Tall Timber: Mass Timber for High-Rise Buildings

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Content

1.0 Introduction
1.1 Understanding Mass Timber 10
1.2 A Brief History of Tall Mass Timber 18
1.3 Tall Timber Global Audit 20

2.0 Case Studies
2.1 25 King, Brisbane, Australia 32
2.2 Ascent, Milwaukee, United States 46
2.3 Brock Commons Tallwood House, Vancouver, Canada 56
2.4 Dalston Works, London, United Kingdom 82
2.5 De Karel Doorman, Rotterdam, Netherlands 94
2.6 HoHo Wien, Vienna, Austria 106
2.7 LifeCycle Tower (LCT) One, Dornbirn, Austria 118
2.8 Mjøstårnet, Brumunddal, Norway 132
2.9 Origine, Québec City, Canada 144
2.10 Sara Kulturhus, Skellefteå, Sweden 162
2.11 Stadthaus, London, United Kingdom 176
2.12 TreeT, Bergen, Norway 188

3.0 Key Topics
3.1 Owner/Developer Motivations 202
   Jeff Spiritos
3.2 Structural Systems 212
   Tobias Fast
3.3 Code Considerations (United States) 218
   Ricky McLain
3.4 Material Testing (Fire) 226
   David Barber
3.5 Fire Safety Engineering 232
   David Barber
3.6 Acoustics 238
   Jason Cattelino
3.7 MEP Systems 246
   Graeme Stewart & Iain Watson
3.8 Building Envelope 250
   Graham Finch
3.9 Construction Process 256
   Tobias Fast, Lisa Podesta & Rainer Strauch
3.10 Cost Considerations – Labor and Materials 262
    Lisa Podesta
3.11 Cost Considerations – Insurance 268
    Jake Concarino & Patrick McBride
3.12 Carbon and Sustainability 274
    Kathryn Fernholz
3.13 Sourcing and Supply 280
    Erica Spiritos

4.0 Analysis, Lessons Learned, and Future Objectives 286

5.0 Glossary of Relevant Terms and References 310

Projects-at-a-Glance

55 Southbank, Melbourne, 2020 209
Tallwood 1 at District 56, Langford, 2022 215
Opalia, Paris, 2017 255
Sensations, Strasbourg, 2019 219
1.1 Introduction
Understanding Mass Timber

The construction industry has a significant role to play in addressing our planet’s overlapping crises, including climate change, mass urbanization, and inequity, among others. The mass timber tall building, in which engineered timber products perform all or most structural work, can be a significant factor in this urgent response. Constructing more tall buildings with mass timber could usher in a paradigmatic shift across the entire process of city-making, increasing its efficiency and productivity, while reducing its contribution to greenhouse gas emissions.

Benefits of Mass Timber

There are numerous benefits of using mass timber in construction, as highlighted below.

The Carbon-Sustainability Equation

- **Less Energy Required**
  Timber is the only building material that regenerates itself naturally, through the growth of trees. This gives it an inherent advantage over other building materials. While the raw materials for steel and concrete must be extracted from the earth, then refined and formed into the final product—both processes that use a tremendous amount of energy, and for which the supplies are not replenished—timber begins to replenish itself as soon as a seed is planted to replace a harvested tree. Removing and converting trees into timber is not a zero-energy enterprise, of course, but it is inherently less carbon-intensive.

  The degree of impact that construction activities and materials will have on ecosystems is directly linked to their longevity, as well as numerous public health outcomes. The production process of steel and concrete both require heating materials to incredibly high temperatures, which accounts for the bulk of their carbon dioxide emissions. Steel then needs to be cooled, which is water-intensive. Steel and concrete, which have been the principal materials of high-rise buildings of the past century, are heavily reliant upon fossil fuels to produce.

  Construction timber, by contrast, is much less energy-, heat-, or chemical-intensive to grow, with most of its principal energy demands going towards kiln-drying it in preparation for use. These and other operations can be at least partially powered by biomass, or sawmill residue, instead of being entirely reliant upon fossil fuels (Ramage et al. 2017).

  Life cycle assessment (LCA) studies conducted on timber buildings, as opposed to those built with more common materials such as steel, concrete, and cement, suggest that its negative impact from resource extraction, to processing, transportation, maintenance, and eventual recycling/disposal can be significantly reduced. A University of Washington study comparing a traditional reinforced-concrete building to a mid-rise timber building concluded that using timber to construct the building resulted in a 26.5 percent reduction in global warming potential (Pierobon et al. 2019).

- **Carbon Sequestration**
  As the AEC industry works globally to reduce the amount of carbon emissions generated through building projects, timber is an outlier—a material that, while growing, actively removes and stores carbon from the environment, and for an extended length of time, as opposed to releasing it. On average, 50 percent of a tree’s dry weight is carbon. A single Douglas fir will sequester 966 kilograms of carbon over a 20-year span. In the United States, forests and other non-agricultural lands absorb a net 13 percent of the country’s global carbon emissions. Throughout their life cycle, trees emit carbon as their parts decompose: needles and leaves fall to the ground; bark and dead branches are torn or blown off; and finally, when the tree itself dies, it begins to release carbon back into the atmosphere through decay. But the process of complete decomposition may take decades, depending upon factors like climate and temperature (Russell 2020). As long as the wood products are not allowed to decompose, for example by using them as a building material, their utility as a carbon sink remains intact for the entire life cycle of the timber element.

- **Carbon Storage**
  One of the central sustainability propositions of using mass timber as a building material is that it “locks” or stores carbon in the buildings, instead of releasing it into the atmosphere. For example, Stadthaus, London (see Chapter 2.11, page 177), stores 185,000 kilograms of carbon dioxide equivalent (CO₂ eq), compared to the 125,000 kilograms of carbon dioxide that would be released into the atmosphere had the building been constructed of concrete.
Sustainably Managed Forests

All forests represent carbon sinks to some degree, but the most efficient ones are abundant with young trees, defined as trees that are younger than 140 years. Younger trees sequester carbon at greater rates (~25 percent) than older trees, so cutting down trees to use in construction, then replanting, has a positive carbon impact (Pugh et al. 2019). Reforested agricultural lands and/or land that has been decimated by forest fires represent significant opportunities to serve as highly efficient carbon sinks.

Cutting down trees may seem counterintuitive as a measure to reduce carbon emissions, but when carbon sequestration is the goal, the manner of execution makes all the difference. In fact, the area of United States’ forested land has remained relatively stable since 1910, and the wood volume within that land has been increasing—partially due to the lessening demand for paper products (Oswalt & Smith 2014).

Intentionally harvesting small-diameter trees to use for mass timber not only clears up space for healthier, sturdier trees to grow, but it also potentially preserves habitat to host at-risk and endangered species, as well as preserves forested lands (see Figure 1.1.1).

Refraining from actively thinning out forests can also be detrimental to some tree species. Shade-intolerant black cherry, white ash, and hickory trees, for example, suffer when forested areas become too shady, suffocating the growth of young trees (Jackson & Finley 2021). Using intentional forestry management strategies and designating specific forests as a pipeline to building timber products will increase habitat retention, carbon sequestration efficiency, and allow forests to regenerate by permitting sunlight to penetrate through.

The specific cycle of a sustainably managed forest proceeds through site preparation, reforestation, thinning and salvage, followed by harvesting timber, which is then removed from the cycle for usage in planned quantities. Recycling is the final step. Forests on public lands usually lack the funding to consistently be thinned to the extent that all risks can be mitigated, but by funneled weak and small trees towards the mass timber market, an additional source of funding could be secured. Logs with diameters as small as 114 millimeters (4.5 inches), which generally have no other market, could be used for mass timber production (Roberts 2020). Applying a financial incentive to maintain forests responsibly as part of the tall timber pipeline would disincentivize transforming them into urban development or agricultural land.

Habitat Retention and Ownership

Over half of the United States’ forested lands—56 percent of a total of 303 million hectares (751 million acres)—is privately owned, and thus falls outside of the management jurisdiction of federally- and

On average, 50 percent of a tree’s dry weight is carbon.
A single Douglas fir will sequester 966 kilograms of carbon over a 20-year span.

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Figure 1.1.1. When done selectively, the removal of small-diameter trees can be part of a larger sustainable forest management plan. © Bureau of Land Management Oregon and Washington
1.3 Introduction

Tall Timber Global Audit

Introduction/Definitions

In early 2023, there were 161 buildings around the world of eight stories or higher, proposed, under construction, or completed. To maintain a high level of confidence and consistency, and to distinguish from earlier, conventional timber-framed typologies, as described in “Mass Timber Defined” (see page 13), in this audit of the current state of tall timber, we set a minimum height threshold of eight stories above grade. Further criteria for this dataset are presented below (CTBUH 2022). Note that these same criteria are applied to the case studies and other projects mentioned in the guide.

Building Height
The heights of buildings cited in this guide correlate to the CTBUH Height Criteria. All three types are cited:

Architectural Top
This is measured from the level of the lowest, significant, open-air, pedestrian entrance to the architectural top of the building, also including spires, but not including antennae, signage, flagpoles or other functional-technical equipment. This measurement is the most widely utilized, and is employed to define the CTBUH rankings of the “World’s Tallest Buildings.”

Height to Highest Occupied Floor
This is measured from the lowest, significant, open-air, pedestrian entrance to the finished floor level of the highest occupiable floor within the building.

Height to Tip
This is measured from the lowest, significant, open-air, pedestrian entrance to the highest point of the building, irrespective of material or function of the highest element.

Tall Building Characteristics

Function
The Council defines a “single-function” building as one in which 85 percent or more of its total height is dedicated to a single function. A “mixed-use” tall building contains two or more functions, where each of the functions occupies a significant proportion of the tower’s total space. Support areas, such as car parks and mechanical plant space, do not constitute mixed-use functions. Functions are denoted in descending order, i.e., “hotel/office” indicates the hotel function is above the office function.

Number of Floors
The number of floors listed for a building includes all above-ground floors, including the ground floor itself, and significant mezzanine/major mechanical plant floors, unless they have a significantly smaller floor area than the major floors below. Mechanical penthouses or plant rooms above the general roof area are not counted.

Building Status

Proposed
A proposed building:
- Has a specific site, and ownership interests within the building team.
- Has a full professional design team progressing the design beyond the conceptual stage.
- Has obtained, or is in the process of obtaining, formal planning consent or legal permission for construction.
- Is fully intended to progress to construction and completion.

Completed
A completed building must fulfill all the following criteria:
- It must be topped out structurally and architecturally. The architectural topping out of a building implies that all structural and finished architectural elements are in place.
- It must be fully clad (see definition above).
- It must be open for business, or at least partially occupiable.

Tall Mass Timber Buildings, by Function

The predominant functional use of eight-story-plus mass-timber high-rises globally completed to date has been
<table>
<thead>
<tr>
<th>Rank</th>
<th>Building Name</th>
<th>City, Country</th>
<th>Height (m)</th>
<th>Floor Count</th>
<th>Structural System</th>
<th>Function</th>
<th>Status (as of Feb 2022)</th>
<th>Completion Year</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Atlassian Central</td>
<td>Sydney, Australia</td>
<td>182.6</td>
<td>42</td>
<td>Concrete-Steel-Timber Hybrid</td>
<td>Mixed-Use</td>
<td>Under Construction</td>
<td>2027</td>
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<td>Milwaukee, USA</td>
<td>86.6</td>
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<td>Residential</td>
<td>Completed</td>
<td>2022</td>
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<td>3</td>
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<td>Brumunddal, Norway</td>
<td>85.4</td>
<td>18</td>
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<td>Mixed-Use</td>
<td>Completed</td>
<td>2019</td>
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<td>4</td>
<td>HoHo Wien</td>
<td>Vienna, Austria</td>
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<td>2020</td>
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<td>HAUT</td>
<td>Amsterdam, Netherlands</td>
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<td>Office</td>
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<tr>
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<td>Roots Tower</td>
<td>Hamburg, Germany</td>
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<td>Residential</td>
<td>Under Construction</td>
<td>2023</td>
</tr>
<tr>
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<td>Baufeld 1 Suurustoffi Abro</td>
<td>Risch-Rotkreuz, Switzerland</td>
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<td>Mixed-Use</td>
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<td>Completed</td>
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<td>Singapore</td>
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<td>Institutional</td>
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<td>2019</td>
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<td>Bordeaux, France</td>
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<td>2021</td>
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<td>Residential</td>
<td>Completed</td>
<td>2013</td>
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<tr>
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<td>Lyon, France</td>
<td>53.0</td>
<td>17</td>
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<td>Mixed-Use</td>
<td>Under Construction</td>
<td>2023</td>
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<td>Limberlost Place</td>
<td>Toronto, Canada</td>
<td>52.5</td>
<td>10</td>
<td>All-Timber</td>
<td>Institutional</td>
<td>Under Construction</td>
<td>2024</td>
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<tr>
<td>18</td>
<td>Ngtyan Koriayo</td>
<td>Greater Geelong, Australia</td>
<td>52.0*</td>
<td>12</td>
<td>Concrete-Timber Hybrid</td>
<td>Office</td>
<td>Under Construction</td>
<td>2022</td>
</tr>
<tr>
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<td>503 on Tenth</td>
<td>Portland, USA</td>
<td>50.0</td>
<td>10</td>
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<td>Office</td>
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<td>2023</td>
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<tr>
<td>20</td>
<td>Treet</td>
<td>Bergen, Norway</td>
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<td>14</td>
<td>All-Timber</td>
<td>Residential</td>
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<td>2015</td>
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<td>Lighthouse Joensuu</td>
<td>Joensuu, Finland</td>
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<td>Brisbane, Australia</td>
<td>46.8</td>
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<td>Office</td>
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<tr>
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<td>Stockholm, Sweden</td>
<td>44.0*</td>
<td>13</td>
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<td>Residential</td>
<td>Under Construction</td>
<td>2023</td>
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<tr>
<td>=24</td>
<td>Hoas Tuulinittty</td>
<td>Espoo, Finland</td>
<td>44.0*</td>
<td>13</td>
<td>All-Timber</td>
<td>Residential</td>
<td>Completed</td>
<td>2021</td>
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<tr>
<td>=24</td>
<td>Obayashi Training Facility</td>
<td>Yokohama, Japan</td>
<td>44.0</td>
<td>11</td>
<td>All-Timber</td>
<td>Office</td>
<td>Completed</td>
<td>2022</td>
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<tr>
<td>=24</td>
<td>Palazzo Nice Meridia</td>
<td>Nice, France</td>
<td>44.0*</td>
<td>10</td>
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<td>Office</td>
<td>Completed</td>
<td>2019</td>
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<td>28</td>
<td>T3 Bayside</td>
<td>Toronto, Canada</td>
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<td>Office</td>
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<td>Residential</td>
<td>Completed</td>
<td>2019</td>
</tr>
</tbody>
</table>

Table 1.3.1. The tallest 30 mass timber buildings worldwide, completed or under construction, as of February 2023. Please note that heights marked with an (*) are estimated, based on the floor count of the building. Find out more at talltimbercenter.com.
2.1 Case Study

25 King
Brisbane, Australia

Background/Overview

Located in the heart of Brisbane’s Royal National Agricultural and Industrial Association of Queensland (RNA) Showgrounds, 25 King (see figures 2.1.1 and 2.1.2) is one of Australia’s tallest and largest timber commercial buildings. The site anchors one end of King Street, a burgeoning precinct in Brisbane whose planners are working to prioritize sustainability and well-being through design. The building’s expression—marked on the exterior by its ground-level timber colonnade and “verandah” south façade—nods to the Showgrounds’ historic pavilions and traditional “Queenslander” buildings.

Owner/Developer Motivations

Although the building was initially conceived as having a concrete structure, the project site overlaps a road tunnel; the potential complications from this provided further incentive to use a lightweight structural material to achieve the desired height. When engineering firm Aurecon was secured as the anchor tenant, the company expressed a keen interest in a building that would communicate its commitment to sustainability, thus driving the decision to use timber. The developer and architect had confidence in this approach from prior success with mass

Project Base Metrics

Status
- Completed: 2018

Building Function
- Office

Structural Classification
- All-Timber over Concrete

Structural Materials
- Mass Timber:
  - Columns (GLT): levels 2 to 10
  - Beams (GLT): levels 2 to 10
  - Floors (CLT): levels 3 to 11
  - Braces (GLT): levels 1 to 10
  - Core (CLT): levels 2 to 11
- Concrete:
  - Foundations
  - Floors: levels -1 to 2
  - Columns: levels -1 to 1
  - Beams: levels -1 to 1
  - Core: levels -1 to 1

Building Milestone Dates
- Construction start: May 2017
- Completion date: October 2018
- Construction period: 16 months

Height
- Height to architectural top: 46.8 meters
- Height to highest occupied floor: 34.4 meters
- Height to tip: 46.8 meters

Number of Floors
- Above grade: 11
- Below grade: 1

Building Floor Area
- Total gross floor area: 16,446 m²
- Net internal area: 14,963 m²
- Area of building footprint: 1,863 m²
- Entire site/plot: 1,884 m²
- Site coverage: 99%

Number of Elevators
- 4

Building Occupancy
- 1,500 persons

Building Density
- 11 m² GFA/person

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Figure 2.1.1. Overall view of 25 King, Brisbane. © Tom Roe
Figure 2.1.2. Ground and typical floor plans. © Bates Smart, redrawn by CTBUH
Mjøstårnet, Brumunddal, Norway

Background/Overview

Mjøstårnet is an 18-story, all-timber building (see Figure 2.8.1), which, at a height of 85.4 meters, ranked as the tallest timber building in the world overall until mid-2022, and is expected to continue to be the “tallest building with an all-timber structure” into 2023. The mixed-use project features a restaurant, offices, a hotel, apartments, conference space and a rooftop terrace (see Figure 2.8.2). The building is located on the shore of Lake Mjøsa, the largest lake in Norway, about 140 kilometers north of Oslo. The building is intended as a demonstration of the possibilities of using timber in high-rise construction.

Owner/Developer Motivations

The initiative to develop Mjøstårnet came from local investor Arthur Buchardt and his company AB Invest AS. Buchardt was a lifelong resident of Brumunddal who wanted to build the world’s tallest timber building as

Project Base Metrics

Status
- Completed: 2019

Building Function
- Mixed-Use
  - Level 1: lobby and restaurant
  - Levels 2 to 3: conference rooms
  - Levels 4 to 7: offices
  - Levels 8 to 11: hotel
  - Levels 12 to 17: apartments
  - Level 18: occupiable floor with terraces

Structural Classification
- All-Timber

Structural Materials
- Mass Timber:
  - Columns (GLT): levels 1 to 18
  - Beams (GLT): levels 1 to 18
  - Framed floors (LVL): levels 2 to 11
  - Core walls (CLT): levels 1 to 18
  - Braces (GLT): levels 1 to 18
  - Pergola (GLT): level 18
- Concrete:
  - Foundations
  - Floors: levels -1 and 12 to 18

Building Milestone Dates
- Construction start: April 2017
- Completion date: March 2019
- Construction period: 23 months

Height
- Height to architectural top: 85.4 meters
- Height to highest occupied floor: 68.2 meters
- Height to tip: 88.8 meters

Number of Floors
- Above grade: 18
- Below grade: 1

Building Floor Area
- Total gross floor area: 11,480 m²
- Net internal area: 11,300 m²
- Area of building footprint: tower and bath house: 3,752 m²
- Entire site/plot: 15,680 m²
- Site coverage: 24%

Number of Units
- 33 apartments
- 72 hotel rooms

Number of Elevators
- 3

Building Occupancy
- 913 persons (not including the ground floor)

Building Density
- 10.7 m² GFA/person
3.4 Key Topics

Material Testing (Fire)
David Barber, Principal, Arup

David Barber is a principal with Arup, where he specializes in the fire safety of mass timber buildings. For over 25 years Barber has assisted with the growth and development of timber construction, including fire testing, developing new timber technologies, authoring fire safety design guides, changing building codes and standards, working with timber product suppliers and completing fire safety solutions for low-, mid-rise, and high-rise timber buildings.

Introduction

Mass timber has been successfully used for mid-rise construction for decades, and with the desire for more sustainable construction and reduced embodied carbon, mass timber’s role in building construction is expanding into larger and taller buildings. As codes and standards change globally to allow for more mass timber to be used, fire testing becomes more relevant, given that larger, taller and more complex buildings will normally require higher levels of fire performance.

All materials used for construction are required by building regulations or codes to meet predetermined fire performance criteria, so that goals for occupant life safety, prevention of fire spread, and facilitating firefighting operations can be met. For most buildings, the key fire performance criteria are that load-bearing elements need to be fire-resistant (see Figure 3.4.1), with requirements based on building use, height, floor area and adjacency to lot boundaries. Additionally, all interior surfaces need to meet flammability limits to slow the early growth of a fire. Building codes reference fire testing standards or calculation methods that provide a consistent approach for all materials.

Wherever fire testing is required for a load-bearing element, it is exposed to a predetermined time-temperature curve, typically called a “standard fire.” ASTM E119 (ASTM 2020) is the nationally accepted test standard in the United States that provides the test method, set-up, loading, pass/fail criteria and reporting requirements to allow a material to achieve a fire-resistance rating, as referenced by the International Building Code (ICC 2021). Within Europe, fire tests on wall and floor assemblies will be carried out to EN 1363-1 (CEN 1999, 2000, 2012 & 2014) series of standards relating to fire resistance testing. All materials undergo the same type of test and must pass the same acceptance criteria.

When a calculation method is available to determine fire resistance, this will be documented within a code, a nationally accepted consensus standard, or guideline. The calculation methodology will be based on numerous completed fire tests, such that the calculation method allows engineers and designers to carry out the required assessment with knowledge that the end result will be conservative. The published method also allows for checkers to carry out the required reviews.

<table>
<thead>
<tr>
<th>Standards</th>
<th>Time (min)</th>
<th>Char Depth, $a_{char}$ (in.)</th>
<th>Effective Char Depth, $a_{eff}$ (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NDS (2018)</td>
<td>60</td>
<td>1.5 (38.1 mm)</td>
<td>1.8 (45.7 mm)</td>
</tr>
<tr>
<td>American National Standard</td>
<td>90</td>
<td>2.1 (53.3 mm)</td>
<td>2.5 (63.5 mm)</td>
</tr>
<tr>
<td></td>
<td>120</td>
<td>2.6 (66 mm)</td>
<td>3.2 (81.3 mm)</td>
</tr>
</tbody>
</table>

Table 3.4.1. Design values for the char rate of mass timber members. The effective char depth is approximately 20 percent higher than the actual char depth, to account for the reduced strength of the timber in the elevated temperature zone.

Figure 3.4.1. Load-bearing GLT column, before and after a 90-minute fire-resistance test, showing extent of reduced cross-section. © Arup
Fire Testing or Calculations?

Given the significant difference in time and cost between fire testing and calculation methods, a calculation method will always be preferred by engineers and designers. But often this choice is not as straightforward. A good example of the difference between fire testing and calculation methods is in the determination of fire resistance for glued laminated timber (GLT) and cross-laminated timber (CLT) building elements.

GLT members and other engineered timbers have code-approved fire-resistance calculation methods available in guidance such as the NDS (AWC 2018), CSA O86 (CSA 2019) and EN1995-1-2 Eurocode 5 (CEN 2004a) (see Table 3.4.1). Building approval authorities are familiar with these methods, and the assessment of fire resistance for beams and columns is therefore straightforward. The fire resistance for CLT is not as straightforward. Similar to GLT, there are well-proven calculation methods available, published in guidance such as the NDS and CLT Handbook (Karacabeyli & Douglas 2013). Yet many building approval authorities will only rely on fire testing to prove fire resistance for CLT panels, given that they are a relatively new product (see figures 3.4.2 and 3.4.3). This requirement for fire testing of CLT places a cost burden on the CLT suppliers, or leads to inefficient building design, as architects and engineers find other tested but less-suitable products.

Fire testing or calculation methods can also be used to determine the fire resistance for connections of mass timber elements. The use of a calculation method will be dependent on the type of mass timber connection, the calculation methodologies available in guidance, fire test evidence to support the analysis, and acceptance of the method by the building approval authorities. Where analysis is not possible or not efficient, then fire-testing a mass timber connection is required.

Fire testing is normally required to determine timber flammability where it is used as an interior lining, or for acceptance of timber within exterior walls, as well as for fire-sealing penetrations, joints, and other timber interfaces. Fire testing is carried out in the United States to ASTM E84 (ASTM 2021) to determine flame spread and smoke development. In Europe, the Euroclass system to EN 13501-1 (CEN 2018) is used and measured by the single burning item test to EN 13823 (CEN 2020b), and the single-flame source test to EN ISO 11925-2 (CEN 2020c). There are no calculation methods for these building elements.

Figure 3.4.2. A CLT panel being tested for fire resistance. © Arup
Analysis, Lessons Learned, and Future Objectives

Introduction

This chapter collects the findings of individual case studies in Chapter 2 and the key topics/considerations provided by discipline experts in Chapter 3, subjecting them to a broader analysis and commentary, organized in the same order in which the same key topics and factors of analysis appear in each case study. The objective is to reach a broad set of conclusions about state-of-the-art methods in mass timber design for high-rises, before moving to lessons learned and future objectives.

The case studies (see Table 4.0.1) were selected from a broader tall timber audit pool researched by CTBUH on several bases: height, preponderance of available information, unique or differentiated use of timber as a material, and high levels of stakeholder participation in the research. The case studies are representative of the broad spectrum of mass timber high-rises currently constructed, but the data produced was not exhaustive across all factors in each. This section summarizes the gathered statistics collected for

![Table 4.0.1. The project base metrics data from each case study provides a comparison of height, area, and occupancy.](image)
Each case study in the guide. Where a substantial quorum of figures could be obtained, comparisons are drawn. Even in cases where relatively little data could be obtained, the data is nevertheless displayed where it is known, as the authors believe this is part of creating an authoritative reference for a new way of building.

### Building Characteristics

#### Function

In terms of function, of the 12 case studies in the Guide, two are office-only buildings, five are mixed-use, and five are either residential or hotel uses. Compared to the overall dataset of tall mass timber buildings, eight stories and higher (see Chapter 1.3, page 20), where 64 percent of the buildings are residential/or hotel functions, the case study residential/hotel projects represent a smaller proportion (42 percent).

#### Height/Area

The two extremes in this guide are represented by the newest and tallest (Ascent, Milwaukee, USA) and the

<table>
<thead>
<tr>
<th>Building Name</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCT One</td>
<td>Dornbirn, Austria</td>
</tr>
<tr>
<td>Mjøstårnet</td>
<td>Brumunddal, Norway</td>
</tr>
<tr>
<td>Brock Commons</td>
<td>Vancouver, Canada</td>
</tr>
<tr>
<td>Dalston Works</td>
<td>London, UK</td>
</tr>
<tr>
<td>De Karel Doorman</td>
<td>Rotterdam, Netherlands</td>
</tr>
<tr>
<td>HoHo Wien</td>
<td>Vienna, Austria</td>
</tr>
<tr>
<td>Ascent</td>
<td>Milwaukee, USA</td>
</tr>
<tr>
<td>Origine</td>
<td>Québec, Canada</td>
</tr>
<tr>
<td>Sara Kulturhus</td>
<td>Skellefteå, Sweden</td>
</tr>
<tr>
<td>Stadthaus</td>
<td>London, UK</td>
</tr>
<tr>
<td>Treet</td>
<td>Bergen, Norway</td>
</tr>
</tbody>
</table>

#### Building Characteristics Table

<table>
<thead>
<tr>
<th>Category</th>
<th>Office</th>
<th>Mixed-Use</th>
<th>Residential</th>
<th>Mixed-Use</th>
<th>Residential</th>
<th>Residential</th>
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<tbody>
<tr>
<td>Concrete-Timber Hybrid</td>
<td>All-Timber</td>
<td>All-Timber over Concrete</td>
<td>All-Timber over Concrete</td>
<td>All-Timber over Concrete</td>
<td>All-Timber over Concrete</td>
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</tr>
<tr>
<td>12 months</td>
<td>23 months</td>
<td>17 months</td>
<td>36 months</td>
<td>11 months</td>
<td>21 months</td>
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<tr>
<td>27 m</td>
<td>85.4 m</td>
<td>40.9 m</td>
<td>72.8 m</td>
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<td>22 m</td>
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<td>40.9 m</td>
<td>72.8 m</td>
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<td>7</td>
<td>18</td>
<td>13</td>
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<td>14</td>
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<td>1</td>
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<td>1</td>
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<tr>
<td>2,319 m²</td>
<td>11,480 m²</td>
<td>11,547 m²</td>
<td>28,000 m²</td>
<td>2,750 m²</td>
<td>8,080 m²</td>
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<tr>
<td>1,774 m²</td>
<td>11,300 m²</td>
<td>-</td>
<td>27,867 m²</td>
<td>1,861 m²</td>
<td>5,830 m²</td>
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<td>301 m²</td>
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<td>280 m²</td>
<td>490 m²</td>
<td></td>
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<tr>
<td>-</td>
<td>15,680 m²</td>
<td>2,025 m²</td>
<td>7,100 m²</td>
<td>860 m²</td>
<td>2,600 m²</td>
<td></td>
</tr>
<tr>
<td>-</td>
<td>24%</td>
<td>83%</td>
<td>84% m²</td>
<td>33%</td>
<td>19%</td>
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</tr>
<tr>
<td>N/A</td>
<td>105</td>
<td>93</td>
<td>208</td>
<td>29</td>
<td>62</td>
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</tr>
<tr>
<td>1</td>
<td>3</td>
<td>2</td>
<td>8</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>147 persons</td>
<td>913 persons</td>
<td>282 persons</td>
<td>-</td>
<td>118 persons</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>15.7 m² GFA/person</td>
<td>10.7 m² GFA/person</td>
<td>40.9 m² GFA/person</td>
<td>-</td>
<td>23.3 m² GFA/person</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

Average
As a natural building material, mass timber provides extraordinary benefits. Through the growth of trees, its production sequesters rather than emits carbon dioxide, and thus helps counteract climate change. Fused into mass timber panels, beams, and columns, its relative light weight and great strength make it a competitive choice for building tall, reducing on-site assembly time, construction personnel, and associated costs, while offering the precision that comes with prefabrication. The aesthetic appeal of exposed timber drives psychological and physiological well-being, which can also translate into lease and sale premiums. There are challenges of course, with many national and local fire codes heavily restricting the use of timber in the structure and façades of high-rise buildings. But as more use cases and test results become available, attitudes and codes are adapting.

This publication, the outcome of a grant from the USDA Forest Service and Binational Softwood Lumber Council, is a key step forward in increasing understanding of this exciting material. Through twelve detailed, richly illustrated case studies—as well as key topical considerations contributed by the leading experts in timber construction—Tall Timber is the definitive guide for all practitioners involved in the development, design, and operation of tall buildings. The reader will gain a greater understanding of this ancient, newly-reborn material, with its vast potential to build greener, more sustainable cities. It is a companion to the Tall Timber Center, a comprehensive online resource at talltimbercenter.com.