car Parking**	None
15	**Balconies**	None
16	**Swimming Pool/Spa/Sauna**	None
17	**Hazardous Materials**	None
18	**Eco Surfaces**	None
19	**Renewable Energy Systems**	PV panels installed to roof
20	**Combustible Void Protection**	Dry lined with sprinkler protection and fire detection
21	**Detection/Suppression**	Early detection and sprinkler system
22	**Separation**	Assessed to provide correct fire resistance from boundary
23	**Firefighter Provisions**	Dry risers provided
24	**Stairwells**	2 no. stairwells
25	**Flood Risk and Resilience**	Non timber roof. Considered a low flood risk zone.
26	**EOW Risk and Resilience**	Plumbed services and service risers all within concrete core

FIRE RISK MITIGATIONS FOR EXAMPLE BUILDING 2		
Intervention		**Reason for inclusion**
Sprinklers	●	To satisfy Principle 1(a) by reducing the probability that the structure becomes a source of fuel.
Non-combustible core	●	To satisfy Principle 1(a) providing means of vertical escape and firefighting access that cannot become source of fuel.
Minimum two staircases	●	To satisfy Principle 1(a) providing alternative means of vertical escape.
Compartmentation between floors	●	To satisfy Principle 4(a) mitigating internal (vertical) fire spread
Façade design to prevent floor to floor fire spread	●	To satisfy Principle 4(a), noting this may involve fire resisting elements of façades, staggering openings (including windows, doors) or façade projections.
Demonstration of auto-extinction	●	To satisfy Principle 6 and 8, demonstrating the structure can survive burnout.
Heat-resistant adhesives	○	To satisfy Principle 8, reducing the risk of heat-induced delamination, unless concluded through the QDR and agreed with approving authorities, insurers and other stakeholders as not being required.
Protection to top of mass timber slab	●	To satisfy Principle 6, preventing simultaneous ignition on the top and bottom of the mass timber slab.
Non-combustible façade construction	●	To satisfy Principle 4(a) and 4(b), mitigating internal (vertical) and external fire spread
Fire and Rescue Service required to tackle smouldering fire	●	To satisfy Principle 10, managing smouldering combustion
Connections between floors enclosed in fire resisting construction	●	To satisfy Principle 4(a), mitigating internal (vertical) fire spread

KEY

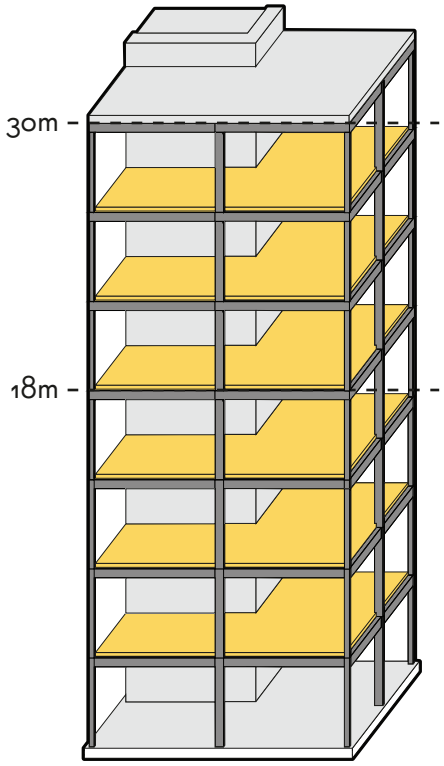
● Intervention required ○ Possible intervention required

DURABILITY RISK MITIGATIONS FOR EXAMPLE BUILDING 2		
Intervention		**Reason for inclusion**
Roof to minimum 1:40 falls	●	To satisfy Principle 3 - Risk identification; Principle 5 - Keep timber dry; Principle 8 - Remove critical vulnerabilities
End grain sealant applied post machining of panels	●	To satisfy Principle 3 - Risk identification; Principle 5 - Keep timber dry; Principle 8 - Remove critical vulnerabilities
Taped joints	●	To satisfy Principle 3 - Risk identification; Principle 5 - Keep timber dry; Principle 8 - Remove critical vulnerabilities
GF timber min. 150mm from FFL to external walls. Above FFL to internal walls	●	To satisfy Principle 1 - Understand material properties; Principle 2 - Specify appropriate materials; Principle 3 - Risk identification; Principle 5 - Keep timber dry; Principle 8 - Remove critical vulnerabilities
Construction phase moisture management strategy	●	To satisfy Principle 7 - Moisture management in assembly
Install membrane to top face of CLT floors	●	To satisfy Principle 7 - Moisture management in assembly
System leak detection (water mains pressure)	●	To satisfy Principle 6 - Early intervention
Localised moisture detectors near timber structure in high risk areas.	●	To satisfy Principle 6 - Early intervention
Localised moisture detectors in timber		Timber not located close to moisture sources
Ground level concrete/steel podium		Building not considered within a flood risk and only low risk areas at ground floor
Change to lightweight timber frame in high risk areas		Not required as high risk areas in concrete structure
External down pipes or down pipes in concrete structure	●	To satisfy Principle 1 - Understand material properties; Principle 2 - Specify appropriate materials; Principle 3 - Risk identification; Principle 5 - Keep timber dry; Principle 8 - Remove critical vulnerabilities
Services in higher durability zones	●	Service risers and high-risk serviced zones within concrete core.
Alternative material to roof slabs	●	To satisfy Principle 1 - Understand material properties; Principle 2 - Specify appropriate materials; Principle 3 - Risk identification; Principle 5 - Keep timber dry; Principle 8 - Remove critical vulnerabilities

KEY

● Intervention required

6.3 EXAMPLE BUILDING - TYPOLOGY 3



STRUCTURAL MATERIAL
Hybrid (CLT & steel/concrete)

HEIGHT
10 storeys and <30m

BUILDING NIA
>30,000 m², <50,000 m²

MAX. FLOOR CAPACITY
1 in 12 m² NIA

CONSTRUCTION
Offsite Category 3 and 5

EXPOSED SURFACES
CLT/Steel or Concrete

COST
£50 million

CONSEQUENCE CLASS
Class 2B

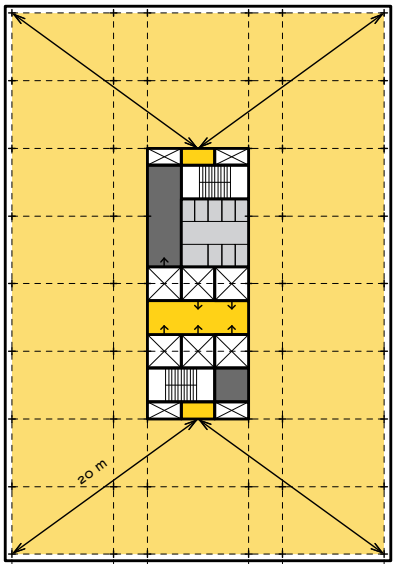
BUILDING DESCRIPTION

Illustrative example Type 3 is a **commercial office building** with retail use at ground floor.

It is made from a **hybrid construction**, using mass timber floor slabs and steel columns and beams. It has a concrete core with exposed CLT floor slabs to upper floor office space.

The building has a **non combustible roof** installed to falls.

It is clad in a **non-combustible rainscreen cladding system**, with provisions to prevent fire spread between floors.



An example plan of the illustrative building

	FPA RICSA BRET PARAMETER	OUTCOME
1	**Building Use and Occupancy**	Commercial
2	**Building Height and Storeys**	10 storeys, <30m
3	**Building Footprint**	>30,000 m²/<50,000 m²
4	**Size of Compartment (% Area)**	Single floor, <15% of total area
5	**Size of Compartment (% Volume)**	<15% total volume
6	**Structural Material**	Hybrid (CLT & steel/concrete)
7	**Ground Floor Structure**	Concrete
8	**Construction Method**	Offsite Category 3 and 5
9	**Core Structure**	Steel or concrete
10	**Floor Structure**	CLT
11	**Façade System**	Non-combustible, fire spread prevention between floors
12	**Interior Surfaces**	CLT + steel/concrete
13	**Atria**	None
14	**Internal Car Parking**	None
15	**Balconies**	None
16	**Swimming Pool/Spa/Sauna**	None
17	**Hazardous Materials**	None
18	**Eco Surfaces**	None
19	**Renewable Energy Systems**	PV panels installed to roof
20	**Combustible Void Protection**	Dry lined with sprinkler protection and fire detection
21	**Detection/Suppression**	Early detection system and sprinkler system
22	**Separation**	> 6m from relevant boundary
23	**Firefighter Provisions**	Dry risers provided
24	**Stairwells**	2 no. stairwells
25	**Flood Risk and Resilience**	Non timber roof. Considered a low flood risk zone.
26	**EOW Risk and Resilience**	Plumbed services and service risers all within concrete core

FIRE RISK MITIGATIONS FOR EXAMPLE BUILDING 3		
Intervention		**Reason for inclusion**
Sprinklers	○	To satisfy Principle 1(a) by reducing the probability that the structure becomes a source of fuel. Required unless concluded through the QDR and agreed with approving authorities, insurers and other stakeholders as not being required.
Non-combustible core	●	To satisfy Principle 1(a) providing means of vertical escape and firefighting access that cannot become source of fuel.
Minimum two staircases	●	To satisfy Principle 1(a) providing alternative means of vertical escape.
Compartmentation between floors	●	To satisfy Principle 4(a) mitigating internal (vertical) fire spread
Façade design to prevent floor to floor fire spread	●	To satisfy Principle 4(a), noting this may involve fire resisting elements of façades, staggering openings (including windows, doors) or façade projections.
Demonstration of auto-extinction	●	To satisfy Principle 6 and 8, demonstrating the structure can survive burnout.
Heat-resistant adhesives		Not required unless identified through the QDR and development of the fire strategy as a necessary measure to reduce the risk of heat-induced delamination.
Protection to top of mass timber slab	●	To satisfy Principle 6, preventing simultaneous ignition on the top and bottom of the mass timber slab.
Non-combustible façade construction	●	To satisfy Principle 4(a) and 4(b), mitigating internal (vertical) and external fire spread
Fire and Rescue Service required to tackle smouldering fire	●	To satisfy Principle 10, managing smouldering combustion
Connections between floors enclosed in fire resisting construction	●	To satisfy Principle 4(a), mitigating internal (vertical) fire spread

KEY

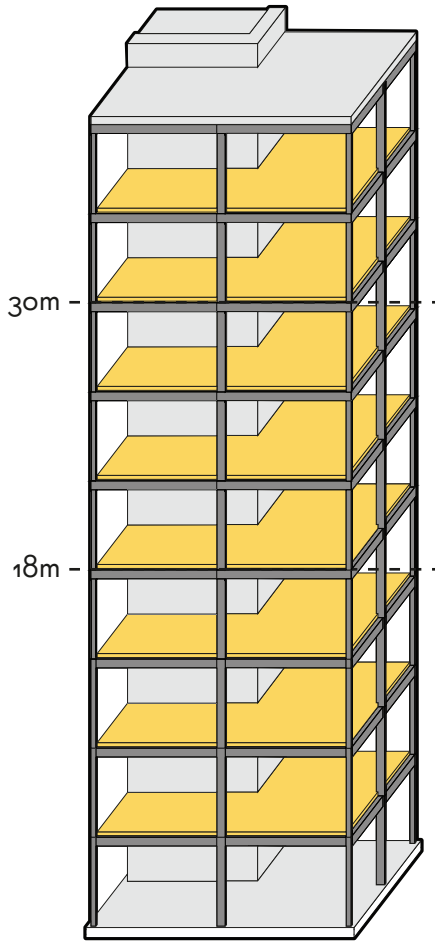
● Intervention required ○ Possible intervention required

DURABILITY RISK MITIGATIONS FOR EXAMPLE BUILDING 3		
Intervention		**Reason for inclusion**
Roof to minimum 1:40 falls	●	To satisfy Principle 3 - Risk identification; Principle 5 - Keep timber dry; Principle 8 - Remove critical vulnerabilities
End grain sealant applied post machining of panels	●	To satisfy Principle 3 - Risk identification; Principle 5 - Keep timber dry; Principle 8 - Remove critical vulnerabilities
Taped joints	●	To satisfy Principle 3 - Risk identification; Principle 5 - Keep timber dry; Principle 8 - Remove critical vulnerabilities
GF timber min. 150mm from FFL to external walls. Above FFL to internal walls	●	To satisfy Principle 1 - Understand material properties; Principle 2 - Specify appropriate materials; Principle 3 - Risk identification; Principle 5 - Keep timber dry; Principle 8 - Remove critical vulnerabilities
Construction phase moisture management strategy	●	To satisfy Principle 7 - Moisture management in assembly
Install membrane to top face of CLT floors	●	To satisfy Principle 7 - Moisture management in assembly
System leak detection (water mains pressure)	●	To satisfy Principle 6 - Early intervention
Localised moisture detectors near timber structure in high risk areas.		Timber not located close to moisture sources or high risk areas.
Localised moisture detectors in timber		Timber not located close to moisture sources..
Ground level concrete/steel podium	●	To satisfy Principle 1 - Understand material properties; Principle 2 - Specify appropriate materials; Principle 3 - Risk identification; Principle 5 - Keep timber dry; Principle 8 - Remove critical vulnerabilities
Change to lightweight timber frame in high risk areas		Not required as high risk areas in concrete structure
External down pipes or down pipes in concrete structure	●	To satisfy Principle 1 - Understand material properties; Principle 2 - Specify appropriate materials; Principle 3 - Risk identification; Principle 5 - Keep timber dry; Principle 8 - Remove critical vulnerabilities
Services in higher durability zones	●	Service risers and high-risk serviced zones within concrete core.
Alternative material to roof slabs	●	To satisfy Principle 1 - Understand material properties; Principle 2 - Specify appropriate materials; Principle 3 - Risk identification; Principle 5 - Keep timber dry; Principle 8 - Remove critical vulnerabilities

KEY

● Intervention required

6.4 EXAMPLE BUILDING - TYPOLOGY 4



STRUCTURAL MATERIAL
Hybrid (CLT & steel/concrete)

HEIGHT
>15 storeys and >30 m

BUILDING NIA
>10,000 m²

MAX. FLOOR CAPACITY
1 in 12 m² NIA

CONSTRUCTION
Offsite Category 3 and 5

EXPOSED SURFACES
CLT Soffits and Concrete

COST
<£500 million

CONSEQUENCE CLASS
Class 3

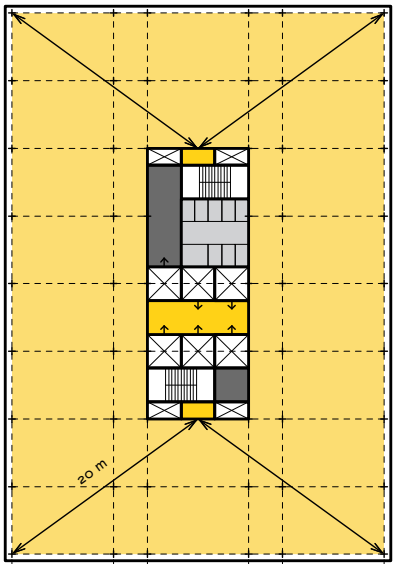
BUILDING DESCRIPTION

Illustrative example Type 4 is a **commercial office building** with retail use at ground floor.

It is made from a **hybrid construction**, using mass timber floor slabs and steel columns and beams. It has a concrete core with exposed CLT floor slabs to upper floor office space.

The building has a **non combustible roof** installed to falls.

It is clad in a **non-combustible rainscreen cladding system**, with provisions to prevent fire spread between floors.



An example plan of the illustrative building

	FPA RICSA BRET PARAMETER	OUTCOME
1	**Building Use and Occupancy**	Commercial
2	**Building Height and Storeys**	>15 storeys >30 m
3	**Building Footprint**	>30,000 m²/<50,000 m²
4	**Size of Compartment (% Area)**	Single floor, <10% of total area
5	**Size of Compartment (% Volume)**	<10% total volume
6	**Structural Material**	Hybrid (CLT & steel/concrete)
7	**Ground Floor Structure**	Concrete
8	**Construction Method**	Offsite Category 3 and 5
9	**Core Structure**	Steel or concrete
10	**Floor Structure**	CLT
11	**Façade System**	Non-combustible, fire spread prevention between floors
12	**Interior Surfaces**	CLT + steel/concrete
13	**Atria**	None
14	**Internal Car Parking**	None
15	**Balconies**	None
16	**Swimming Pool/Spa/Sauna**	None
17	**Hazardous Materials**	None
18	**Eco Surfaces**	None
19	**Renewable Energy Systems**	PV panels installed to roof
20	**Combustible Void Protection**	Dry lined with sprinkler protection and fire detection
21	**Detection/Suppression**	Early detection system and sprinkler system
22	**Separation**	> 6m from relevant boundary
23	**Firefighter Provisions**	Dry risers provided
24	**Stairwells**	2 no. stairwells
25	**Flood Risk and Resilience**	Non timber roof. Considered a low flood risk zone
26	**EOW Risk and Resilience**	Plumbed services and service risers all within concrete core

FIRE RISK MITIGATIONS FOR EXAMPLE BUILDING 4		
Intervention		**Reason for inclusion**
Sprinklers	●	To satisfy Principle 1(a) by reducing the probability that the structure becomes a source of fuel.
Non-combustible core	●	To satisfy Principle 1(a) providing means of vertical escape and firefighting access that cannot become source of fuel.
Minimum two staircases	●	To satisfy Principle 1(a) providing alternative means of vertical escape.
Compartmentation between floors	●	To satisfy Principle 4(a) mitigating internal (vertical) fire spread
Façade design to prevent floor to floor fire spread	●	To satisfy Principle 4(a), noting this may involve fire resisting elements of façades, staggering openings (including windows, doors) or façade projections.
Demonstration of auto-extinction	●	To satisfy Principle 6 and 8, demonstrating the structure can survive burnout.
Heat-resistant adhesives	●	To satisfy Principle 8, reducing the risk of heat-induced delamination, unless concluded through the QDR.
Protection to top of mass timber slab	●	To satisfy Principle 6, preventing simultaneous ignition on the top and bottom of the mass timber slab.
Non-combustible façade construction	●	To satisfy Principle 4(a) and 4(b), mitigating internal (vertical) and external fire spread
Fire and Rescue Service required to tackle smouldering fire	●	To satisfy Principle 10, managing smouldering combustion
Connections between floors enclosed in fire resisting construction	●	To satisfy Principle 4(a), mitigating internal (vertical) fire spread

KEY

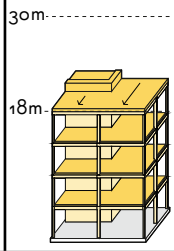
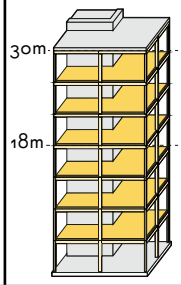
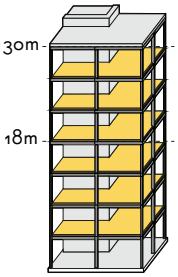
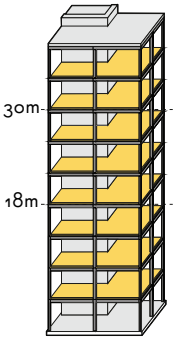
● Intervention required

DURABILITY RISK MITIGATIONS FOR EXAMPLE BUILDING 4		
Intervention		**Reason for inclusion**
Roof to minimum 1:40 falls	●	To satisfy Principle 3 - Risk identification; Principle 5 - Keep timber dry; Principle 8 - Remove critical vulnerabilities
End grain sealant applied post machining of panels	●	To satisfy Principle 3 - Risk identification; Principle 5 - Keep timber dry; Principle 8 - Remove critical vulnerabilities
Taped joints	●	To satisfy Principle 3 - Risk identification; Principle 5 - Keep timber dry; Principle 8 - Remove critical vulnerabilities
GF timber min. 150mm from FFL to external walls. Above FFL to internal walls	●	To satisfy Principle 1 - Understand material properties; Principle 2 - Specify appropriate materials; Principle 3 - Risk identification; Principle 5 - Keep timber dry; Principle 8 - Remove critical vulnerabilities
Construction phase moisture management strategy	●	To satisfy Principle 7 - Moisture management in assembly
Install membrane to top face of CLT floors	●	To satisfy Principle 7 - Moisture management in assembly
System leak detection (water mains pressure)	●	To satisfy Principle 6 - Early intervention
Localised moisture detectors near timber structure in high risk areas.		Timber not located close to moisture sources or high risk areas.
Localised moisture detectors in timber		Timber not located close to moisture sources..
Ground level concrete/steel podium	●	To satisfy Principle 1 - Understand material properties; Principle 2 - Specify appropriate materials; Principle 3 - Risk identification; Principle 5 - Keep timber dry; Principle 8 - Remove critical vulnerabilities
Change to lightweight timber frame in high risk areas		Not required as high risk areas in concrete structure
External down pipes or down pipes in concrete structure	●	To satisfy Principle 1 - Understand material properties; Principle 2 - Specify appropriate materials; Principle 3 - Risk identification; Principle 5 - Keep timber dry; Principle 8 - Remove critical vulnerabilities
Services in higher durability zones	●	Service risers and high-risk serviced zones within concrete core.
Alternative material to roof slabs	●	To satisfy Principle 1 - Understand material properties; Principle 2 - Specify appropriate materials; Principle 3 - Risk identification; Principle 5 - Keep timber dry; Principle 8 - Remove critical vulnerabilities

KEY

● Intervention required

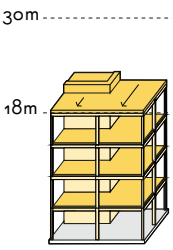
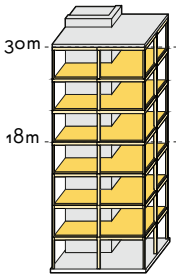
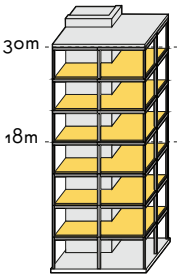
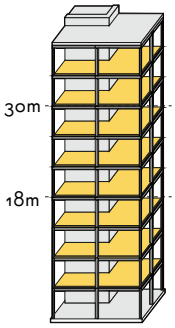
6.5 COMPARATIVE EXAMPLES

FIRE SAFETY INTERVENTIONS	TYPE 1 <18m ≤4 storeys Timber structure 	TYPE 2 18m-30m ≤15 storeys Timber structure 	TYPE 3 18m-30m ≤15 storeys Hybrid structure 	TYPE 4 >30m >15 storeys Hybrid structure 
Sprinklers		●	○	●
Non-combustible core		●	●	●
Minimum two staircases	○	●	●	●
Compartmentation between floors	○	●	●	●
Façade design to prevent floor to floor fire spread	○	●	●	●
Demonstration of auto-extinction		●	●	●
Heat-resistant adhesives		○		●
Protection to top of mass timber slab	○	●	●	●
Non-combustible façade construction	○	●	●	●
Fire and Rescue Service required to tackle smouldering fire		●	●	●
Floor connections enclosed in fire resistant construction	○	●	●	●

KEY

● Intervention required ○ Possible intervention required ● Intervention required

For more information see the introduction to Section 6 and section 6.1-6.4

DURABILITY INTERVENTIONS	**TYPE 1** <18m ≤4 storeys Timber structure 	**TYPE 2** 18m-30m ≤15 storeys Timber structure 	**TYPE 3** 18m-30m ≤15 storeys Hybrid structure 	**TYPE 4** >30m >15 storeys Hybrid structure 
Roof to minimum 1:40 falls	●	●	●	●
End grain sealant applied post machining of panels	●	●	●	●
Taped joints	●	●	●	●
GF timber ≥150mm FFL to external walls, above FFL to internal walls	●	●	●	●
Construction phase water management strategy	●	●	●	●
Install membrane to top face of CLT floors	●	●	●	●
System leak detection (water mains pressure)	●	●	●	●
Localised moisture detectors near timber structure in high risk area	●	●		
Localised moisture detectors in timber	●			
Ground level concrete/steel podium			●	●
Change to lightweight timber frame in high risk areas	●			
External down pipes or down pipes in concrete structure		●	●	●
Services in higher durability zones		●	●	●
Alternative material to roof slabs		●	●	●

7. APPENDICES

7.1 TYPES OF INSURANCE

The insurance requirement for every project is unique. There is no single insurance product or set of insurance policies that can meet everyone's unique needs and requirements.

The following is a list of commonly available and generally necessary insurances, accompanied by a brief description of their basic purpose.

Insurances for construction-related projects need the experienced advice and guidance of a competent insurance broker or consultant advisor. The nuances of insurance contracts are too many and varied for anyone to take the risk of arranging insurances without competent advice.

This is even more important in the case of insurances for projects involving mass timber construction because the insurance industry has yet to design insurance contracts specifically for mass timber, in light of the new and, to some extent, unknown risks that it will present.

Contractors all risk insurance/contract works insurance (annual or single project)
A key critical policy that covers the 'Client' and Contractor/s against 'All Risks' (as defined), including: Contract Works; Owned Plant and Machinery; Hired In Plant; Business Interruption; Public & Employers' Liability; Contractors JCT 6.5.1 (collapse & subsidence etc) (other extensions to cover may be available form some insurers).

Combined/contents/office building insurance
Covers the property and business interests of the Business owner. Physical loss or damage; Public and Employers' liabilities, Business interruption; Loss of rent and other relevant covers, by arrangement with insurer.

Professional indemnity insurance
Essential cover for all providers of professional / subcontractor services. Covers the legal liability of the individual firm for negligence and / or negligent breach of contract. Clients and contractors should ensure it is held and maintained by every relevant party for the duration of the project and six years beyond. PI insurance only covers claims MADE during the period of the policy.

Public liability insurance
Essential insurance and always required of business owners and contractors to provide cover against liability for personal injury or death, or loss or damage to property of third parties who may come into or near the site. Public liability insurance and Employers' liability insurance are usually offered in a single policy.

Directors' and officers insurance
Covers the legal liability of the company's directors and officers (as defined) arising from 'Wrongful Acts' (as defined). Essentially, failing to meet their statutory obligations as a shadow director, or officer of a company. Essential protection for the personal liability of the directors and officers and must cover them in case of insolvency/administration, etc.

Collateral warranty
A collateral warranty acts as a legally binding bridge between parties in a project that do not have a direct relationship with each other. Eg principal contractor, sub-contractor/s consultant/s, funder, purchaser or tenant.

The warranty enables the third party to enforce certain rights or obligations otherwise not available to them directly against the party providing the collateral warranty, providing an additional layer of protection and assurance in complex contractual arrangements. It is a complex matrix of obligations that should be reinforced by the relevant (typically the PI and PL) insurances.

Latent defects insurance
Covers new buildings (or new works to existing buildings) in the event that a latent defect (as defined) become apparent. Can provide useful indemnity against consequences of defects but cover is tightly defined, and claims can be complex and time consuming.

Integrated projects insurance
A novel and not yet 'tried and tested' concept intended to remove the 'apportionment of blame - interparty Alliance' claims that typically frustrate a claim against the principal contractor for liability arising from a subcontractor / professional. Not widely available. Not a proven concept.

Legal expenses insurance
Provides cover up to a specific limit of indemnity against the cost of pursuing or defending legal actions. Typically, includes contract disputes; Tax investigations; Criminal defence; Health & Safety investigations; Employment disputes. Cover varies between insurers and will only pay if prospects of success are at least 51%.

Legal indemnity insurance
Covers legal costs of Breach of covenant; Absence of easement; Absence of planning permission/building regulations; Rights of Light.

Residual value insurance
Protects against loss of asset value typically for Commercial Real Estate or Tools, Plant, Equipment Assures that a properly maintained asset will have a specified value at a future date. Helps to make asset risk counter-cyclical to inflation and with benefits including eg risk mitigation and capital optimization.

Terrorism insurance
Covers risks of loss arising from terrorist acts. Can be obtained on a 'stand-alone' basis or as an addition to a conventional buildings or commercial combined policy. Relevant for projects or buildings located in areas which may be considered as high-risk terrorist targets.

Performance bond
A bond is not an insurance contract – it is a bond Commonly used to protect against the risk of a contractor failing to fulfil contractual obligations; eg through insolvency/ administration. A bond provides a guarantee (without proof of legal liability) up to the amount of the bond. Bonds can be issued either by an insurance company or bank.

Miscellaneaous insurances
The above is not an exhaustive or definitive list of insurances. If a business entity perceives a risk that it would like to transfer to a third party, and the said risk is not covered by the ordinarily available insurances, then the risk can be presented to Lignum Risk Partners for an assessment as to whether a bespoke insurance contract can be designed to meet the specific need and offered to the markets. The traditional insurance market is augmented by the Alternative Risk Transfer (ART) market, and this can give greater scope for transferring unusual or innovative risks.

This information is not and does not purport to be professional insurance advice.

No responsibility is or can be taken by the authors of this guide for reliance upon the insurance information.

It is highly recommended that professional insurance advice is taken from an advisor with expertise and experience appropriate to each class of insurance.

7.2 GLOSSARY

ANISOTROPY: An anisotropic material such as wood exhibits properties that are different dependent upon the directionality, location considered on the material, or where and how force is applied to the material. Anisotropic materials have properties of the material that are directionally dependent. (Wikipedia)

BIOLOGICAL DECAY (OF TIMBER): Any undesirable change in the properties of material of economic importance brought about by the activities of living organisms. (Hans Hueck definition of biodegradation)

CAPILLARITY: Capillarity suction moves liquid moisture slowly through porous materials from regions of high liquid concentration to regions of low concentration; (...) although the rate of moisture transport by this mechanism is relatively slow, it can act for years. (ASHRAE Journal Jan 2002 Moisture)

DURABILITY: Ability of a constructed asset or any of its components to perform its required functions over a specified period of time without unforeseen maintenance or repairs. (ISO Standard 20887:2020)

DISASSEMBLY: Non-destructive taking apart of a construction work or constructed asset into constituent materials and components. (ISO Standard 20887:2020(E))

DEFLECTION: Movement/deformation of a structural element/component from its original position due to forces and loads being applied to it. (designingbuildings.co.uk)

DELAMINATION: In this document only the separations in bonding areas that are caused by adhesive failure are called delamination.

DEMOLITION: The action taken at the end of a building's useful life with little or no regard for the potential reuse, recovery, repurposing or recycling of its components. (Circularity Concepts in wood Construction. Unece.org)

DESIGN LIFE (OF A BUILDING): Period of use (of a building, structure or component) as intended by the designer after which it may need to be replaced. Before this period has elapsed, it should remain fit for purpose; will vary according to the type and use of the element being considered. BS EN 1990, Eurocode - Basis of structural design, (Eurocode 0) gives indicative design lives for various types of structure. (designingbuildings.co.uk)

EQUILIBRIUM MOISTURE CONTENT (EMC): Moisture content at which wood is neither gaining nor losing moisture. EMC is influenced more by relative humidity than temperature, and the environment and elements to which it is exposed. (MTBSP, 2021 / Glass and Zelinka 2010)

ENGINEERED TIMBER: 'Engineered timber', also known as 'Mass timber', relates to wood-based composite materials. Typically, solid softwood is processed in a factory, combined with other materials (for example adhesives) and formed into a new material. These engineered timber products combine all the positive attributes of timber, for example strength, weight, sustainability etc, while removing some of the negative attributes, such as variability, stability and limited section sizes. (designingbuildings.co.uk)

ENVIRONMENTAL PRODUCT DECLARATION (EPD): A standardised (ISO14025), verified document that transparently reports the lifecycle assessment of a product in a single place. The European Technical Assessment is the documented assessment of the performance of a construction product in relation to its essential characteristics undertaken to CE-mark the product.

HYGROSCOPICITY: Hygroscopicity affects all wood properties. For example, moisture content can increase weight 100 percent or more, with consequent effects on transportation costs. Variation in moisture content causes wood to shrink or swell, altering its dimensions. Resistance to decay and insects is greatly affected. The working,

gluing, and finishing of wood and its mechanical, thermal, and acoustic properties are all influenced by moisture content.

MOISTURE: The humidity which, as a result of unforeseen events, leads to an increase in humidity in wooden components. Causes can be weathering during the construction phase, increased building moisture or convective moisture entry through leaks in the building envelope.

MOISTURE CONTENT (MC): The term 'moisture content' (MC) refers to the amount of water contained in the pores (voids) of a material. It is usually expressed as the percentage by mass of the water present relative to the material's dry weight. (designingbuildings.co.uk)

MOISTURE MANAGEMENT: All activities that are undertaken both to prevent moisture from entering a structure where it may cause damage as well as designing a structure to withstand unwanted moisture. Since moisture originates from various sources, such as built-in moisture from manufacturing, transport and storage of building materials; moisture loads from occupants and the surrounding air; outdoor climate, rain, snow, etc, it consequently affects all stages of building and maintenance. (OBERG, A., WIEGE, E., Moisture risks with CLT-panels subjected to outdoor climate during construction, 2018)

RELATIVE HUMIDITY (RH): A measure of the water vapour density of air compared to the water vapour density for saturated air at the same temperature and pressure (maximum amount of moisture that air can 'hold' at that temperature and pressure). (designingbuildings.co.uk)

RECOVERABILITY / REPAIRABILTIY: Measure of the degree to and ease with which a product can be repaired and maintained, usually by end consumers. (Wikipedia)

RISK FACTOR: A characteristic used in a risk model as an input to determine the level of risk in a risk assessment. (NIST Special Publication 800-39)

REDUNDANCY: In engineering, redundancy is the intentional duplication of critical components or functions of a system with the goal of increasing reliability of the system, usually in the form of a backup or fail-safe, or to improve actual system performance. (Wikipedia)

SERVICEABILITY: The capability of a building, assembly, component, product or construction to perform the function (s) for which it is designed and used. (Journal of Cleaner Production, 2019)

SERVICE CLASS: A system used in timber engineering standards to specify environmental conditions: surrounding temperature and humidity which affect levels of moisture in timber exposed to these conditions. (TRADA, Moisture and humidity,2016 EN 1995 1-1)

SERVICE LIFE: Period after installation during which a building, or its part, meets or exceeds the performance requirements. ("Home Quality Mark One, Technical Manual SD239, England, Scotland & Wales, BRE, 2018". The actual time during which the building or any of its components performs without unforeseen costs or disruption for maintenance and repair. (CSA S478))

USE CLASS: Defined by British and European Standards, providing a guide to the risk of decay and insect attack to timber components, depending upon their end use. The higher the Use Class, the higher the level of preservative protection required. (BS EN 355:2012)

USEFUL LIFE (OF A BUILDING): Amount of time an asset is expected to be functional and fit-for-purpose. With regard to a building, useful life can be defined as the number of years before the building deteriorates to the point that it is no longer safe or desirable for continued use, the point at which it no longer meets existing code requirements and would be too costly to bring up to code, the point in time at which other uses for the building site are more financially viable than keeping the existing building in place, and so on. (Circularity Concepts in wood Construction. Unece.org)

VULNERABILITY: The features of an asset that we can influence or control in order to make it more or less susceptible to a particular hazard. (Guide To Climate Change Impacts, On Scotland's Historic Environment, published by Historic Environment Scotland).

The likelihood that assets will be damaged or destroyed when exposed to a hazard event. (UK Department for International Development)

WORKING LIFE (OF A BUILDING): The assumed period for which a structure or part of it is to be used for its intended purpose with anticipated maintenance but without major repair being necessary. (Eurocode 0 EN 1990)

ABBREVIATIONS

ASBP Alliance for Sustainable Building Products

BBN Built by Nature

BRET Building Risk Evaluation Tool

BWICS Builders Work Holes

CLT Cross Laminated Timber

CTG Commercial Timber Guidebook

CW Curtain Walling

DfMA Design for Manufacture and Assembly

DPC Damp Proof Course

EOW Escape Of Water

EPD Environmental Product Declaration

ETA European Technical Assessment

FFL Finished Floor Level

FPA Fire Protection Association

HID Heat Induced Delamination

ISO International Organization for Standardization

LVL Laminated Veneer Lumber

MEP Mechanical, Electrical and Plumbing

MTIP Mass Timber Insurance Playbook

NIA Net Internal Area

PUR Polyurethane Reactive

PV Photovoltaic

QDR Qualitative Design Review

RC Reinforced Concrete

RICS Royal Institute of Chartered Surveyors

RWO Rainwater Outlet

SSL Structural Slab Level

STA Structural Timber Association

SVP Soil Vent Pipe

WTA Waugh Thistleton Architects

7.3 OTHER KEY GUIDANCE DOCUMENTS

ASPB Mass Timber Insurance Playbook (MTIP), 2023

AVIVA Mass timber – Considerations for planning & design (RIBA Stages 0-4), 2024

BMTRADA Learning Resources, Introduction to timber engineering design, Moisture and humidity, 2019

RDH BUILDING SCIENCE Moisture risk management strategies for mass timber buildings, 2022, Version 2.1

RISCAUTHORITY Insurance Challenges of Massive Timber Construction, 2022

STA (Structural Timber Association), 16 steps to fire safety, 2017

STA Moisture Management Strategy, 2022, Version 1

STA Structural timber buildings fire safety in use guidance, Volume 6 – Mass timber structures; Building Regulation compliance B3(1), 2020.

STA Technical Note 24 – Moisture Protection during construction, 2022

SWEDISH WOOD Moisture-proof CLT construction without a full temporary shelter, First edition, 2022

TDUK Moisture Management During Construction, Matt Caldwell, Timber Development UK, 2024

TDUK, SWEDISH WOOD, STA www.timberfiresafety.org

WANG, J., STIRLING, R., MORRIS, P., LLOYD, J., Durability of mass timber structures: a review of the biological risks, Wood and fiber science: journal of the Society of Wood Science and Technology, 08-2018

RISCAUTHORITY IQ6 Mass timber questionnaire, 2024

FPA JCoP Construction site Escape of Water, 2024

7.4 CORE TEAM

ELLIOTT WOOD

Elliott Wood has led a consortium of experts, including Waugh Thistleton Architects, OFR Consultants and Lignum Risk Partners to produce the Commercial Timber Guidebook. As a leading structural engineering consultancy Elliott Wood has extensive experience in the design and delivery of large-scale mass timber buildings in the UK and is committed to research, development and testing to accelerate the uptake mass timber in the commercial sector.

Elliott Wood is currently delivering 38 Berkeley Square which, once complete, will be the tallest commercial timber and steel framed building in the UK. It is also the first project to achieve signoff from the London Fire Brigade and Building Control in the new era of heightened scrutiny on exposed timber, post 2020. Other exposed mass timber projects include: The Department Store Studios, a five-storey new build workspace framed by cross-laminated timber (CLT) and Notting Hill Gate, an extension and retrofit of a series of 1950s office blocks – including adding additional floors using a hybrid steel and cross-laminated timber (CLT) construction.

As a certified B Corp, Elliott Wood inspires clients and organisations to think differently about their projects — not just aesthetically and commercially — but for the benefit of the planet and people who use them every day. They have been doing this for over 30 years, marrying small details with bigger ideas and revealing hidden opportunities that allow a project to have a positive impact. Their curious and collaborative nature enables them to challenge the status quo and push the boundaries to deliver on our purpose: Engineering a Better Society.

WAUGH THISTLETON ARCHITECTS

Waugh Thistleton Architects is a London-based architectural practice founded by Andrew Waugh and Anthony Thistleton in 1997. Known for their innovative approach to sustainable design and pioneering use of timber, they have established themselves as global leaders in the field of environmentally conscious architecture. Their work spans across housing, commercial, and public projects. The common theme running through all these types is with a deep commitment to reducing the environmental impact of buildings.

Pioneers of the use of cross-laminated-timber (CLT) in the UK and beyond, in 2009 Waugh Thistelton designed and delivered the world's first tall timber tower, Murray Grove, for which they won the RIBA President's Medal for Research. Several other projects they have completed testify to their innovative, research-led approach to architectural practice: Dalston Works (2017) is the UK's tallest and largest CLT building; Vitsoe (2018) was the first example of a large-scale building completed using a hardwood LVL frame, Multiply (2018) the first example of UK manufactured CLT panels being applied to a structure. WTA developed volumetric modular housing systems for L&G and Swan (2018) and published a design guide to disseminate lessons learnt. Commercial buildings including Orsman Road (2020) and Black & White (2022) are manifestations of design for disassembly approaches.

Waugh Thistleton Architects are committed to creating beautiful buildings that are a joy to inhabit, recognized not just for their technical achievements but for their ability to balance sustainability with aesthetic and functional quality in architecture. Through innovation, advocacy, and collaboration, they continue to push the boundaries of what is possible in sustainable building design.

OFR CONSULTANTS

OFR Consultants have drafted and edited the fire-related sections of the Commercial Timber Guidebook, leading discussions with a group of fire consultants and academics to establish consensus on the fire principles presented in the Guidebook. They have extensive experience in supporting the design of mass timber and hybrid structures for new buildings and building extensions across various sectors. OFR is also actively involved in research and development collaborations with key manufacturers through the STA and the development of international codes and standards via the BSI.

The OFR team working on the Guidebook, consisting of Sam Liptrott, Prof. Danny Hopkin, Dr. Carmen Gorska, and Luis Gonzalez Avila, brings a wealth of experience and knowledge in fire safety engineering, design, and implementation from their projects and research. OFR focus on delivering major projects and innovations that meet client goals and deliver the highest standards of fire safety, in dialogue with key stakeholders and in collaboration with other specialists.

In their commitment to ensuring fire safety, OFR emphasises the importance of demonstrating safety through proper analysis and studies, focussing on evidencing compliance. They advocate for practical innovation and real-world application of fire safety solutions, leveraging cutting-edge research and expertise to deliver creative and effective strategies for buildings. OFR's expertise in structural fire performance and mass timber has positioned them as leaders in the industry, with a focus on developing new techniques and guidelines for mass timber structures exposed to fire, such as the widely referenced, industry-recognised Volume 6 of the STA Guide (Structural timber buildings fire safety in use guidance. Volume 6 - Mass timber structures; Building Regulation compliance B3(1), STA, 2023). OFR bring their experience and knowledge from undertaking ca. 20 large-scale fire experiments to all mass timber project engagements, be those the delivery of buildings, the development of guidance or the identification of future research needs.

LIGNUM RISK PARTNERS LIMITED

Lignum Risk Partners develops and designs innovative insurance solutions for innovators and pioneers in sustainability. Lignum helps to overcome obstacles relating to insurability and the management and transferability of risk.

Lignum Risk Partners specialises in creating insurance solutions to problems for which no immediately apparent answers exist. Lignum knows how insurance works, how to identify newly emerging risk and anticipate their future adverse risk-bearing developments. Lignum knows how to determine whether risks are transferable, how to transfer them, and how to design insurance contracts that suit the purpose.

Lignum Risk Partners is unique amongst its peers in bringing together specialist skills in global Alternative Risk Transfer/Finance, assessment and management of risk and insurable options, insurance claims advocacy (including experts to the courts and insurance dispute trouble shooters), together with associated general legal, environmental and social sustainability advice including low carbon and the circular economy.

As an independent consultancy not tied to any insurance or reinsurance company or alternative risk markets, Lignum Risk Partners is valued equally by brokers, underwriters and its clients as an unique resource in the developing sustainability sectors. Lignum's well-established relationships with global risk capital markets enable it to offer Alternative Risk Transfer (ART) and Alternative Risk Financing (ARF) solutions that are tailored for each individual client's needs.

FIRE CONSENSUS PANEL

Design Fire Consultants, Hoare Lea, OFR Consultants, Semper, University College London (Jose Torero), University of Edinburgh (Luke Bisby).

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