IMIA – Mass Timber Structures

Working Group Members

Vincent Banton	Zurich
Johannes Schmorleiz	AXA XL
Robert Innes	Zurich
Sven Neumann	HDI GLOBAL
Henrique Gante da Silva	HDI GLOBAL
Stephen Convery	SCOR
Trevelyan COURTNEY-WILDMAN	AXA XL
Mohamed Ali	Swiss Re
Fetene Tewodros Gashaw	Munich Re

Chairperson: Kate Fairhead, Marsh

IMIA EC Sponsor: Marina Zyuganova, Renaissance Insurance Group

Image: Ascent Tower, Milwaukee.
Source: **https://www.international-construction.com/news/world-s-tallest-mass-timber-structure/8022569.article**

Introduction

Structural timber construction is increasing in popularity for numerous stakeholders in the industry across the world, notably in the form of mass timber systems or hybrid constructions as defined later in the paper.

Structural timber construction is considered by many as a critical means to improve the sustainability of the construction industry. The 2020 Global Status Report for Buildings and Construction found that "when adding emissions from the building construction industry on top of operational emissions, the [build] sector accounted for 38% of total global energy-related CO2 emissions" (Global Alliance for Buildings and Construction, 2020). Timber is considered the only construction material that removes carbon from the atmosphere, resulting in true zero embodied carbon emissions – concrete, by comparison, uses a substantial amount of cement which as an industry is responsible for the emission of 2.8bn tonnes of CO2 annually, equating to 4-8% of global CO2 emissions (UK Green Building Council, 2021 / Global Data PLC, 2021).

In addition to the sustainability advantages of structural timber construction, there can also be the following benefits during build period:

1. The lightweight material can be a key design advantage at load constrained sites
2. Prefabrication can assist in assuring quality control, health and safety and less waste
3. Timber is often cost and programme efficient
4. Timber has an improved thermal performance
5. Research studies show occupant wellbeing is higher when spending time in a timber building. Measurable reductions in stress levels and heart rate have been proven in environments that use natural materials (Gardiner & Theobald, 2021)

To spur innovation and certify the performance of wood/timber as a construction material, many countries have made and are making a great effort to support the research and development of these products. Governments, companies and key stakeholders are being lobbied by organisations such as The Alliance for Sustainable Building Products, The Timber Acceleration Hub and The International Association for Mass Timber Construction. Some governments, such as in France and Germany, have set in place plans to ensure greater use of timber materials in new construction projects. In Canada, the Natural Resources Report, titled 'The State of Mass Timber in Canada 2021', noted that 'the steady increase in mass timber projects across the country can be linked directly to the major milestones in Canadian wood policy.' (Natural Resources Canada, 2021)

These factors, combined with the advancements in construction that enable mass timber materials to be a viable methodology for larger projects, means we can expect to see more structural timber construction being built in the years to come.

At present, in light of the unprecedented use of mass timber in high-rise buildings, even as a hybrid structure, insurance is noted as a key obstacle to these projects (Gardiner & Theobald, 2021). When answering a question on the main hurdles of the 40-story hybrid new-build office project known as 'Ascent', Tim Gokhman Managing Director at New Land Enterprises cited insurance as the key economic challenge (CD Smith, 2021).

In light of this, and the global drive towards greater usage of structural timber construction, the purpose of this Working Group Paper is to assist insurers in their review of structural timber construction, with a particular focus on mass timber. We intend for this paper to act as an aid to the market, helping to build an understanding of what good risk management looks like and how to underwrite a policy to ensure that all parties involved are comfortable with the level of risk transfer at the final placement.

Images: EDGE Suedkreuz Berlin - https://edge.tech/developments/edge-suedkreuz-berlin

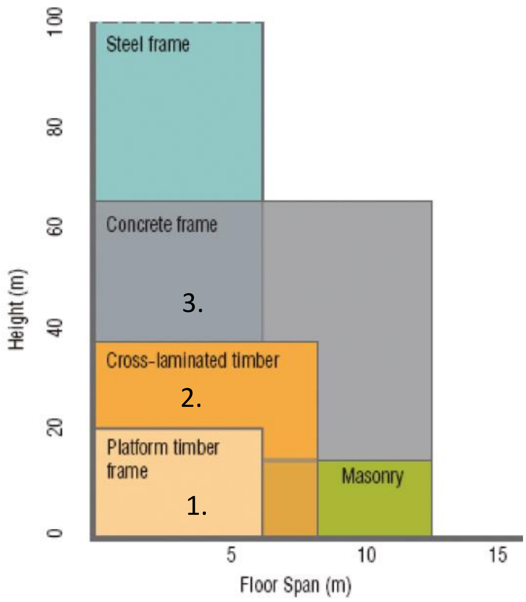
What is structural timber construction? Types of structural timber and their use

This chapter defines the different timber structures and buildings, including hybrid structures which form the two structural timber technologies and two sectors of the timber construction market.

Timber technology	**Construction sector**
Mass timber systems	Low and medium rise buildings
Lightweight timber systems	High rise and complex buildings

Structural timber systems can be associated with steel or concrete construction to form hybrid structures. The use of Cross-Laminated Timber (CLT) in construction has extended the feasible height range for standard timber-framed building structures.

1. **Lightweight timber systems** are divided into Structural Timber Frame buildings and Structural Insulated Panels (SIP). Load-bearing structures use construction timber are is strength graded.
2. **Mass timber systems** include traditional heavy timbers, Cross-Laminated Timber (CLT), Glue-Laminated Timber (GLT), Nail-Laminated Timber (NLT), Dowel-Laminated Timber (DLT), Tongue & Groove (T&G) and Mass Plywood Panels (MPP).
3. **Hybrid constructions** combine wood with different materials and techniques to deliver a wide range of structural solutions (Timber, steel, concrete, and glass) either with one specific hybrid material or multiple configurations to exploit the strength of each.



Standard design characteristics for engineered wood panel products

Lightweight timber systems (18m max)

Timber frame construction is a traditional method of building. Engineered Timber products have been used continuously in Europe since the 1960's. Generic **open panel** internal, external loadbearing walls and roof systems have been tested and catalogued with fire resistances up to 1 hour. **Closed panels** are made from studs, rails, and insulation, with sheathings and/or linings on the faces of the panel. A vapour barrier is also provided on the warm side of the insulation and a breather membrane on the outer face. Closed panels may also include fitted windows and internal service zone battens for ease of construction. Used in multi-storey timber frame buildings to 6 or 7 storeys it is designed to Eurocode 5.

Structural insulated panels (SIP) are an advanced method of construction, using sandwich panel techniques with two faces of oriented strand board (or other panels), and a rigid core of expanded polystyrene or polyurethane (PUR) foam. SIPS are lightweight, free from thermal bridging and quick to erect as infill walling to steel, concrete or engineered timber frames or as a full structural wrap. They can be engineered for load-bearing capability, racking resistance and wind-loading requirements.

https://www.timber-frame-suppliers.co.uk/open-panel-timber-frame-system/

https://www.homebuilding.co.uk/advice/structural-insulated-panels

SIP Systems have been included in the US International Residential Code (IRC). In Europe, SIPs may be subject to accreditation (e.g., UK BBA Agrément Certificate N° 06/4312).

Consequently, SIPs are not considered to be a standard building product.

Mass Timber systems

Mass timber is a general term for large, engineered wood products that typically involve the lamination and compression of multiple layers to create solid panels of wood. Mass timber systems are structural elements of solid, built-up, panelised, or engineered wood products that meet minimum cross-sectional dimensions.

The following wood products can form part of Mass timber systems:

Traditional Timber (EN 14081) Building construction using cut timber has existed for centuries. Known as "Heavy Timber", it was refined to an acceptable risk in commercial and industrial structures by ensuring the use of only large section timbers; however, this slow-burning plank-on-timber construction has been replaced by concrete floors.

Cross laminated timber (CLT or X-lam - EN 16351) is a highly anisotropic (different stresses in different directions) and shear compliant laminated composite using strength graded timber and tested adhesives. CLT engineered wood panels were developed in Europe in 1970's particularly in Austria and Germany from a French engineer's design Pierre Gautier 1947 (Wikipedia). CLT is an engineered structural two-way spanning timber panel made up of at least three (up to 11) cross-bonded layers of finger jointed timber. Panels between 50mm & 500mm thick and up to 3m x 24m long can be used for structural wall, roof, and floor plates. It can also be stiffened by timber ribs. Generally used in medium to high rise structures across the commercial, leisure and education construction sectors.

The design of CLT plates is based on design recommendations, technical approvals, and active research. Due to an absence of agreement amongst suppliers and other stakeholders, calculation models for CLT are not expected to be incorporated into Eurocode 5 until 2023 at the earliest. Consequently, CLT is not yet considered to be a standard building product and is still under trial.

Design rules for CLT often adopt Glued Laminated Timber design values and rules. Performance requirements can be found in BS EN 16351: reissued in 2021 including the latest adhesives standards, fire reaction and resistance and control provisions for factory production.

Glued laminated timber (GLT or Glulam - EN 14080) is an engineered wood product, manufactured from layers of parallel timber laminations, normally Spruce or Pine with common depths from 180-630mm and widths from 66-200mm. Individual laminates can be finger-jointed to produce long lengths. Curved glulam is manufactured by bending laminates on formers before being bonded together with adhesive, clamping, and curing. Image (STA EB8).

The following materials are also commonly utilised:

- **Nail-Laminated Timber (NLT)**
- **Dowel-Laminated Timber (DLT)**
- **Laminated Veneer Lumber (LVL - EN 14374)**
- **Mass Plywood Panels (MPP)**

- **Post Tensioned Timber (PTT)**
- **Parallel Strand Lumber (PSL)**
- **Laminated Strand Lumber (LSL)**

Hybrid constructions

Current examples of hybrid-timber structures include post-tensioned timber systems, wood-concrete and wood-steel composite systems and mass-timber combined with light-frame wood construction. Available in multiple thicknesses, widths, and spans, CLT is strong, lightweight, dimensionally stable, and inherently fire-resistant. CLT members can act as walls, floors, and roofs in combination with timber or other forms of structural support, including steel.

Post-tensioned structural timber uses unbonded steel tendons in ducts in large timber box beams to produce moment-resisting timber frames, with long-spans for low to medium-rise residential and commercial buildings.

Prefabricated CLT units are often supported on a podium structure which can be steel, or concrete framed with concrete or composite metal decking at 1st floor level. Building cores are often constructed with cast-in-place RC from foundation to roof level.

Identifying Key Risks and Risk Management

Water Risk

Timber is more sensitive to weather and moisture changes than traditional construction materials. It can easily warp, distort or be affected from excessive exposure to humidity or water.

It is important that the timber is allowed to dry out after being exposed to rain or excess levels of water. Timber expands when the moisture content increases and conversely contracts when the moisture content falls, therefore the site conditions must be carefully considered during design. Timber manufacture usually has a target moisture content of between 12% and 16%, anything above 18% is considered too high. The moisture content will gradually achieve equilibrium with the local ambient relative humidity and can vary by about 5% over the course of a year.

Mould is a product of sustained water exposure or moisture. If mould is not addressed, more severe conditions such as decay and rot may also occur. The thickness, insulation-filled cavity, and glued laminations will all influence how the wood wets, swelling directions, drying rate, and (depending upon the extent of delamination) potential loss in mechanical strength.

Rotting CLT panel. Source: www.cross-safety.org

Corrosion of secondary connectors can be a side effect, especially where the timber has been treated against insect attack or with fire retardant chemicals as many of the wood preservatives can be corrosive.

External Events - Climate and Weather

Timber could be exposed to rain, storm, flood and other weather events before the structure is made 100% weather tight. Wetter and humid seasons will create a more difficult environment during these vulnerable stages.

The local climate can provide a higher risk of water damage at locations where there is a consistent and sustained presence of high humidity, sudden changes in moisture, high flood risk, volatile swings in temperature and/ot high rainfall with strong sunlight. An example would be tropical regions or areas near marine environments.

Poor planning for delivery of material, waiting too long before installation, inadequate site storage and slow erection periods could result in timber components being exposed to the elements and, potentially, at a stage in the programme when they are not fully protected or designed for such exposure. The same consideration needs to be made during the delivery phase, as there is a risk of exposure to the elements whilst in transportation.

Internal Events - Water Escape

Water escape has been an industry issue over recent years, notably with large claims arising from un-detected burst or leaking pipes and joints. Most buildings are susceptible to physical damage due to escape of water, but what is critical for mass timber project, differing from more traditional builds, is that trapped or unnoticed water could impact the moisture levels of the timber material. As explained more fully above, this could lead to mould, decay or rot.

Water Risk Management

Managing External Water Ingress

Ideally, works should be planned to coincide with the dryer seasons, with just-in-time deliveries and rapid erection of the structure with waterproofing. Local climatic differences can change the weather protection needed on a specific construction site. During the wet seasons, temporary fixed or movable tents could be considered until the building is finally waterproofed. Surfaces of mass timber elements could be treated with a suitable sealant to ensure watertightness of the works. For example, a waterproof coating to the floor and sheathing.

The building should be suitably designed to prevent water retention on timber surfaces or in voids which cannot be inspected or accessed. Where practical, upstands should be installed around all floor-to-floor openings to limit water spread and a sloped design for drainage. Onsite training should be given to workers that are required to install penetrations through watertight membranes.

To ensure long-term durability, steps should be taken to keep timber components dry during construction and installation. A well designed and constructed exterior wall assembly with an air and water vapour barrier will protect the wood against water infiltration. All rooms should be ventilated, once they are watertight and airtight.

Where the site is subject to flooding, the client should determine the characteristics of a possible flood events and plan for worst case source of flooding, (frequency, depth, velocity, and speed of onset.) Mitigating the potential impacts of flooding through design and flood resilient and resistant construction materials is important. For example, the ground floor of the building could consist of non-timber elements which are less likely to be damaged in the event of a flood.

The presence of humidity tends to exacerbate the corrosion of connectors where the timber has been treated against insect attack or with fire retardant chemicals, as many of the wood preservatives are corrosive. Hot galvanized or stainless-steel fasteners, anchors, and hardware are consequently recommended.

Managing Internal Water Escape

Guidance has been developed to mitigate the risk of water damage on construction sites by the Construction Insurance Risk Engineers Group (CIREG). 'Managing Escape of Water Risks on Construction Sites' document provides a wider overview of water escape in general.

The Water Management Plan should be developed to demonstrate how the escape of water and the impact of moisture and humidity will be managed and mitigated for all stages of construction. Water management systems should be programmed to monitor, close supplies outside working hours, and alert appointed persons of anomalies.

The plan should also include appropriate procedures for charging and discharging any temporary or permanent water supplies. A means for detecting and rapidly shutting down the system must be present. Rapid detection and quick isolation are key to the mitigation of water damage.

Autonomous flow management devices should be installed at inlet on the mains temporary and permanent water supplies (including chilled water, underfloor heating, and irrigation pipes), between any booster pump and water tank and on each floor. Temporary water supplies should be switched off outside working hours. These pipes and joints within or immediately adjacent to the building should be visually inspected every three months. Flow management devices should be physically checked at least weekly and logged in an appropriate system.

A dedicated quality control process should be outlined for all plumbing joint installations and additional measures such as ultrasonic testing, nitrogen testing, or any other suitable non-destructive testing method should be considered. A formal permit system should be in place for wet testing or any work to a live plumbing system to help and control the risks of an escape of water event. A void closure hold point should be adopted to ensure all plumbing systems have been satisfactory installed, tested and commissioned before the void is closed

Water tanks or other water storage systems should be stored at ground level and appropriately bunded before filling. Firefighting water mains, whether temporary or permanent, must be supplied separately and be clearly identified at valve points and throughout their pathway.

Fire Risk

Timber used in construction is combustible and can contribute as a source of fuel during a fire. This has been demonstrated on multiple occasions by damaging and expensive fires.

However, not all timber framed structures are equally susceptible to fire. If ignited and heat begins to generate, then the enhancement of fire spread is dependent on:

- volume of material
- whether the material has been treated
- proximity of structural members to each other
- the cross-sectional area or thickness of members

To note, the most vulnerable stage is during maximum fire load, when the structural shell is complete but with no secondary components to provide fire protection.

In respect of the fire performance, when comparing mass timber and traditional lightweight timber frame, it is important to note:

- Mass timber is likely to be of greater overall mass. A greater section size can have a reduced internal temperature during burning so it would have less of an impact on its structural capacity.
- Mass timber is more likely to have been fire designed and fire tested.

The mass timber industry is heavily investing in fire tests, and it is recommended that insurers enquire about the testing undertaken for the materials being utilised. Numerous entities are giving positive assurances on the response of mass timer in the event of a fire. For example, the Canadian Wood Council (CWC) undertook a mass timber compartment fire test simulating an office. The CWC announced afterward, “It can be concluded that the fire performance of the mass timber structure was similar to that of non-combustible construction and confirms that mass timber can perform well under the very rare fire scenario in which the sprinkler system fails, and the fire department is unable to respond.” (Freill, 2022). It is recommended that you ask the client for information around the fire testing undertaken for the product being utilised.

Structural integrity

Timber is susceptible to a decrease in strength when exposed to temperatures exceeding 200^{o}C or 390^{o}F which is much lower than steel or concrete. When a timber element is subjected to fire the surface typically reaches to temperatures where pyrolysis can occur. In this scenario, the exposed timber begins to char and this char layer initially enables the internal temperatures to stay within an acceptable range temperatures such that it shouldn't impact structural performance. However, this initial protection is reliant on the char layers not delaminating. This can happen and is more likely to occur versus concrete spalling due to the lower temperatures required. If delamination occurs there is a risk that the structural capacity will be affected as the layers below progressively begin to char. The additional delaminated char layers could add to the overall fire load. Therefore, there needs to be careful thought as to how delamination can be prevented and this should be demonstrated to insurers.

Pyrolysis starts when the temperature of timber exceeds 200°C / 390°F and starts to char when it exceeds 300°C / 570°F. Char can protect the timber beneath, but it can delaminate adding to the fuel load and exposing "fresh timber" Source: https://www.swedishwood.com/publications/list_of_swedish_woods_publications/the-clt-handbook/

Where encapsulation is provided then this should provide sufficient protection to ensure internal temperatures of the mass timber do not impact its structural capacity.

During the final permanent construction phase, where exposed mass timber has been designed to ensure the surface temperature remains within an acceptable range, then careful consideration is needed to not compromise the temporary construction phase where the fire load in the building may differ.

There is a known phenomenon, known as the decay phase, where a mass timber element can continue to lose strength even once a fire has been extinguished and is beyond its fire design performance period. Consideration should be provided to ensure the structural integrity of the building is not compromised once a fire is extinguished.

Replacement

As discussed later in this paper, consideration is also required that where charring occurs how this char layer will be repaired or replaced to ensure that adequate structural capacity is maintained in the permanent condition, and in the event of future fires in both the temporary and permanent condition.

Onsite risks and mitigations

Fire risk to timber construction begins as soon as the first piece of timber is delivered to site and remains throughout the construction process. During construction, the following key risks and mitigation may be considered. They revolve mainly around inadequate or deficient processes:

- Hot work activities - permits, procedures, separation areas, protections, barriers, training, competency.
- Standard of housekeeping – smoking, waste management, storage of flammable gases/liquids, storage of general materials.
- Temporary services - heating, electrical supplies, appliances, cabling, extinguishers, inactive sprinklers or active/passive protection.
- Cladding and combustible insulation materials – polystyrene, timber, adhesives, solvents, plastics.
- Fire prevention plans - monitoring systems, regular fire watch, non-compliance with codes.
- Fire compartmentation and protection - fire doors, fire walls, cable/duct penetrations, openings, vulnerability before compartmentation as the exposed volume and number of storeys increases, late finishing of critical prevention measures, fire protection usually only becomes effective as the structure nears completion, untreated members.
- Security - arson, vandalism, fireworks, adjacent premises burning of waste.

- Planning and sequencing - incomplete fire-rated sections still exposed before starting another section**,** large quantity of smaller cross-sectional members in close proximity, lack of external façade installation affecting neighbouring property.
- Extinguishment – availability or access of firefighting services, temporary extinguishers, retardants, encapsulation
- Faulty electrical systems or failure during hot testing and commissioning.
- Insufficient regard to building regulations for fire design and compliance.

Fire Risk Management

Fire Prevention

On a mass timber project, we want to see that the Insured has minimised to the extent possible the fire risk, through considered design and onsite risk management.

Guidance has been developed to mitigate the risk of fire on construction sites. In the UK, guidance has been set by the Structural Timber Association (STAS), working with the Fire and Rescue Service, Association of British Insurers (ABI), The Fire Protection Association (FPA), Health and Safety Executive (HSE) and Fire Engineers. The choice of materials within the structural solution is important in assessing the potential of fire spread, and the effectiveness of the passive and active fire protection strategy.

Structural fire safety is achieved either by passive protection (fire resistant coatings or lining boards) or active protection (smoke ventilation, alarm systems and sprinklers) or, ideally, a combination of both.

Passive Protection during Construction

Flame paths:

Three potential flame paths are present in all constructions and must be considered during design to ensure overall fire safety. Designs using step-joints or compressed mineral wool sealing between members, penetration sealing systems and intumescent coatings around recessed electrical sockets are recommended.

Extensive research into connections, joints and service installations is required together with full scale compartment fire testing to improve the predictions of char depth, charred layer falloff and fire protective cladding falloff.

Compartmentalisation:

Timber frame structures can be separated into three categories reflecting the rapidity of fire spread. Category A Standard Timber, Category B Timber with flame retardant treatment and Category C Timber with non-combustible sheathing. Vertical Fire Compartments (VFCs) are proposed during the construction period for each timber frame material category to delay the fire spread inside the building and provide for separation distances to third party buildings and other buildings under construction. Where fire compartmentation can be realistically implemented, it should be carried out on every level before works proceed above. This includes fire compartments, temporary fire doors, cable and duct penetrations.

All permanent fire rated walls, floors, panels, doors, fire-stopping, sub compartments and fire compartments should be completed as soon as possible. Temporary fire rated boarding should be placed to reduce the spread of fire and smoke, where it is not possible to fit final materials early in the construction process.

Most fires can be prevented by designing out risks, taking simple precautions, and by adopting safe working practices. Fire risk design, assessments and plans should:

- follow the appropriate regulations/guidelines,
- provide fire resistance for a fully developed fire during construction, demonstrating the buildings potential structural integrity in the event of a fire and that the building would not suffer disproportionate collapse.
- evidence that in the event of a fire the ability for workers to safely evacuate the building

Surfaces:
Exposed timber surfaces should be fire-retardant treated or protected via encapsulation. Fire propagation and its containment during the construction period must be specified by conceptual design. For permanently exposed timber, the construction stage fire strategy needs to clearly demonstrate how it is dealt with. Fire-retardant treatment generally retains its effectiveness indefinitely in normal interior atmospheres; however, most of the salts utilised are water soluble and can leach out if the treated timber is exposed outdoors.

Insulation:
Extruded polystyrene foam and other combustible insulation should not be used on timber projects. Incombustible materials should be used to fill building voids which may contribute to fire spread.

Hot Works:
Designing out the risks of ignition and reducing the amount of hot work on site to an absolute minimum should be encouraged. This could be done with prefabrication, use of Building Information Modelling (BIM), materials that do not require hot working such as cold-welded waterproofing, compression jointed pipe networks, non-combustible electrical cabinets, avoiding asphalt roofs, displacing transformers and inverters outside the building or in fire rated enclosures, reducing the fire impact of photovoltaic panels, use of flame retardant electrical cables.

Active Protection during Construction

Arson, hot work, electricity, and smoking are the most likely causes of fire during the construction of timber buildings. The client must show a high-level of management for each of these risks. Although not an exhaustive list, we would expect to see a client:

- Good maintenance:
    - Minimising and disposing of combustible waste, packing materials, wood, shavings, and oily rags from the building at all times.
    - Keeping combustible storage, flammable liquids, gas cylinders, refuelling and combustible temporary buildings at least 20m from the building.
    - Enforcing a total ban on smoking and burning of materials.
- Electricity:
    - Keeping heating, drying and dehumidifying equipment restricted to as a low voltage where possible and removed from the structure outside working hours.
    - Requiring a competent electrician to inspect portable electrical appliances, temporary electrics and extension leads to be used in the structure.

    - Switch off all power to non-security or fire installations outside working hours.
- Hot Work:
    - Minimise the amount of Hot work inside the building
    - Increase the frequency of hot work inspections. The area must be continually monitored for at least one hour following completion of the hot works and be visited two hours after completion prior to closing the permit.
    - Ensure on-site security is provided outside of working hours and make verifiable hourly patrols including inside the structure.
- Arson/early detection:
    - Have a high-level of onsite site security, providing 24/7 surveillance.
    - The installation of automatic fire alarm systems that detect fires at the earliest possible moment. Not only should the system alert people at risk and the fire brigade, they should also localise the fire and control any installed fire systems.
        - In timber buildings, early fire detection is even more important, as extinguishing water causes further damage to the building material, acerbating the repairs that may be necessary.
        - Early smoke detection has been shown to radically reduce the need for full fire extinction and the difficult and costly repair of timber structures, thus significantly decreasing fire damage in timber buildings.
    - Commission fixed fire detection, fixed risers and sprinklers as soon as practicable.
    - Provide Fire extinguishers throughout the construction area and within close proximity of the building.

Automatic sprinkler systems are believed to be the most effective and reliable means of active fire protection in all buildings, Although sprinklers can reduce the degree of damage observed, during the construction period, good fire avoidance design and management and passive protection is preferential.

Design, Manufacturing and Installation Risk

Mass timber design and construction is different in many respects to conventional light wood frame or even concrete and steel framed structures. It is a relatively young product in the construction market. Suppliers, manufacturers, and installers are producing designs at a rapidly evolving rate. The product is being introduced for more extensive and complex use as projects continually become more innovative and adventurous.

Comparing mass timber to traditional wood frame, designers have generally found that the working stresses are lower. This is mainly due to the larger cross-sections of members. Other structural benefits of mass timber construction, compared to traditional wood frame, include:

- Walls having higher axial load capacity due to the bearing area of loaded elements and higher in-plane shear strength walls to resist horizontal loads.
- Structures having more significant deadweight to resist overturning forces. This may result in less need for mechanical holding-down requirements.
- Wall panels with better inherent fire resistance due to their large section size, compared to timber-frame walls.
- Slabs can manage with thinner floors, compared to joisted timber floors. Structural fixings are easier to provide and more likely to achieve their design capacity.

Tallest mass timber hybrid structure ever to be built. 180m high Atlassian Tower Sydney. Source: ArchitectureAU - New vision of Shop Architects and BVN's Atlassian HQ

The following key risks during construction have been identified for Design, Manufacturing and Installation. They revolve mainly around inadequate management, lack of experience and defective processes:

Design Stage

- Lack of constructability review or proficiency for the design between key designers, the main contractor and key subcontractors.
- Lack of any independent design checks by proficient third-party consultants.
- Systems integration – prefabricated components and penetrations not included in early design
- Incomplete detailed design with fast tracking to achieve timelines, especially with regard to unproven, prototypical or innovative architectural features.
- Noncompliance with respected international building codes which could lead to early failure of loadbearing elements when exposed to fire.

Manufacturing Stage

- Deficiency in quality control procedures or connections to appropriate quality assurance standards.
- No established supply chain.
- Unrecognised product certifications for the mass timber elements.

Installation Stage

- Unknown names and details of any suppliers, manufacturers and installers.
- Shortage of experience and past performance of known parties individually or working together in partnership.
- Lack of details for on-site supervision and co-ordination, including technical assistance by the manufacturer or supplier.
- Absence of crane erection and lift pre-planning.
- Unclear construction sequence and approved erection plan which has not been reviewed by the supplier and any structural designer.
- Majority of penetrations and cutting not performed during prefabrication but onsite during installation.
- Significant temporary works required to support the timber elements during construction.

Design, Manufacturing and Installation Risk Management

Design

Third party checks on the robustness of the design and specification are preferred to give greater levels of comfort on the final product. Additionally, constructability reviews should be undertaken between key designers and contractors.

It is important to ensure mechanical, electrical and structural design are well integrated to avoid cutting of timber on-site, wherever possible, or errors may occur in the staging process. In-situ corrective cutting, or adaption, may lead to further constructability issues or defects.

Manufacturing

Specialised manufacturers or suppliers often produce from bespoke designs for architecturally complex projects. It may be the case that those products cannot be replicated or made by anyone else. Further production of the design may be difficult or maybe not possible at all if that premises was lost, or the manufacturer ceases production permanently. The client needs to provide information to evidence their reliance on the manufacturer(s), and any contingencies incorporated in their risk review.

Cost overruns and issues with supply chain are common issue with any material and outside factors such as pandemics, war or other political events affect this. The price of timber fluctuates with high volatility and may be subject to large increases in cost. Other commercial considerations and risk include possibility of negative cash flows, timing of international orders and coordinating with peak demand seasons. From an insurance perspective, these factors are important in the assessment of the potential quantum of loss.

Naturally with any innovative product there will be gaps in expertise and experience as the technology progresses. As a highly engineered and technical product, extended delays may occur while trying to resource and refabricate damaged elements. Sourcing from alternative suppliers may also lead to further delays and increased shipping costs. Disassembling a portion of the structure to replace damaged elements could increase project delays and final reinstatement costs.

A project close to a reputable manufacturer will have a different risk to those transporting their materials across the country or internationally. Prefabricated module designs need to consider the deformability of large ready-for-assembly panels during transport from timber fabrication to the construction site.

If there is not a clear handover process between the manufacturers and installers, then defects in the construction may occur. It is important for all parties to have experience in the manufacturing and constructing of mass timber, with strong quality control protocols connecting both stages.

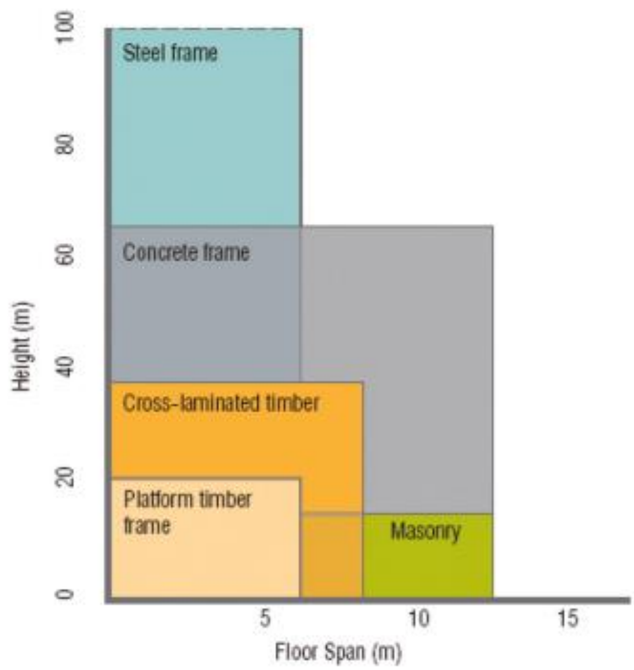
Installation

Erection:

Without proper supervision and correctly applied specifications at the point of installation, issues and defects can occur. Past failures have been traced back to process changes during manufacturing which resulted in defects during construction. In addition, inexperienced contractors may use outdated or incorrect techniques when connecting and fixing members.

The extent of mass timber within a structure and the installation methodology are two factors that need to be considered. For example, the risk increases significantly for a structure that is 100% mass timber versus a structure that is only partially constructed from the timber material (hybrid).

High rise multi-storey mass timber structures will have a much greater erection or collapse exposure during a fire. CLT structures of eight storeys have already been constructed in the United Kingdom. Current knowledge supports up to 12 storey designs. The feasibility of building structures up to 30 storeys has been investigated and some projects around the world are beginning to implement at this scale.



Material	Floor span capability	Height capability
Steel frame	6–7m for composite steel/concrete floors	>100 storeys
Concrete frame	8–12m for solid, prestressed, troughed and ribbed slabs	>20 storeys
Platform timber frame	5–6m for engineered timber joists	7 storeys or 20m
CLT construction	6–8m	12 storeys or more possible*

* Design height limits above 12 storeys are subject to the engineering of the floors-to-walls interface design specific to the project.

Span and height capabilities of mainstream structural materials in standard design
Source: Structural Timber Association UK

Penetrations should be performed during prefabrication at the manufacturers premise. Cutting onsite can be complex and cause defects or direct damage. Temporary works required to support the timber elements walls are usually braced raking props. Erection commences from a corner or braced location before floor panels are lowered onto them and fixed. The completed floor structure provides the platform for the erection of the wall panels to the following storey. There is an increased risk of collapse of any temporary structure during erection; therefore, a thorough design for temporary works needs to be in place.

Positive Risk:

Mass timber lends itself well to prefabrication, resulting in very rapid construction, reliable on-site programming and ease of dismantling at the end if its service life.

Mass timber structures require fewer onsite mechanical fixings where large-prefabricated panel elements are adopted. They also require less onsite trades and can be assembled with lightweight power tools, although cranes are usually needed to lift the panels into place. Fixing cladding materials, services and fittings to walls is generally easier to achieve with woodscrews than concrete and masonry walls. If public liability insurance forms part of the construction policy requested, these should be considered positive health and safety features to the build.

The use of BIIM involves the client and all members of the construction team early in the project and produces snagging items where interference occurs between the different trades. BIM and machine fabrication permits the high precision which will help to avoid site assembly defaults. BIM also impedes late design changes, via imposed step by step approvals – this is particularly critical for mass timber, where on-site variations must be kept to a minimum.

Storage:

Safe and efficient material storage requires on good co-operation and co-ordination between everyone involved including, client, contractors, suppliers, and sub-contractors. Material storage should be included in the construction phase plan. Deliveries of timber elements should be planned to reduce the quantity of stored materials on site.

All timber elements stored on site should be stored in accordance with the manufacturer's recommendations, such as appropriate stacking height, storing off the ground and in suitable climatic conditions. Where timber elements are exposed to prolonged ultraviolet light they should be suitably treated.

Storage areas should be designated for plant, materials, waste, flammable substances, flammable liquids and gases and hazardous substances. Flammable materials should be stored away from other materials and protected from accidental ignition. The storage area should be outside the timber structure, or where this is not possible, covered by the site fire detection system and have adequate firefighting equipment close by.

Waste timber materials on site should be restricted to a minimum and should be contained in skips or wheeled bins with fire retardant coverings. All waste construction materials such as packing, wood, and shavings should be removed from the building every day.

Repair and Replacement

Prefabrication has numerous positive risks, as discussed earlier, but there is a concern over the ease of repair or replacement in the event of physical loss or damage. Potentially, depending on the circumstances of the occurrence, the quantum of the loss could be exacerbated. This risk is heightened by the fact, wood prices increased over the last two years tremendously. Due to the increasing desire for sustainability and the current economic situation, the prices will probably rise even more in future.

In light of the relative infancy of the material, it is not clear what the consequences of a physical damage event could be. In the absence of a wealth of claims data, insurers should engage with their client to understand their perspective on the following:

- Will a discoloured/charred but structurally stable layer of mass timber be acceptable to the Employer? Or will they insist upon full replacement?
- How easy is it to repair partial damage to prefabricated parts in-situ?
- What is the lead in time for replacement?
- What is the anticipated scale of damage from a large scale occurrence (eg fire, flood or burst pipe) within the building (i.e. number of compartments and floors affected)?

Comfort here, will improve the perception of the risk, and aid underwriters in their consideration of loss scenarios.

Other Considerations

Earthquake

Generally, timber as a structural material works particularly well in the case of earthquakes. Its lateral force resisting systems tend to have high degrees of ductility. In short, a building that balances stiffness and lightness behaves well in an earthquake. A building that is too rigid becomes fragile as its structure will eventually break with the vibrations. Several investigations, with real tests, have shown that buildings made from mass timber, with metal connectors, perform well against this natural phenomena.

Insect attack

Provisions for termite protection are provided in some building codes across the world – these include:

- Chemical treatment of the soil
- termite traps
- pressure treated timber preservatives
- naturally durable timber
- physical barriers.

We would expect to see:

- No timber in contact with the ground.
- No tree branches in contact with the building.
- Regulatory provisions followed and in highly infested areas minimum protection including a continuous termite barrier beneath the foundations over the whole area of the building.
- Treated or naturally insect resistant timber used.
- A full insect inspection carried out during the construction period.

Wind Storm

Failure simulations of USA residential structures built using standard light-frame construction subject to tornado hazards show about a ~10% probability of failure for small EF-0 and EF-1 tornadoes (~150km/h). CLT structures of the same form have a ~10% probability of failure during EF-4 events (~300km/h). Although the 3-ply CLT buildings are more expensive, CLT is shown to be much more robust. Performance in catastrophe events is also driven by fixings rather than by the material itself.

Noise

Methods and measurements in finished CLT buildings show that a good sound environment can be achieved. Client acoustic requirements for the building must be determined early in the design process to select a suitable sound insulation class in collaboration with acoustic engineers.

Low-frequency sound is a problem in lightweight CLT structures and high-performance floor structures must be designed, as it is difficult to rectify any problems retrospectively. Sound insulation is a more sensitive issue than in concrete or masonry construction and good engineering is required to limit impact sound and sound transmission. Hybrid constructions are a solution.

A benefit to mass timber is that there is less noise on site due to the prefabrication process.

Underwriting Considerations

Each of the risks discussed in this paper need to be considered by underwriters when considering a timber project. We have discussed each in turn, as well as repeated the key information requirements needed to adequately assess the key risks and corresponding risk management associated with timber projects.

Overarching all risks, are the following information requirements:

- Experienced project team
- Advanced design
- Detailed construction programme, with clear consideration for different risks throughout delivery
- Construction method statements

Every project will need to be evaluated for its own merits, looking at factors such as location, usage, extent of structural timber and the project team, but we intend the section below to be a useful reference point on the mass timber specific considerations. It is not intended for all policy amendments listed to be required on every risk.

Underwriting the key risks:

Water

While the vulnerability of mass timber buildings towards fire is comparable to other building constructions to a certain extent, as further detailed earlier in this paper, the vulnerability towards water is much higher.

Irrespective of the build material, within the last 5 years water damage-based claims have continued to increase substantially, both in their frequency and severity. Large losses from escape of water are now as frequent, if not more so, than fire related incidents. Water damage is associated with very high costs. In addition to the direct costs for materials, clean-up work and repairs, particularly indirect costs due to time delays (dry work, removal of debris, etc.) and disruptions in operations and distribution are quite significant. With timber construction, there is the risk these costs could be heightened - even small incidents may lead to substantial claims as timber cannot be dried as easily as concrete, for instance.

Specific Information Requirements:

- Water risk management plan
- Flood risk assessment
- Plan to measure/monitor the moisture level
- Humidity level monitoring internal/external
- Is industry practice for water mitigation being followed?

Underwriting Considerations/Recommendations:

- A higher deductible/excess, with consideration being given to whether a co-insurance deductible is appropriate.
- A sublimit for water damage claims
- Imposition of risk management conditions under the policy, for example:
    - Obligations for safety measures for professional sealing of the building shell against the weather
    - CIREG: Managing Escape of Water Risk on Construction Sites adherence Condition

- Series Loss Clause, increasing the deductible or reducing the coverage, after a quantum of similar losses arising from water.
- Application of exclusions and/or sub-limits for key concerns, for example mould and corrosion.

Fire

In many companies the assessment of the Probable Maximum Loss (PML) of a building is a fire event. Where structural timber materials are present many companies must note their PML as 100%, thereby impacting the capacity they can deploy on any given placement. It is worth noting that the probability of a PML event occurring at completion of the structure is similar to a steel and concrete building. However, the probability of a large fire mid construction may be higher timber depending on whether the material is fully fire proofed.

Although we understand every company calculates their PML separately, consideration whether a 100% PML is appropriate should be made in light of the materials incorporated into the project (CLT frame versus hybrid structure) and, if applicable, whether there is a sufficient distance between the buildings forming part of the project.

Where a fire occurs in a mass timber project, it is likely that there will be questions around the structural integrity of the undamaged portions of the structure. If there is melting / smoke damage the relevant public authorities or the Employer may decide that the project will need to be demolished and re-built. So, while these types of wood may be more fire resistive there is no guarantee that they salvaged in the event of a fire.

Specific Information Requirements:

- Fire risk management plan
- Is the timber exposed or encapsulated? If exposed, when will treatment be applied?
- Storage details
- Site security
- Distance between buildings if there are multiple blocks or from third party buildings if public liability insurance is being requested
- Fire testing undertaken for the materials being used
- Confirmation of mass timber treatment, and when it is to be applied
- Is industry practice for fire mitigation being followed?

Underwriting Considerations/Recommendations:

- A higher deductible/excess
- Sub-limit for offsite storage
- Imposition of risk management conditions under the policy, critically:
    - Minimum security standards – for example, it is a condition under the policy that the site is fully fenced or has 24-hour security
    - Hot works conditions

Design, Manufacturing and Installation

The presence of timber in the structure should encourage early engagement from key trades, ensuring that the design can be delivered effectively. For example, it's important for penetrations to be made by the manufacturer, rather than onsite.

Specific Information Requirements:

- Quality Assurance / Quality Control Process

- Constructability review
- Compliance with building codes
- Product certifications
- Temporary works method statements
- On-site storage plan
- Ease of on-site repair / replacement
- Waste management
- Crane installation and operations plan

Underwriting Considerations/Recommendations:

- Manage capacity with Escalation Clause
- Ensure that subrogation rights against suppliers are maintained, or that the manufacturer's warranty is primary to the insurance policy
- Extended maintenance only
- Series Loss Clause
- Review of extent of design coverage
- Escalation Provision

Natural Hazards

Wind exposure will be an issue during the erection of the prefabricated elements. Once in place the exposure is not higher than for other building materials.

Earthquakes present less of an issue due to the flexibility of wood, but breaking joints could cause further damage especially with water contact.

Specific Information Requirements:

- Confirmation that tarpaulins and other covers need to be secured for the existing weather conditions
- Check if the construction process is adapted to weather timeframes for construction or if safety measures are in place such as tents
- A management system combined with an alert system for Natural Catastrophe events should be in place

Underwriting Considerations/Recommendations:

- Natural Catastrophe sub-limit

Other Underwriting Considerations

Offsite storage/Transit

Underwriters need to understand the extent of coverage they are providing for offsite storage and transit. During transit, the timber could be insured under either a construction insurance policy or by a marine insurance policy, depending the policy coverage, the location and the form of transportation being utilised.

In comparison to other building materials the protection measures need to be adapted to the more vulnerable components. This applies if the material is stored on site, in an offsite storage area and during transport between insured risk locations.

Specific Information Requirements:

- Offsite storage locations and risk management
- Transit plan

Underwriting Considerations/Recommendations:

- Restrict Geographical Limits to ensure that the policy only provides cover for transit/off-site storage where the risk information gives sufficient comfort
- Apply a sublimit for offsite storage/transit, notably under the Delay in Start Up (DSU) section
- Ensure that subrogation rights against transit and/or storage companies are maintained

Delay in Start Up (DSU)

The growing demand for timber construction beckons questions over the lead in time for its replacement, especially noting that often it's manufactured in accordance with the specific projects design requirements. If there is a high reliance on the manufacturer, who may have progressed to the delivery of alternative contracts at the time replacement timber material is required, the duration of a delay could be exacerbated.

In addition, even small damages to timber material could cause a major DSU loss, because, depending on the circumstance, reparation of the prefabricated materials on site may not be possible, therefore causing the damage part to be replaced.

A large-scale fire is more likely to take place part way through construction than at the end of the period. It is important for underwriters to monitor progress as far as possible as a DSU loss can more challenging to adjust part way through compared to the end.

Specific Information Requirements:

- Ease of on-site repair / replacement
- Extent of reliance on one manufacturer / supplier

Underwriting Considerations/Recommendations:

- A higher deductible/excess
- Careful deployment of capacity due to the potential risk of a totally loss

Mass Timber Projects

In this section we illustrate the growth of mass timber construction with a few projects from around the globe that have either been completed in the past decade, are under construction and in planning phase. Within, we have also included a couple of interesting claims examples.

Forte Living, Melbourne, Australia (2012)

Type:	Residential building (23 apartments)
Location:	Melbourne, Australia
Duration:	ca. 11 months | Start on site: Feb. 2012, Completion: Dec.2012
Height:	10-storey, 32.2 m (ca. 106 ft)
Mass Timber:	CLT structure (floors and walls)

Image: Forte Living - https://www.woodsolutions.com.au/case-studies/forte-living

Forte's ground floor and first storey floor slab were constructed from geopolymer concrete. Once the concrete had set, the CLT panels were transported from their nearby storage site and erected on top of it, starting with the panels that formed the stair and lift cores.

The duration of CLT installation was about 2 months, from June 2012 to August 2012. The construction time is deemed to have been reduced by more than 30%.

Structurally, the building was designed through disproportionate collapse. That is, the CLT structure has been analysed to ensure that should a wall section be damaged, the remaining structure is able to take the load. Fire resistance is initially achieved through the direct fixing of fire grade plasterboard combined with the charring of the timber, ensuring that the structural component required is maintained through the provision of sacrificial layers.

GlaxoSmithKline Laboratory Building *2014

Type:	GSK Carbon Neutral Laboratory of Sustainable Chemistry
Location:	Nottingham, UK
Constr. Cost:	GBP 20 million
Mass Timber:	CLT and Glulam
Loss Event:	FIRE due to electrical fault
Loss *Date:	September 2014 / Project was under construction

Image: Destruction of building due to fire caused by electrical fault - https://www.architecture.com/awards-and-competitions-landing-page/awards/riba-regional-awards/riba-east-midlands-award-winners/2018/the-gsk-carbon-neutral-laboratories-for-sustainable-chemistry / https://www.theconstructionindex.co.uk/news/view/morgan-sindall-to-rebuild-nottingham-lab-destroyed-by-fire

The building was about 70% complete at the time of occurrence. It was reported that the fire started because of a fault with the temporary power supply to the building (electrical fault) associated with an unusually high plastic combustible loading in the vicinity of the fire origin.

Without fire doors or in some areas glazing, there were open voids between floors. This caused the building to be self-ventilating and once the fire had taken hold it then passed through the building rapidly. The university stated that the contractors met all health and safety requirements, including the adequate safety check of electrical appliance used on site.

After the fire, mass timber remained in the design, and the building successfully won numerous awards - 2016 Structural Timber Awards: Client of the Year, 2017 Building magazine: Sustainability Project of the Year and 2018: RIBA Regional Award (Timber Research and Development Association, Website accessed 2022)

Brock Commons, Canada (2017)

Type:	Student residence
Location:	University of British Columbia (UBC), Vancouver, BC, Canada
Duration:	ca. 21 months | Start: Nov. 2015, Completion: Jul. 2017
Cost:	USD 51.5 million
Size:	15,120 m² (162,800 sq-ft)
Height:	18-storey, 53 m (ca. 174 ft)
Mass Timber:	CLT panels, Glulam columns

Image: Brock Commons - https://www.thinkwood.com/construction-projects/brock-commons-tallwood-house

The wood construction was completed in about 10 weeks after the after the prefabricated components arrived on site. The assembly started on June 6th, 2016 and finished on August 10th, 2016.

The building is an 18-storey hybrid mass timber structure comprising of 17 stories of mass timber construction above a concrete podium and two full-height concrete cores that house elevators, stairs and services conduits. The floor structure consists of 5-ply CLT panels supported on glue laminated timber (Glulam) columns. The roof is made of prefabricated sections of steel beams and metal decking. The facades consist of a steel frame construction with a cladding of laminated panels.

In order to increase the resistance of the wooden structure in the event of a fire, all wooden components were clad with gypsum board. The construction remains visible only on the top floor, which is used by the students as a lounge.

In the event of an emergency, a sophisticated safety system ensures that the sprinkler system works even if the public electricity and water supply is interrupted.

Mjøstårnet in Brumunddal, Norway (2019)

Type:	Mixed-use, residential, hotel and office
Location:	Nils Amblis veg 1A, 2380 Brumunddal, Norway
Duration:	ca. 24 months | Start: Apr. 2017, Completion: Mar. 2019
Size:	11,300 m² (ca. 121,600 sq-ft)
Height:	18-storey, 81 m (ca. 266 ft)
Mass Timber:	CLT, Glulam, LVL

Image: Mjøstårnet in Norway - MJØSTÅRNET - CONSTRUCTION OF AN 81 M TALL TIMBER BUILDING - R. Abrahamsen, Moelven Limtre AS, Moelv, Norway

Ground works started in April 2017. Installation of timber structures started in September 2017 and it was structurally topped out in June 2018. The building was completed and opened in March 2019.

The building key structural components are composed of engineered timber, i.e., Glulam timber for beams and columns and CLT for the core walls containing the building's elevator and stairway shafts. Glulam columns were fabricated with pre-drilled holes and assembled on-site into vertical trusses of up to five floors in height, providing stability to horizontal and vertical forces. Floor slabs up to floor level 11 are crafted from timber beams, topped with LVL and a thin 50-millimeter layer of concrete for acoustical and vibrational performance. Level 12 and above have floor slabs fully composed of concrete to increase weight and achieve the desired dynamic behaviour in periods of strong winds.

The fire strategy report for this project states that the main load bearing system must be designed to withstand 120 minutes of fire. Secondary load bearing such as floors must withstand 90 minutes of fire. The fire resistance was obtained by calculating the remaining cross section after charring according to Eurocode.

"Tor zur Welt" building *2019

Type: Residential building (29 units)

Location: Hamburg, Germany

Height: 8-storey

Mass Timber: CLT floor, roof and wall panels, Glulam columns

Loss Event: Water damage due to external water ingress

Loss *Date: October 2019 / Project was under construction

Damages were traced back to three causes, all of which led to the CLT panels at the ceilings above Levels 2 through 7 becoming soaked.

Cause 1: Missing sealant on the walls and on the ceilings of the staircase heads. The roof seal on the staircase shafts were not installed until September 2019. Until then, those areas were exposed to the weather without protection. The water was able to penetrate the building through the insulation of the outer wall sandwich elements.

Cause 2: Leakage in the area of the cable penetrations through the roof ceiling and waterproofing. The flashing between cables and penetrations were flush or tight and water was able to penetrate in the building unhindered.

Cause 3: Removal of the weather protection seal from 39 balconies. In June 2019, the assembly for the bracket for the balcony railing took place. For this installation, the welding line was removed from the edges of the balconies. As a result, the balcony edges were now exposed to the weather without protection. These strips were no longer protected and were working as gullies. Water could therefore enter the building unhindered from these areas.

As a result, overall dry-out measures had to be conducted, the gypsum board and drywall in affected areas had to be replaced, and the integrity of the water damaged CLT panels would be further evaluated by experts once the panels were completely dried-out.

3088GJ Rotterdam *2020

Type: Hall used by firefighters as a firefighting training facility

Location: Rotterdam, Netherlands

Mass Timber: Glulam roof girders

Loss Event: Structural damage

Loss *Date: 2020 / Property was already in use

The hall was already in use for some years and was used as a training facility by firefighters. Occasionally, heat was produced inside the hall to be put out as part of training procedures.

The reported cause of the damage was related to the rapid temperature variance inside the hall, which was produced by the excessive heat during firefighting training.

The result of such exposure was the delamination of two glulam girders leading to a 2cm extra-deflection of those elements, as well as the failure of wood beam (purlins) supporting the roof spanning across girders.

Ascent Tower, Milwaukee (2022)

Type:	Residential tower (259 units/apartments)
Location:	Milwaukee, WI, USA
Duration:	ca. 24 months | Start: Fall 2020, Completion: Summer 2022
Constr. Cost:	USD 80 million
Size:	493,000 sq-ft (ca. 45,801 m²)
Height:	25-storey, 284 ft (ca. 87 m)
Mass Timber:	CLT, Glulam
Designer:	Thornton Tomasetti

Image: Ascent Tower in Milwaukee - https://www.archpaper.com/2022/08/ctbuh-declares-milwaukee-tower-ascent-the-worlds-tallest-timber-building/
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https://www.dezeen.com/2022/08/03/ascent-tower-milwaukee-worlds-tallest-timber-building/

The mass timber residential floors are constructed above five levels of concrete parking garage. A system of glue-laminated timber (glulam) beams and columns support cross-laminated timber (CLT) floors. Two concrete cores provide lateral stability.

The design exposes the mass timber construction wherever possible to display its natural qualities. Fire testing proved that the timber structural members meet or exceed fire rating code requirements.

A system of post-tensioned concrete beams transfer loads from the timber residential floors to the concrete garage structure below. The superstructure is supported on concrete-filled steel pipe piles.

Other Examples of Projects

Name	Date	Location	Description
T3	2016	Minneapolis, USA	7 storey mixed retail and office space, built with NLT panels, Glulam beams and columns
WOODIE Hamburg	2017	Hamburg, Germany	7 storey modular student accommodation, composed of five or six floors with a total of 371 prefabricated wooden modules stacked over a reinforced concrete podium slab
Carbon 12 Portland	2018	Portland, USA	14 storey residential build with ground floor retail space. Hybrid structure, with glued laminated timber (glulam) and CLT (cross-laminated timber) utilised around the steel core, ground floor, connecting braces and ground floor.
HoHo Vienna	2019	Donaustadt, Austria	24 storey mixed retail, office, hotel and residential building. The concrete structure is coupled with a modular CLT construction system, based on four prefabricated serial components including CLT-concrete composite ceilings, CLT columns, beams and wall elements.
EDGE Suedkreuz	2021	Berlin, Germany	7 storey hybrid construction offices, with CLT panels and glulam beams and columns
Black and White Building	2022	London, UK	6 storey office building made fully of mass timber materials.
iCampus i8	2024	Munich, Germany	6 storey flexible office and administration building, wood-hybrid construction, including wood-concrete composite floor-deck systems, the cores as conventional reinforced concrete construction. Vertical load transfer is provided by the reinforced concrete cores and mass timber columns
W350 Project	2041	Tokyo, Japan	70 storey mixed-used building including residential, office and retail space. 90% wood and the rest being steel, as steel braces will be used to enhance resistance to wind and earthquakes

Image: iCampus i8 in the Werksviertel in Munich - https://www.e-architect.com/germany/i8-offices-icampus-im-werksviertel-munich

Conclusion

Environmental awareness coupled with sustainable design and construction practices are increasingly becoming a requirement for many building projects around the world. Sustainable design aspires to use less energy and material resources in conjunction with lowering the environmental impacts on a building from its cradle to grave. Sustainability and corporate responsibility are a topic discussed at board level in most companies, including in the insurance sector.

In acknowledgement that increasing use of renewable and sustainable building materials in construction, such as wood/timber, is becoming a worldwide movement, we, as a marketplace, need to support this trend, whilst being comfortable with the level of risk transfer.

The purpose of this paper is to assist the insurance market in their review of structural timber construction projects.

We have highlighted the key risks associated with structural timber construction, such as fire, water and design, then detailed to what extent these can be managed at an individual project level with the intention of giving insurers the knowledge to identify a where a client is planning to implement robust risk management measures. The underwriting submission is critical to facilitate this. As evidenced by this paper, the relative infancy of mass timber as a product combined with the loss experiences of light weight timber projects, give underwriters cause for concern due to the heightened exposures associated. Without detailed information on the project, underwriters do not have the wealth of experience or claims data to have a sufficient comfort to accept the transfer of risk.

Insurers need to accept the construction market transition to usage of structural timber, and it is recommended in this paper to carefully review the coverage provided under the policy for each project to ensure our clients are supported whilst insurers' portfolios are not exposed beyond their level of comfort. In Section 6. we have outlined options for insurers' consideration, discussing the application of specific exclusions, restricted transit/offsite storage coverage and heightened deductible/excess levels. The relevance of our policy coverage discussion points depend on the circumstances of the project, but each should be considered and dismissed or accepted in accordance with its relevance.

The final section of this paper, which is further supported by Appendix 1 - A deep dive into successful Construction development, looks at examples of timber projects, and market losses. The intention here is to help insurers employ lessons learnt, either by coverage amendments in the policy or through ensuring the implementation of specific risk management measures.

The insurance market needs to support the enhanced incorporation of structural timber, and we intend for this paper to act as a means to help facilitate this.

The comments and opinions expressed in this publication are those of the individual contributors alone at the time of publication. They do not purport to reflect the opinions or views of any entity employing or otherwise affiliated with the contributors.

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Appendix 1

A deep dive into successful construction development

In this section we present the case study of the project **Adohi Residence Hall at the University of Arkansas**, considering the insights and lessons learned from the perspective of the general contractor of this project. The information here is based on the presentation by John Stack, Sr. Project Manager of Nabholz Construction, during the IMUA Builder's Risk Construction Forum on 05-Nov-2020.

Overview

Type:	Student residence (708 beds)
Location:	Fayetteville (in the Ozarks), Arkansas, USA
Status:	Completed - Fall 2019
Constr. Cost:	USD 79 million
Size:	202,000 sq-ft (18,770 m²)
Height:	5-storey, 350 m (ca. 1,148 ft)
Mass Timber:	CLT floors and roof panels; Glulam columns and beams

Image: Adohi Hall at the University of Arkansas

Project description

When the University of Arkansas decided to construct the country's first large scale mass timber residential hall (later named Adohi Hall), they chose Nabholz Construction as General Contractor (GC). It was the general contractor's first project using CLT panels, but not the first mass timber project. Nabholz at that point had successfully completed several Glulam and T&G (Tongue & Groove) Decking projects.

With the challenge in hand, the GC sent some of the key project personnel to manufacturing facilities and mass timber construction projects under construction to build their experience. This allowed the project team to build a pool of case studies, in which lessons learned across the industry could be applied in their own project.

The Adohi Hall is a 5-storey building, comprising of 4-storey residential floors arranged above the communal spaces on the ground floor. The building complex occupies a linear, sloping, 4-acre site and situated in midst of the city's high school and college campus. The project site is surrounded by residence halls, the Stadium drive, as well as a large arena and related athletic facilities.

Structurally, the building uses exposed Glulam posts and beams with CLT slabs for floors and roofs. Aside from a second-story garden supported by diamond-shaped wood-and-steel trusses, the specification of mass timber formed the basis for nearly every design decision, from the residential modules, which were based on standard CLT panel sizes, to the building's lightweight metal skin.

Project pre-planning and Risk assessment

Pre-planning and risk assessments were fundamental for the success of the project, especially for a construction typology that is not a standard practice across the industry.

Before staring the project, attention to the following aspects of pre-planning and risk management were taken:

- Pedestrian and Worker Safety (CCIP / WC)
- Procurement of Mass Timber
- Skilled Work Force for Mass Timber Installation
- 3D Modelling of CLT penetrations
- Quality Management Systems
- Protecting the Timber from Water Damage
- Potential Fire Risk
- Aggressive Schedule

Skilled Work Force

Finding skilled local work force and/or specialized subcontractors for the erection of the mass timber structure can be a challenge. For this project, the GC evaluated the talent pool in the region, conducted a competitively bid the erection. As a result of this procurement process, the Nabholz team was selected for the erection of the mass timber structure.

3D modelling and CLT penetrations

The 3D modelling aspect of the project, in which a well-managed Building Information Modelling (BIM), was essential. BIM was implemented across all disciplines involved in the project, promoting and improving the project coordination and design compatibilization, bridging all aspects of the project, including design, fabrication of mass timber, logistic program and erection.

Image: BIM model and Project compatibilization

With the BIM model, Clash Detection tools were used in the design coordination of mass timber structural components - CLT panels, Glulam elements and Structural connections - and the penetrations required for the MEP installations (mechanical, electrical, plumbing).

The project had around 3,800 penetrations and the location of each and every one of those penetrations through the CLT depth were easily visualized in the BIM model. In the initial compatibilization of the project in BIM, the clash-detection indicated 9,000 collisions that had to be coordinated. Those were collisions of the MEP installations with mass timber structural elements, which required coordination and communication with the design team and the engineers to ensure that the placement of the penetrations would not compromise the CLT panels' structural integrity by placing too many penetrations too close, for example.

In this manner, the manufacturing of the mass timber components would then be executed with maximum accuracy, so that the erection of the structure could take place in a LEGO-like manner, reducing on-site work and consequently accelerating the project.

According to the GC, the process above described was expensive and required a lot of effort and time. Nevertheless, the use of BIM was essential for the success of the project development, i.e., design-manufacturing-erection.

Quality Management Systems

The already established quality management system of the GC had to be adjusted for the peculiarities of a mass timber project. The quality management team evaluated each aspect of the project looking at the specific risk factors for the mass timber project.

Project Delivery

Fire Risk Management

The general contractor partnered up with Hilti to coordinate the oversight of each penetration to accommodate the fire protection that was necessary at each and every one of the penetrations related to mass timber floor and roof assemblies.

Hilti has been working on a permanent standard and a line of products to be used in lieu of the traditional joint system with calk around mineral wool.

The image below gives an idea of the number of penetrations that were coordinated during the design phase.

Image: BIM Model and Penetration mapping

The mass timber products were delivered to the site with the holes pre-drilled. In the image below you can see the penetrations and floor assemblies installed.

Image: Penetrations and Assembly

Hot Works Permit was implemented and enforced with certain additional procedures that had to be followed. After completion of hot works activities, personal was assigned to stay on site to survey the area, equipped with adequate firefighting equipment, with the objective to make sure that the wood would not burn while the job site was unattended.

Logistics involving Mass Timber Delivery to the Site

The main aspects regarding mass timber delivery are listed below:

- Proper Sequencing

The procurement logistics for the project proved to be challenging.

From the manufacturing plant in Austria, the elements would be transported via cargo ships to the US, stopping first on the East Coast and then transported via truck to the construction site, but the trucks would arrive at the site out of sequence, leading to additional work.

In face of this issue, a specialized freight company was assigned the task of reorganizing the transportation logistics, working together with the manufacturer and their freight company. With a new route and proper coordination, the shipments started to arrive on site in the planned sequence.

- Inspection and Documentation of the product as it arrives

The products should be inspected for quality control and documentation verification at every intermediate freight transfer point until the product arrives at the construction site.

In the project, there was a situation in which the shipment went through rough sea conditions and when the container was opened for inspection, some water came out of it. The mass timber components that were in that container had to undergo extensive testing for moisture content. Fortunately, the standard requirements were met and a replacement shipment from across the ocean was not necessary.

- Organization in lay down / assembly area

In this project, the Glulam beams were shipped out without the knife plate connections (beam to column connections). The knife plates were then either assembled in the yard or installed once the beams and columns were erected.

Considering the number of connections, the organization of the layout area for assembly is critical.

Protection during transportation and on-site storage

The image below shows a delivery / unloading feature that not only protected the product during transportation, but also facilitated the unloading on site.

Image: Unloading, Transport protection and Lay-down area

As part of the measures to protect the mass timber elements during construction, it was decided to wrap the bottom of the columns to prevent superficial damages, which could occur due to normal work activity, e.g., workers carrying tool bags and ladders around. Afterall, the columns were not only a structural element, but a finished product.

Image: Protection of column against impact

Water ingress management

In order to prevent water from running down the face of the column, which could lead to stain on the column as a finished product, around the bottom of every column, the general contractor decided to use Trim-Co Flex-Flash (see image below).

In order to prevent the water from infiltrating between panels during the construction phase, it was decided to apply sealant and then Stego® Tape (see image below) along the spline surface connections between CLT panels, which measured 4.0ft x 40ft (1.2m x 12m). The use of Stego® Tape was a constructive best practice solution based on lessons learned from other mass timber construction sites visited by the project team.

Image: Protection of joints during construction against water infiltration

Challenges with multi-storey columns

The project was conceived with multi-storey columns and, while it made things easy for the shippers, it proved to be a big headache for the installers. The general contractor concluded that the use of shorter columns, instead of multi-storey columns, would have been a better solution in some cases, as it would potentially reduce the amount on-site intervention. The image below illustrates the design adjustment implemented on site, which was needed to be done so that the CLT panel would wrap around the column providing adequate static support and finishing.

Image: Multi-Storey columns

The image below shows one type of detail for steel column bases supporting the Glulam columns typical. These "little steel chairs" allow the wood column stay off the ground, preventing water from accumulate around the wood column base during the construction.

Image: Steel base place (HSS) supporting Glulam column at Concrete support

Tolerances

The tolerances for wood are substantially lower than that for steel and concrete. The designer and manufacturers must account for the different materials and type of connections in the design and detailing. The image below shows a beam hanger steel connection between a Glulam beam and a concrete wall. As noted in the image below, the tolerance requirements of the different material components, i.e., concrete and mass timber in the case illustrated in the image below, have been accounted for in the design.

Based on experience from the GC during construction, the slotted-bolted connection shown in the image above proved difficult and time consuming to install. Another detail that would be preferred is a saddle connection.

The completed project

Image: Adohi Hall project completed