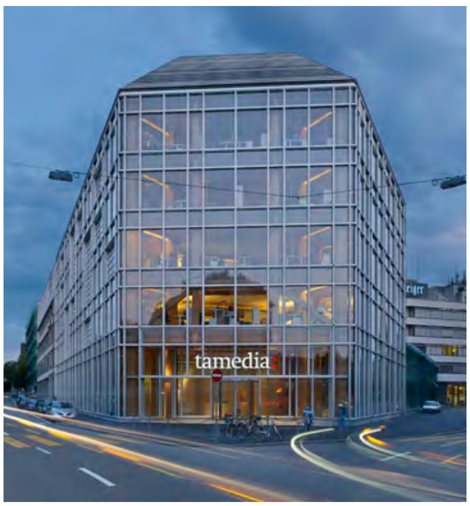










SUMMARY REPORT:
SURVEY OF INTERNATIONAL TALL WOOD BUILDINGS

(BULLETINS INCLUDED)

MAY 2014

Forestry Innovation Investment

BSLC
Binational Softwood Lumber Council

COVER PAGE PHOTO CREDITS:
(From left to right; top to bottom)

1. UBC Earth Sciences Building.
   Architecture by Perkins+Will
   Photo credit: Martin Tessler

2. 3XGRÜN
   Architecture by Atelier PK, Roedig Schop Architekten and Rozynski Sturm
   Photo credit: Stefan Mueller

3. Bridport House
   Architecture by Karakusevic Carson Architects
   Photo credit: Wilmott Dixon Group

4. Cenni di Cambiamento
   Architecture by ROSSIPRODI ASSOCIATI srl.
   Photo credit: Riccardo Ronchi

5. LifeCycle Tower ONE (LCT ONE)
   Architecture by Hermann Kaufmann ZT GmbH
   Photo credit: www.creebuildings.com

6. Forté
   Architecture by Lend Lease
   Photo credit: Lend Lease

7. E3
   Architecture by Kaden Klingbeil
   Photo credit: Bernd Borchardt

8. Holz8 (H8)
   Architecture by SHANKULA Architekten
   Photo credit: Huber&Sohn

9. Tamedia
   Architecture by Shigeru Ban Architects
   Photo credit: Didier Boy de la Tour

10. Limnologen
    Architecture by Arkitektbolaget Kronoberg
    Photo credit: Midroc Property Development

SUMMARY REPORT

EXECUTIVE SUMMARY

Over the past several years, a number of tall wood projects have been completed around the world, demonstrating successful applications of mass timber technologies. Learning from the experiences of early adopters is essential for establishing opportunities for tall wood buildings in North America and other parts of the world.

A survey of ten tall wood building projects in several countries (the Survey) was undertaken to determine and present some common lessons learned from the experiences of four key stakeholder groups involved in the projects. The Survey was focused on the experiences of each project's Developer/Owner, Design Team, Authorities Having Jurisdiction (AHJ), and Construction Team. It also examined the topics of project insurance, project financing and building operations and performance. This report presents the results of the Survey.

The Survey methodology included having key individuals from the stakeholder groups complete a short online questionnaire and participate in individual face-to-face or telephone interviews. More than 50 individuals participated in the Survey. The face-to-face interviews were conducted at the stakeholders' offices at nine of the ten project sites during the month of November 2013.

The majority of building projects surveyed are located in Europe, and the results revealed some important distinctions about building construction practices. There is a strong regulatory grounding in Europe that supports the use of low carbon content materials, renewable resources and energy efficiency in construction. These policies directly and indirectly encourage tall wood and mass timber construction. As well, for the buildings surveyed, there is a greater blending of professional roles across related sectors, creating a strong ethos of collaboration between developers, designers, timber fabricators and researchers. These nuances appear to be significant for advancing strong and credible solutions for tall wood buildings.

The results of the Survey indicate that there are a number of strong and common lessons learned across the projects in addition to specific considerations for each. Many of these elements can be considered to be critical for achieving success. All projects were developed and presented to the relevant authorities having jurisdiction in some form of an alternative solution.

Project Name: 3XGRÜN
Architecture by: Atelier PK, Roedig Schop Architekten and Rozynski Sturm
Photo credit: Stefan Mueller

For the purpose of presentation in this report, the common lessons learned and specific project considerations are categorized and summarized as:

- **Commitment**
  All stakeholders stressed the importance of committing to a timber solution at the start of the project. Having an owner/developer's commitment to a wood solution from the outset of a project maintains a clear focus for all involved. Entering into a new, complex building product field that inevitably comes with challenges requires strong focus in order to achieve satisfactory results. The design team in the project also needs to have a similar commitment but, in addition, the designers need to remain flexible in their approach in order to adjust to the budget and expectations of the owner/developer, the requirements of the authorities having jurisdiction and the site conditions during construction.

- **Planning**
  All stakeholders consistently indicated the importance of pre-planning and investing significant effort early in the design development process in order to identify and resolve design and construction-related issues and conflicts. An owner/developer should understand, from early on, the project's business case and the impact and constraints presented by the regulatory environment and should account for additional effort to cover complexities and costs of innovation.

  The design team must be cognisant of the extra engagement and time required to successfully research, design, obtain approval for and construct a tall wood project. In-depth analysis during the design development process coupled with pre-planning and coordination of prefabrication details and construction can significantly help execute a successful project.

- **Collaboration**
  Stakeholders groups were directly linked to or had strong collaborative ties with each other, researchers and timber fabricators.

  It was demonstrated that the project construction timeline could be shortened by having prefabrication and system integration embraced by the design team, main contractor, principal subcontractors and material suppliers.

  In several cases, engaging early with the authority having jurisdiction and directly involving them in the design development process was a key to the approach required for approvals for fire protection and acoustic performance.

- **Holistic Innovation**
  Most stakeholders emphasized the need to approach mass timber/tall wood projects as wholly innovative, rather than with a focus on only an application, a component or a system that is related to wood elements.

  From an innovative process point of view, unlike conventional construction, it is beneficial to engage the construction team early in the process to align design concepts, regulatory requirements and construction realities. This interaction begins to identify critical issues related to site, material selection and construction coordination and leads to more efficient and practical design solutions.

  For the authorities having jurisdiction, the approval process could be expedited by the presentation of detailed research and well-developed design details that clearly achieve or exceed building safety standards and demonstrate equal or better overall building performance levels.

The Survey results also revealed several interesting details about undertaking tall wood projects, particularly in regard to project initiation and selection of wood as the principal structural material. They include:

- **Motivators**
  Interestingly, the common motivations for pursuing a tall wood project were found to be innovation, market leadership and carbon reduction. Energy efficiency and healthy indoor environments that promote a sense of well-being were indicated to be complimentary design objectives.

- **Shared Objectives**
  Most owners/developers and design teams shared similar objectives at the outset of their projects.
- **Supportive Governing Policies**
  It appears that, in jurisdictions where governing policies exist in support of the use of low carbon content materials, renewable resources and energy efficiency in construction, the acceptance of mass timber solutions is developing more rapidly. In such cases, the governing framework motivated all stakeholders to innovate with wood solutions, and incentive funding was able to be accessed by some.

However, challenges remain in developing, designing, approving and constructing tall wood buildings. They include:

- Work to further test, refine and establish robust and replicable solutions by researchers, material suppliers and the construction industry is still required for mass timber building systems.
- There appeared to be a lack of uniformity of how projects are approved by the authorities having jurisdiction. The degree of difficulty and effort associated with obtaining project approvals was largely dependent on the extent to which the authorities collaborated with the project teams, as well as general familiarity with mass timber, large wood structures or tall wood solutions.
- No single solution was common or typical across all projects to strategically address durability, fire protection or acoustics. Project teams relied on research partnerships, published reports or available test results to support proposed design solutions.
- Perspectives and approaches on weather protection during construction varied widely.

Experiences regarding financing and insurance costs or conditions suggest very little deviation from typical requirements for conventional tall reinforced concrete or steel buildings or for low-rise wood structures. No Owner/Developer experienced challenges obtaining financing attributable to the use of mass timber. In all cases, stakeholders reported they managed to overcome any approval, design or construction obstacles without exceeding the projected project budgets. No Owner/Developer indicated any irregularities regarding building operations or performance.

In summary, the projects collectively have

- explored, initiated and developed new mass timber construction methodologies
- generated novel design solutions and material usage ideas
- presented useful test data
- expanded the capacity of the building construction industry in general, particularly the capacity in the design and construction of tall wood buildings
- streamlined approval pathways for subsequent projects
- provided market recognition for tall wood construction

Overall, the results confirm that wood is a viable option for attaining safe, cost-equivalent, high-performing tall buildings.

ACKNOWLEDGEMENTS:

Forestry Innovation Investment (FII) and the Binational Softwood Lumber Council (BSLC) would like to acknowledge the work carried out by Perkins+Will to conduct the survey, compile the data, and design and prepare the summary report and the bulletins of lessons learned. FII and BSLC would also like to thank all survey participants for their time to share their experiences and opinion.

For questions with regards this report, please contact:

Canada and International:
Sonya Zeitler Fletcher
Director, Market Outreach
Forestry Innovation Investment
Phone: (604) 601-5305
Email: sonya.zeitlerfletcher@bcfii.ca

United States:
Cees de Jager
General Manager
Binational Softwood Lumber Council
Phone: (604) 536-7730
Email: dejager@softwoodlumber.org

GLOSSARY

Alternative Solution is a design solution through which compliance with a building code is achieved by demonstrating that the proposed solution provides an equal or better level of performance to the prescribed acceptable solution given in the building code.

Authority of Having Jurisdiction (AHJ) is the agency that regulates the local, regional or national building industry.

Brettstapel in this document, is the term commonly used for solid timber construction that does not generally use glues or nails. The system works by using dowels with a moisture content lower than that of the posts; over time the dowels expand to achieve moisture equilibrium thus 'locking' the posts together and creating a structural load-bearing system.

Builder-Owner Collective In this document, the term refers to a method of organizing individual owners as a formal, legally recognized group for the purposes of acquiring land to design and construct a multi-family dwelling. This arrangement is relatively common in Germany, and eliminates the traditional role of Developer, allowing the group of individual owners to work directly with the design, often resulting in highly customized suites.

Carbon footprint is the total amount of carbon dioxide emitted into the atmosphere as a result of an activity or process.

Cross-Laminated Timber (CLT) is a laminated timber panel consisting of a minimum of three layers of boards stacked crosswise (typically at 90 degrees) and fastened with glue, dowels or nails.

Char layer is the added thickness of a timber component which exceeds required structural dimensions, designed to protect the timber components in case of fire.

Embodied Carbon is the total amount of carbon dioxide released from material extraction, transport, manufacturing, and related activities.

Grey Water is untreated waste water, which has not come into contact with toilet waste or kitchen sinks, typically from bathroom sinks, bathtubs, and showers.[1]

Hybrid construction in this document, refers to building structures where mass timber products are used in combination with steel or concrete.[2]

Lateral stability is the capacity of a structure to resist the lateral forces without overturning, buckling or collapsing, while maintaining a given position in space.

Mass Timber in this document, refers to a form of construction which uses large prefabricated wood members such as Laminated Veneer Lumber (LVL), Laminated Strand Lumber (LSL), and Cross Laminated Timber (CLT) for wall, floor and roof construction. Glulam can also be used in beam and column applications.[3]

Mixed use is used to describe a project or development typology that integrates more than one use such as residential, commercial and retail spaces.

Panelized System in this document, is a method of constructing with prefabricated panel elements such as CLT or other solid timber panel products, as opposed to a post and beam framing system.

Passive House a rigorous, voluntary energy performance standard for buildings, which aims to reduce the requirement for space heating and cooling, whilst also creating excellent indoor air quality and comfort levels.[4]

---

1 LEED Canada-BD+C 2009 Reference Guide.

2 FP Innovations. (2011) CLT Handbook

3 http://www.masstimber.com/

4 http://www.passivehouse.ca/

Post + Beam in this document, is the structural framing system in which the structural members (vertical posts and horizontal beams) are anchored and joined with structurally engineered mechanical fasteners.

Prefabricated refers to shop manufactured components that are transported to a site and assembled in situ.[5]

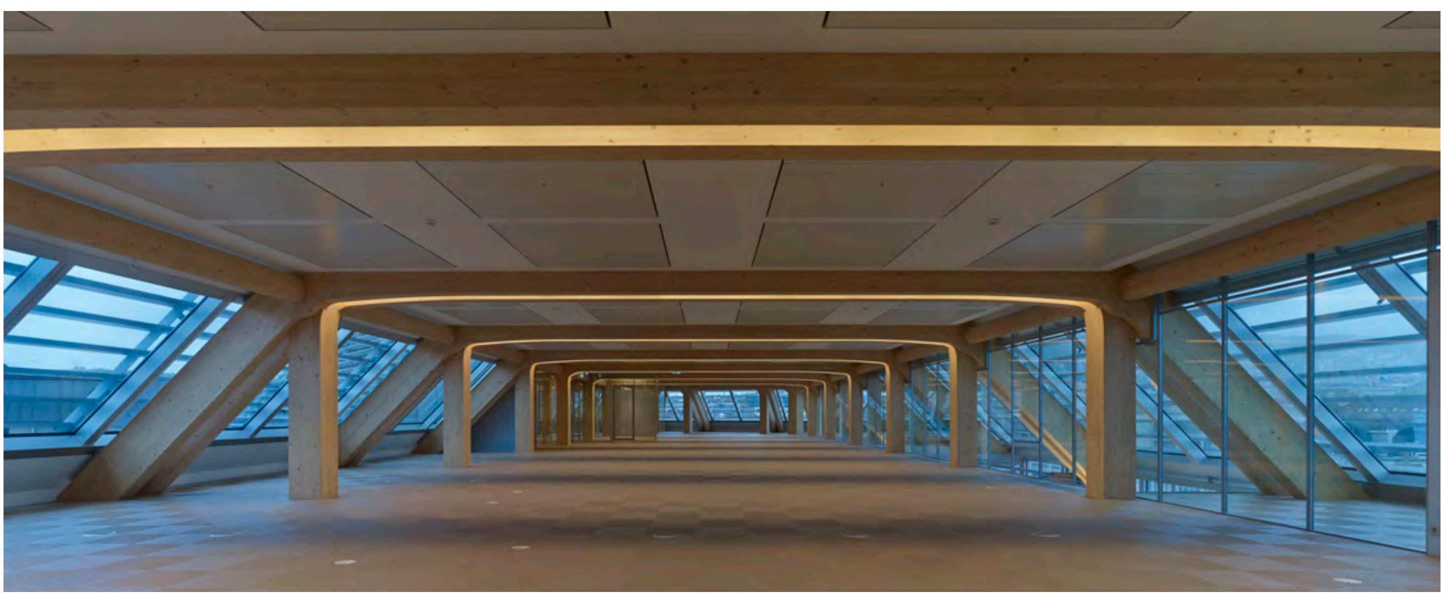
Systems integration in this document, is used to describe how electrical and mechanical systems are incorporated into the overall building design.

Self-financing refers to the internal investment sources that owners or developers are able to draw upon to fund the development of a project, without soliciting outside funding from traditional lending sources.

Tall Wood Building in this document, is a structure consisting primarily of Mass Timber of 5 storeys or more.

5 Green, Michael. (February, 2012) The case for Tall Wood buildings. How Mass Timber Offers a Safe, Economical, and Environmentally Friendly Alternative for Tall Building Structures.

TABLE OF CONTENTS:



Project Name: Tamedia
Architecture by: Shigeru Ban Architects
Photo credit: Didier Boy de la Tour

1.0 INTRODUCTION

The purpose of this report is to summarize the results of a Survey of International Tall Wood Buildings (the Survey) conducted by Perkins+Will on behalf of Forestry Innovation Investment (FII) and the Binational Softwood Lumber Council (BSLC). FII and BSLC believe that collaborating with global leaders in taller wood construction to share experiences and information may help to reduce risk and accelerate early adopter projects around the world – bringing credibility to all advancing the area of tall wood buildings.

The goal of the Survey was to collect lessons learned and experiences from built projects around the world that have utilized various tall wood building technologies. This report presents common themes and trends among project stakeholders including Owner/Developer, Authorities Having Jurisdiction, Design teams and Construction teams. The aim is to share this information with potential North American project stakeholders to help simplify their processes, increase their comfort and potentially lower their risk of designing tall wood structures, ultimately broadening the uptake of wood systems used in tall wood construction. It is also likely that a compilation of these lessons learned and experiences will assist stakeholders of new projects yet to be built around the world.

1.1 SCOPE

The Survey examined ten international built projects identified as buildings using mass timber to construct buildings of five stories or more, and sought to compile the experiences of four key stakeholder groups including the Developer/Owner, Authority Having Jurisdiction, Design team and Construction team. The Survey focused on four distinct but related areas of inquiry:

- Lessons Learned
- Project Insurance
- Project Financing
- Building Operations and Maintenance

Project specific Bulletins of Lessons Learned were prepared to present a summary of each built project examined in the context of the Survey, and this report presents trends and themes that emerged from the Survey within each of the research areas listed above. Refer to Appendix A for the Bulletins of Lessons Learned and Appendix B for a list of published resources for each project.

Project Name: Limnologen
Architecture by: Arkitektbolaget Kronoberg
Photo credit: Midroc Property Development

1.2 METHODOLOGY

Ten built projects were chosen based on a variety of criteria including building typology, timber structure type, date of completion, willingness and availability of stakeholders to participate and extent of information already published. The ten built projects examined are summarized in Table 1 below.

Table 1: Survey of International Tall Wood Buildings - Participant Projects

PROJECT NAME	LOCATION	BUILDING TYPE	STOREYS	WOOD CONSTRUCTION TYPE	COMPLETION DATE
E3	Berlin, Germany	Commercial / Residential	7	Post and Beam	2008
Limnologen	Vaxjo, Sweden	Residential	8	Panelized	2009
Bridport House	London, England	Residential	8	Panelized	2010
3XGRÜN	Berlin, Germany	Residential	5	Combination Panels / Post and Beam	2011
Holz8 (H8)	Bad Aibling, Germany	Commercial / Residential	8	Panelized	2011
Forté	Melbourne, Australia	Commercial / Residential	10	Panelized	2012
University of British Columbia Earth Sciences Building (ESB)	Vancouver, Canada	Institutional	5	Combination Panels / Post and Beam	2012
LifeCycle Tower One (LCT One)	Dornbirn, Austria	Commercial	8	Combination Panels / Post and Beam	2012
Tamedia	Zurich, Switzerland	Commercial	6	Post and Beam	2013
Cenni di Cambiamento	Milan, Italy	Commercial / Residential	9	Panelized	2013

Key individuals representing each of the four stakeholder groups were identified and contacted by email and/or telephone, with a formal invitation to participate in the Survey. Stakeholders were asked to complete a short, online questionnaire to establish the basis for a more detailed one hour in-person or telephone interview with two researchers. Subject matter and questions posed in the online questionnaires and interviews were based on known knowledge gaps and perceived challenges and risks of constructing tall wood buildings in the North American market place. Relevant results from the online questionnaire have been included throughout the report in graphic format to further portray trends and findings of the survey.

Researchers visited all of the project locations in person during the month of November 2013, with the exception of Forté in Melbourne, Australia. Where a participant was either unavailable or could not be identified to represent a specific stakeholder group, information and feedback was acquired from participants in other project disciplines and stakeholder groups or from published documents. It should be noted that stakeholders representing the Authorities Having Jurisdiction (AHJ) were generally more challenging to access, and as such, depth of information and strength of trends are limited. Where appropriate, relevant experiences and lessons associated with the AHJ and approvals process were compiled from other project stakeholders.

2.0 LESSONS LEARNED

2.1 OWNER / DEVELOPER

Participants within the Owner/Developer stakeholder group included conventional development companies, building owner-occupiers, and Building-Owner Collectives who were also acting as project designers. In all cases this stakeholder group was engaged extensively with the details of the project development and execution from the early stages of research and due diligence, through planning, design and construction.

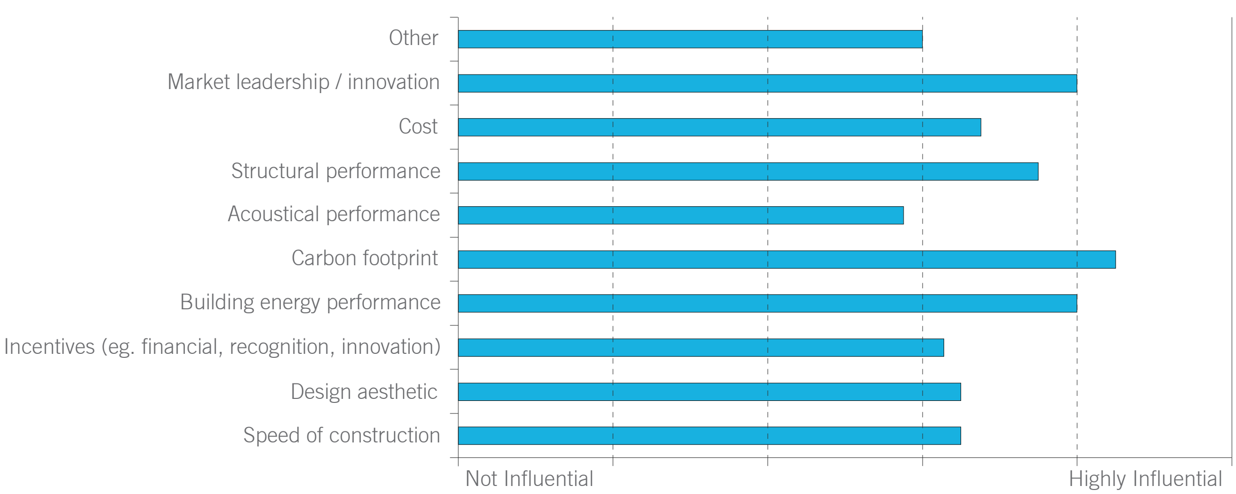
Survey participants were asked to comment on the rationale for pursuing a tall wood project, project risk considerations, budget and cost considerations as well as management processes and strategies. Overall challenges, successes and lessons learned were also solicited. The following section summarizes themes and trends common across all ten projects, and identifies unique scenarios where relevant.

LESSONS FROM TALL WOOD

From the perspective of the Owners/Developers, the Survey results point to the following as factors for successful completion of tall wood projects:

- A commitment to a wood solution was clearly communicated by the Owner/Developer to all project stakeholders from the outset.
- The project business case and budgets recognized and allowed for the cost of innovation.
- The Design Team's vision was aligned with the Owners/Developers' vision.
- The Authority Having Jurisdiction were engaged early in the project process and worked collaboratively with the Owner/Developer and Design Teams to resolve issues and develop acceptable solutions.
- Construction Teams and key timber suppliers, in most cases, were engaged early in the design process in order to help align concepts, regulatory guidelines and construction realities.

Owner/Developer: Online Questionnaire Participant Responses
Influential Factors on the Owner / Developer's Decision to Use Structural Wood Technology:



WHY TALL WOOD

Based on the feedback gathered from the Owner/Developer of the ten international projects, the following were identified by participants as the most influential reasons for pursuing a tall wood project:

- **Low carbon footprint**

  Realize significant carbon savings compared to conventional structural materials such as steel and concrete, by using more timber in construction. In several cases carbon reductions were pursued in response to governing regulatory policy.

- **Innovation and market leadership**

  The opportunity to test a new structural typology with the objective of creating a leading position in the market place for future development.

- **Building energy performance**

  Benefit from the relatively good thermal performance of mass timber products compared to concrete or steel structure to support efficient building energy performance.

Additional motivations identified by the participants that are particularly relevant within the contexts of each project:

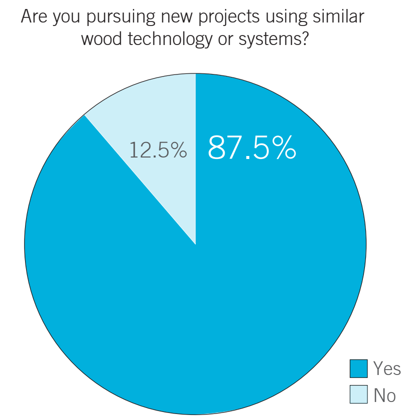
- **Light weight structure**

  Two projects with sensitive site conditions (Bridport House and Forté) identified that mass timber was particularly appealing for its lighter weight compared to a concrete or in some instances, a steel structure. One participant identified the potential for widespread use of mass timber products in renovation and densification projects where a lighter weight structural material is beneficial for adding storeys to existing buildings.

- **Durability**

  Participants from residential building projects indicated they believe mass timber to be a very durable structural option, appropriate for long-term capital and operational investment and to support high-quality finishing in a high-end residential context.

Owner/Developer:
Online Questionnaire Participant Responses



Project Name: E3
Architecture by: Kaden Klingbeil
Photo credit: Bernd Borachrt

DEVELOPING TALL WOOD

Participants were asked to summarize important project process considerations, and to identify special or unique aspects of managing a tall wood project, different from a conventional project. The following common themes were strong among all participants:

- **Commit**

  Begin with the intention to use a wood structure and commit to innovation holistically. Project teams emphasized the need to approach the work as wholly innovative, rather than focusing on wood innovation only.

- **Understand the Market**

  Investigate the market and understand any negative perceptions associated with the use of mass timber such as fire risk, acoustics, or durability. All survey participants focused on finding solutions to address or resolve market perception, and cultivate credibility for mass timber buildings.

- **Research**

  Establish a partnership or collaborate with a research body to support innovation and design solutions. Research collaborations with academic institutions or other research organizations were integral to evaluating and testing design solutions for all survey participants.

Project Name: Cenni di cambiamento
Architecture by: ROSSIPRODI ASSOCIATI srl
Photo credit: Riccardo Ronchi

- **Collaborate**

  Create a strong, integrated and collaborative design process early. Choose knowledgeable professionals willing to innovate.

- **Engage the Authority Having Jurisdiction**

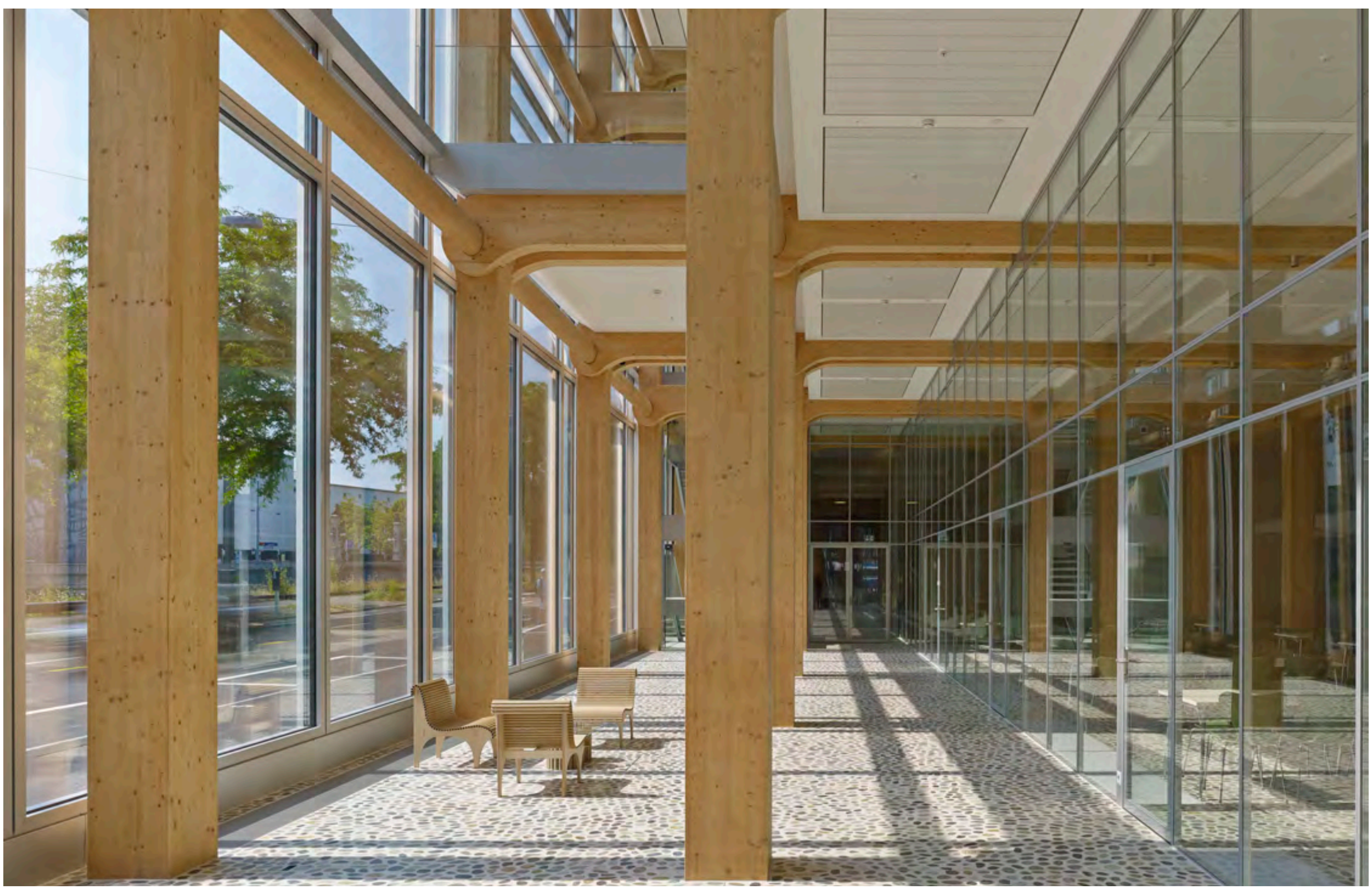
  Engage the AHJ early in the research and due diligence process to establish a collaborative and respectful relationship based on learning and evolving solutions. In all cases with the exception of one, successful approvals were based on an open and evolving dialogue with the Authority to evaluate and implement satisfactory solutions for each unique jurisdiction.

- **Account for Innovation**

  Create a realistic budget that accounts for innovation and experimentation, testing of new design solutions. Use a full cost accounting methodology that recognizes long term operational savings, durability, environmental and social benefits. In all cases, while budget constraints and costs were identified as challenges, participants reported they managed to overcome any design or construction obstacles without exceeding the project budget.

- **Share**

  Monitor, document and share information, experiences and lessons related to developing tall wood buildings. In all cases, participants emphasized the importance of sharing the results of their work to educate the industry, refine design solutions and move toward widespread use of wood in tall construction.



Project Name: Tamedia
Architecture by: Shigeru Ban Architects
Photo credit: Didier Boy de la Tour

2.2 DESIGN TEAM

Design team members surveyed and interviewed included project architects, structural engineers, timber product fabricators and academic research partners. Survey participants were asked to comment on the rationale for pursuing tall wood construction, the design process, design strategies, challenges, successes and lessons learned.

The following section summarizes themes and trends common across all ten projects, and identifies unique scenarios where relevant.

LESSONS FROM TALL WOOD

From the perspective of the Design Teams, the Survey results point to the following as factors for successful completion of tall wood projects:

- Owner/Developers committed to a wood solution early.
- Test results from relevant research helped create acceptable design solutions.
- Additional design development time was given at the beginning of the project to resolve design details.
- Design Solutions were in some cases developed with direct input from the Authority Having Jurisdictions, local fire officials, Construction Teams and material suppliers.
- During construction, unexpected and non-code compliant design details were cooperatively and safely resolved with other stakeholder groups.

Project Name: Forté
Architecture by: Lend Lease
Photo credit: Lend Lease

WHY TALL WOOD

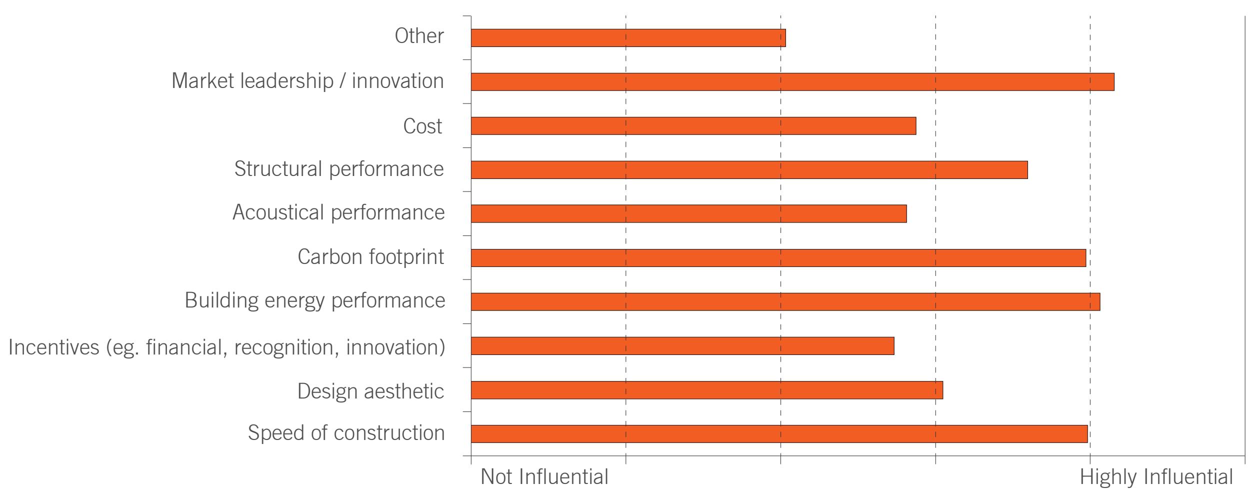
Based on the feedback gathered from design teams for the ten international projects, the following were identified as the most important motivators for pursuing a tall wood project:

- **Market Leadership and Innovation**
  Developing design solutions for a new structural typology with the potential for a place of importance in the market in the near future was a key motivation.
- **Building Performance**
  Energy efficiency and healthy, indoor environments that promote a sense of well-being were indicated to be complimentary design objectives easily achieved by using mass timber.
- **Carbon Footprint Savings**
  Realize significant carbon savings compared to conventional structural materials such as steel and concrete, by using more solid timber in new construction.
- **Speed of Construction**
  Realize construction schedule savings afforded by constructing with prefabricated elements.

In addition to the list above, residential project participants emphasized their desire to demonstrate solid wood construction as an affordable, alternative to conventional concrete or steel, with comparable or better durability and quality.

Design Team: Online Questionnaire Participant Responses

Influential Factors on the Design Team's Decision to Use Structural Wood Technology:



DESIGNING TALL WOOD

In most cases design teams had previous experience with wood construction, although not necessarily with mass timber. Similarly, in most cases, the projects were approached as wood buildings from the start, that is, the decision to use wood as structure was made prior to the commencement of design.

Participants were asked to summarize their project design process and identify special or unique aspects, different from a conventional project. The following common themes were strong among all participants:

- **Commit**

  Begin with the intention to use a wood structure and commit to innovation holistically. Project teams emphasized the need approach the work as wholly innovative, rather than focusing innovation on wood only.

- **Create Research Partnerships**

  Establish a partnership or collaborate with a research body to support innovation and design solutions. Research collaborations with academic institutions or other research organizations were integral to evaluating and testing design solutions for all participants.

- **Collaborate**

  Create a strong, integrated and collaborative design process early. Include the timber product fabricator and construction team during design to ensure details are resolved and logistics and sequencing are considered.

- **Engage the Fire Protection Authority**

  Engage the fire protection authority early in the design process to establish a collaborative and respectful relationship. In almost all cases, participants proposed new and untested design solutions that were not recognized within local building codes, and educating Authorities on the merits of alternatives was critical to securing buy in and alleviate risk concerns.

- **Anticipate Effort**

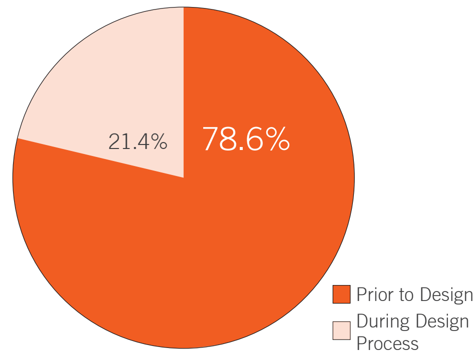
  Be prepared to invest additional effort to resolve design details. Both architectural and structural designers experienced an increase of design time of 10 – 50% compared to a concrete structure, and indicated that detailing interfaces between materials was most time consuming.

- **Simplify**

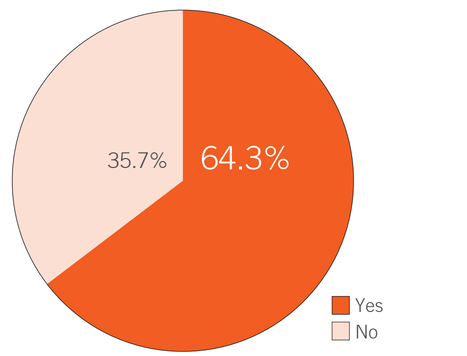
  Design should attempt to simplify solutions as much as possible. Focusing on simple solutions can reduce effort in design detailing, eliminate unnecessary material costs, facilitate prefabrication for more components and shorten project delivery time.

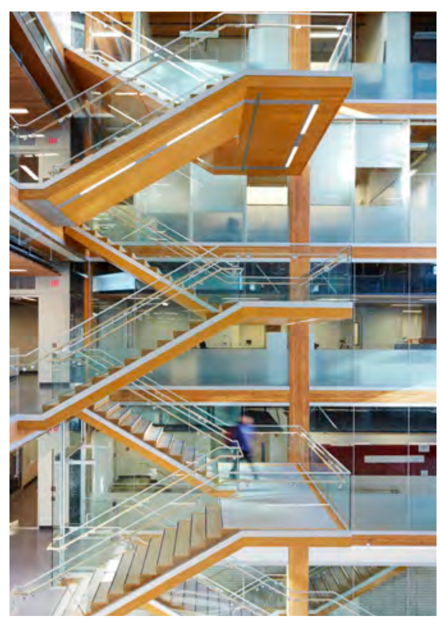
Design Team:
Online Questionnaire Participant Responses

When was the decision made to use structural wood?



Did you require additional resources or design time to support this project?





Project Name: UBC Earth Sciences Building
Architecture by: Perkins+Will
Photo credit: Martin Tessler

DESIGN SOLUTIONS

Design solutions related to known knowledge gaps or perceived challenges of designing for tall wood were explored with all ten project teams. Strategies varied across all teams, and no clear or universal design solutions were evident in any suggesting the industry is still very much evolving. Applied strategies are typically the result of research, trial and error. However, trends are emerging and in some cases a temporal trend toward refined solutions is evident. Construction experience is summarized for corresponding solutions in section 2.4.

Structure

Post and beam with a combination of panel products appear to be the favoured solution for commercial application, to achieve more flexible and open spaces, while a pure panelized application is more common in residential typologies where a regular layout of fixed walls is commonly available. All three commercial buildings included in the Survey (ESB, LCT ONE, Tamedia) applied a post and beam structure to achieve large spans and open floor areas that can be easily customized and changed. Panelized structures appear to work well in residential buildings where compartmentalized suites are desired (Bridport House, Holz8 (H8), 3XGRÜN, Limnologen, Cenni di Cambiamento, Forté).

In all cases project teams prioritized prefabrication of structural timber elements. Although the degree of prefabrication varied across projects, it is clear that fully committing to prefabrication is integral to realizing the benefits of constructing with mass timber. Feedback emphasized that where prefabrication was maximized (Tamedia, Holz8 (H8), 3XGRÜN) the benefits of precision cutting and assembly were realized in quality of construction, accelerated schedule and reduced site disruption during construction. In addition, all participants agreed that where concrete was used in combination with a mass timber system, precast elements must be used or the major benefits of prefabrication are lost (precision, schedule, clean and dry site).

Projects where a mix of structural systems and materials were applied (concrete, steel, glass, mass timber) grappled with complexity which impacted the schedule to different degrees. Every design team identified detailing interfaces between materials as a major effort and challenge, due to the variation in tolerances between materials, and advocated simplified solutions and approaches in all respects.

Lateral Stability

Among the projects surveyed, lateral stability is achieved by one of two strategies, either a concrete core or CLT load bearing walls, some reinforced with steel tie-down rods. The Earth Sciences Building with exposed, ductile heavy timber chevron bracing, is the only exception.

Connection solutions vary and are unique in almost all project examples, although solutions appear to be evolving and focusing quickly. Early projects such as E3 grappled with complex steel connections between wood elements as well as wood-concrete connections. More recent buildings such as LCT ONE focused on simplifying design details to benefit from a modular approach to fabrication, assembly and building configuration.

Tamedia post and beam structure
Architecture by: Shigeru Ban
Photo credit: Blumer-Lehmann AG

Prefabricated panel installation at Holz 8
Architecture by: Schankula Architekten
Photo credit: Huber & Sohn

Exposed view of glulam chevron braces at UBC Earth Sciences Building
Architecture by: Perkins+Will
Photo credit: Equilibrium

Pure timber connection strategies also vary and appear to be evolving quickly. Each project created a unique solution to avoid compression at perpendicular to grain at horizontal joints, however, self-tapping, angled screws appear to be emerging as an economical and reliable strategy to secure joints, along with steel plates as a tie down method (Forté, Cenni di Cambiamento, Bridport House).

Fire protection

The fire protection strategies for each project included various combinations of measures to meet the specified fire rating imposed by each AHJ. Testing was required of each project to demonstrate compliance, and in most cases, projects relied on research partnerships to build mock-ups and execute testing.

In all cases, timber elements were oversized to include a char layer as part of the fire protection strategy, in addition to encapsulating timber elements with gypsum to some degree. Sprinkler systems and intumescent paint applied to exposed timber were also common fire protection strategies. Most projects chose not to install wood cladding on the exterior, and opt for non-combustible façades; where wood façades are installed (Holz8, Limnologen), fire protection strategies were more challenging and complex.

Fire protection was particularly challenging in the case of Tamedia where fire rated glass surround the stair and intermediate zone. Where timber beams penetrate the fire rated glass, they are notched and layered with gypsum to create a noncombustible barrier at the interface, then covered with wood veneer to maintain the aesthetic quality of the timber. This unique detail involved extensive effort to design and execute.

Finally, survey responses suggest that as Authorities become more informed and engaged with mass timber projects, fire protection strategies can be streamlined. In two cases, participants indicated that the AHJ permitted some fire protection to be eliminated as the project construction progressed and on-site inspections eased concern. LCT ONE reported that the sprinkler system was determined to be redundant and Limnologen was allowed to eliminate gypsum on walls in some living spaces in two of the four buildings.

Acoustics + Vibration

Design solutions to address acoustics and vibration are the most varied across projects. Meeting local building code requirements, which also varied widely across participant jurisdictions, was identified by most teams as a major design challenge.

Isolating floor and ceiling assemblies with the use of resilient pad material emerged as a viable and effective strategy in pure wood, panelized structures (Limnologen, Holz8, 3XGRÜN). Strategies appear to be less complex in projects where concrete layers are applied in floor slabs (LCT ONE, Bridport House, ESB, E3). Almost all participants indicated that acoustic solutions were researched and tested through research partnerships.

Holz8 exterior wood façade with metal flashing between each storey prevents the spread of fire
Photo credit: Huber & Sohn

Exterior of Limnlogen
Architecture by: Arkitektbolaget Kronoberg
Photo credit: Midroc Property Development

Composite floor panel used for testing
Project Name: UBC Earth Sciences Building
Photo credit: Equilibrium

Systems Integration

Design solutions for systems integration were varied across projects. In projects where structural elements are covered or concealed, participants indicate that resolving systems is relatively easy. In cases where structure was exposed (Earth Sciences Building, Tamedia), integrating systems was identified as more challenging. Feedback from all project teams stressed the importance of early consideration of systems in design, especially where prefabricated elements must accommodate penetrations.

In the majority of residential cases, system penetrations were done during prefabrication, and concealed within walls and ceilings where structure was not exposed. Where complex cutting was done on-site, problems with precision and scheduling were reported (Limnologen). In the case of Forté, bathroom pods were completely prefabricated and installed as modular components, greatly streamlining systems integration for both design and construction.

In commercial applications, raised floors and dropped ceilings accommodated the majority of systems (LCT ONE, Tamedia). In the unique case of Tamedia, where the design relied on extreme precision and the majority of timber structure was exposed, 3500 penetrations were cut on-site to ensure they were accurately located.

Moisture Protection and Durability

In general, moisture protection is not perceived as a major risk by design teams. In all cases, any exposed structural wood elements are either inside the building envelope, protected by an overhang (ESB) or in the case of cantilevered panels (3XGRÜN, Limnologen, Holz8 (H8)), exposed only on the underside. In two cases, moisture sensors were installed to monitor envelope performance (Limnologen, Forté, Earth Sciences Building).

During operation, moisture is addressed in most cases by a mechanical ventilation system. Residential project teams highlighted the importance of educating occupants on optimal operation strategies.

On-site milling for hydronic heating pipes at Limnologen
Photo credit: Martinsons Byggsystem

Ceiling panel to conceal systems at LCT ONE
Photo credit: Martinsons Byggsystem

Exposed timber on underside of balconies at 3XGRÜN
Architecture by: Atelier PK, Roedig Schop Architekten and Rozynski Sturm
Photo credit: Stefan Mueller

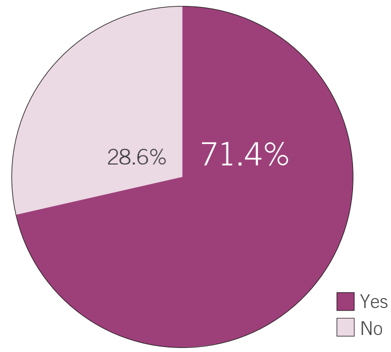
2.3 AUTHORITY HAVING JURISDICTION

Authorities Having Jurisdiction (AHJ) play an integral role in the evolution of mass timber construction solutions, and although representatives of this stakeholder group for each project were contacted and invited to contribute to the Survey, only three of ten were available to share their experience. Where direct contact with AHJs was not possible, relevant information provided by other project stakeholder participants has been included.

In the majority of surveyed cases, multi-storey mass timber buildings exceeding three or four storeys are not specifically provided for in local building codes. Survey participants were asked to comment on requirements and processes related to obtaining approval of mass timber projects, any special or unusual requirements, limitations or conditions, time and effort required to finalize approvals, risks, special expertise accessed, challenges, successes and lessons learned. The most significant outcome from the Survey reveals that each project has positively impacted its local jurisdiction and has led to the adoption of streamlined solutions on subsequent projects.

Design Team:
Online Questionnaire Participant Responses

Frequency of Special / Additional Documentation Required by AHJ due to Use of Structural Wood Technology



LESSONS FROM TALL WOOD

From the perspective of the Authorities Having Jurisdiction, the Survey results point to the following as factors for successful completion of tall wood projects:

- Local, regional or national government policies in support of low carbon construction, engergy efficiency, or renewable resources encourage an efficient approvals process.
- Owners/Developers and Design Teams created 'Alternative Solutions' with supporting test data that met or exceeded building and fire code or local condition requirements.
- Owner/Developers, Design Teams and Construction Teams, in addition to key suppliers, demonstrated a high level of cooperation in establishing strategies and resolving construction-related variances.

Wall panel fabrication for Holz8
Photo credit: Huber&Sohn

The following summarizes themes and trends that emerged from the survey, and identifies unique scenarios where relevant.

- **Collaborate and Consider Details**
    - Both project team and AHJ survey participants indicated engaging with each other as early as possible in the project process is necessary to establish a shared knowledge base and an open and collaborative working relationship.
    - Work with the project team to reach out to other jurisdictions or research institutions to access relevant information or testing data.
    - Invest the time to understand details and strategies early.
- **Establish a Methodology**
    - In most cases, the projects in this Survey were the first tall wood buildings to be approved within their respective jurisdictions. All project teams conveyed that the process of obtaining approvals was not different than other projects where new and untested design solutions are proposed, although most did experience a lengthier and more onerous approvals process.
    - Where jurisdictions had an established ‘alternative solutions’ process in place, projects followed this protocol (Forté and Earth Sciences Building).
    - In several cases, supportive government policy for low carbon construction, energy efficiency, or renewable resources, made the approvals process more straightforward, given that officials were more educated and motivated to support successful examples of policy application (Limnologen, Holz8).
    - In the case of the 3XGRÜN project in Berlin, the design team reported a unique process whereby the AHJ requires two independent fire code consultants to be engaged by the project team to consult on design strategies as well as manage the approval process directly with the Authority. This appears to be a similar to the peer review process used by the AHJ for the Earth Sciences Building; stakeholder groups from both projects communicated that these processes were smooth and successful.
- **Test**
    - In all cases, testing for proposed materials and assemblies was required to demonstrate code compliance and in some cases, testing was conducted in partnership or conjunction with a research program, facility or organization.
- **Inspect**
    - On-site inspections during construction, in addition to performance testing, were also crucial, not only to confirm strategies were executed as expected and making adjustments as necessary, but to experience and learn for future applications.
    - In at least two cases (Limnologen and LCT ONE), fire protection strategies were simplified as the project progressed and the Authority became more informed.
    - In one case (Cenni di cambiamento), the approval process took place during design only; AHJ involvement during construction was limited.

2.4 CONSTRUCTION TEAM

Construction team members surveyed and interviewed included contractors, timber erectors, and timber fabricators involved the construction of the projects.

Survey participants were asked to comment on the rationale for pursuing mass timber construction, the construction process, solutions related specifically to constructing in the context of a tall wood building, challenges, successes and lessons learned. The experiences gathered from construction team members focused mainly on the importance of the planning process rather than individual technical construction solutions. The following section summarizes themes and trends common across all ten projects, and identifies unique scenarios where relevant.

LESSONS FROM TALL WOOD

From the perspective of the Construction Teams, the Survey results point to the following as factors for successful completion of tall wood projects:

- Project/Site/Construction managers were invited to provide input early in the design development process of the project.
- Design Teams, Construction Teams, material suppliers and building trades embraced prefabrication and system integration which shortened timelines.
- Tolerances and complexities of details at interfaces between wood structural elements and other structural materials were the greatest challenges but wete recognized and accommodated during design or construction.
- Construction personnel were productive in a good work environment on site.
- Project sub-trades and suppliers of materials and systems were able to adapt easily their product specification and scope of work to the wood structural solutions.
- Weather-related issues that could affect wood product appearance and performance were accepted and budgeted for.

Project Name: UBC Earth Sciences Building
Architecture by: Perkins+Will
Photo credit: Martin Tessler

WHY TALL WOOD

Based on the feedback gathered from the construction teams, the following were identified as the most important reasons for pursuing a tall wood project:

- **Build a strong business case**

  Proving a strong, profitable business case for mass timber construction was a key motivation for construction teams.

- **Increase capacity**

  Gaining experience and developing industry capacity were indicated to be complimentary objectives for construction teams.

- **Innovation**

  The desire to contribute to the potential for innovation in design and construction of mass timber buildings.

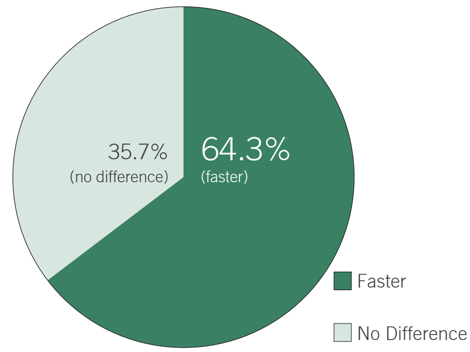
- **Sustainable Construction Material**

  Expanding the market for a sustainable construction material with a low carbon footprint.

- **Compliance**

  In some instances, supporting a local government policy to encourage timber or renewable resources in new construction was a strong motivation for constructing with mass timber.

How did using structural wood impact the construction schedule compared to a conventional project?



CONSTRUCTING TALL WOOD

Stakeholders were asked to summarize the construction process and identify special or unique aspects, different from a conventional project. Based on the participants' experience, the following are key items to consider when constructing a tall wood building:

- **Collaborate early**

  Most participants stressed the importance of early collaboration with the design team, Authority Having Jurisdiction, and sub-trades. Such collaboration ensured that the construction team and fabricators contribute to the design process to support the best execution during construction. In several cases, fabricators contributed significantly to the design process, supporting architectural and structural teams with very specialized material and process specific engineering.

- **Resolve details at design phase**

  The majority of participants emphasized the importance of resolving details during the design process to ensure accurate and precise prefabrication of elements. For example, resolving interfaces between different materials, considering systems, and connections between elements. This early effort led to a more efficient and faster construction process with fewer on-site changes that are often difficult and costly.

- **Logistics**

  Most participants stressed the importance of considering the construction plan in parallel with the design process in order to coordinate material deliveries, resolve issues with limited staging areas on tight urban sites, reduce changes during construction and ensure appropriate sequencing of trades to minimize damage to installed materials. Careful early planning led to, in most cases, a reduction in the overall construction schedule.

- **Define trades scope and engage early**

  Carefully consider and define scope requirements for trades to ensure accurate pricing. Engage skilled trades early to confirm logistics of the construction schedule, and identify any variation in scopes of work that may arise in the context of a mass timber project. Some participants acknowledged a lack of clarity or gaps within various trades' scope which led to overpricing of work. In some instances, expert timber erectors were engaged to provide expertise, complement the construction team, and facilitate a smoother and efficient construction process. In other instances, the contractor provided training to trades to assist with growing industry capacity.

- **Access expertise**

  Eight of the ten projects are located in Europe, where experience and market capacity is further advanced across all stakeholder groups. In less developed markets, project participants noted that accessing experienced timber erection expertise was paramount. In the case of Forté, the construction manager and foreman spent time in the UK to work on building sites using CLT prior to commencing work. The erection crew was also formed under the direction of and experienced site supervisor from the UK who spent time on-site for the initial weeks of construction. In the case of the Earth Sciences Building, a specialized timber erection crew with experience in log structure construction was engaged to work in parallel with the more inexperienced installation crew.

CONSTRUCTION SOLUTIONS

Construction solutions related to known knowledge gaps or perceived challenges of constructing tall wood buildings were explored with all ten project teams. Although, most construction teams had some experience with constructing mass timber buildings or supplemented their teams with a wood expert, each building was unique and resolved on-site construction issues slightly differently. The following experiences include:

Structure

Experience with structure varied across all projects, however all teams identified that careful attention was given to connection details particularly in instances where the wood structure was connected with concrete structural elements. Variation in tolerances between materials was identified by all teams as a challenge of assembly.

Some construction teams indicated that prefabricated timber components maximized the opportunity to realize gains in the construction schedule. In projects where concrete elements were combined with mass timber, all participants they would avoid cast-in-place concrete if all possible; precast eliminates time required for curing, accelerating the construction schedule, and maintains a clean and dry site.

Installation of precast concrete element at 3XGRÜN
Photo credit: Rozynski Sturm Architekten

Fire Protection

In several instances, construction teams were key to resolving fire protection. Early engagement with the fire authority along with on-site construction consultation to inspect progress and resolve any fire protection issues during construction resulted in a successful project outcomes. In the case of Limnologen, collaboration on-site with the Authority actually led to a simplified approach for the last two buildings constructed in the complex.

In the unique case of Tamedia, executing the fire protection strategy was particularly onerous and costly to execute. Where timber elements penetrate fire rated glazing, timber is notched and layered with gypsum to create a non-combustible barrier, then covered with wood veneer to maintain the aesthetic quality of the timber. Survey participants reported that executing this detail was exceptionally time consuming.

Notched interface conceals non-combustible barriers on timber beams at Tamedia.
Architecture by: Shigeru Ban
Photo credit: R. Holt

Moisture Protection + Durability

Weather protection strategies varied across all projects, and was largely dependent on whether the timber structure was to be exposed or concealed. Applied strategies represent both extremes of the spectrum from a full, permanent tent structure during construction to no protection at all, confirming opinions on the need for weather protection are not aligned across the industry. Regardless of strategy, all participants of projects where timber was to be exposed emphasized that completely avoiding staining during construction is unrealistic. In the case of the Earth Sciences Building, participants communicated that when removing stains on fully finished wood components in the field, it is very difficult to match colour and finish quality. The team recommended installing unfinished or lightly finished wood and applying final coatings at the end of construction.

Weather protection at Limnologen.
Moveable rising tent structure.
Photo credit: Johan Vessby

Systems Integration

In all cases, construction teams emphasized the importance of detailed planning to ensure smooth integration of systems. In cases where wood elements were exposed, systems were more challenging to conceal (ESB). In most of the residential projects, systems were identified as generally easy to incorporate, particularly at Forté, where penetrations for plumbing were cut in CLT at the factory, and prefabricated bathroom pods were installed as complete, modular components, contributing greatly to a shorter construction period.

Survey participants for the Limnologen project indicated that where grooves for the in-floor hydronic heating system were cut in the timber panels after installation, it greatly slowed construction progress. Similarly, Tamedia reported exceptional on-site effort to cut 3,500 penetrations for systems.

Installation of prefabricated bathroom pod at Forté.
Photo credit: Lend Lease

3.0 PROJECT INSURANCE

Survey participants in all stakeholder categories were asked to provide details on various aspects of their insurance policies to examine how insurance-related issues may impact the design of, the approval process for and indirect project costs of a tall wood project. Participants were asked to describe their regular insurance policies related to professional practice and identify any differences in policy coverage or premium cost to cover work associated with tall wood construction. See Table 2 for a summary of insurance policy changes by stakeholder group.

Table 2: Summary of Insurance Policy Changes by Stakeholder group

PROJECT NAME	OWNER/ DEVELOPER	DESIGN TEAM	CONSTRUCTION TEAM	AHJ
E3	No Change	No Change	No Change	No Change
Limnologen	No Change	No Change	No Change	No Change
Bridport House	No Change	No Change. Professional Indemnity for design activities	No Change. Required to advise insurer of timber frame construction, no premium or policy change	No Change
3XGRÜN	No Change	No Change	No Change	No Change
HolZ8 (H8)	No Change	No Change	No Change	No Change
Forté	No Change. Construction Works (during construction), Professional Indemnity, Public Liability, Employee Insurance and Body Corporate Insurance (insurance of the building on completion)	No Change. Public Liability and Professional Indemnity	No Change	No Change
Earth Sciences Building	Yes (required). Course of Construction insurance premium (see above)	No Change	No Change	No Change
LifeCycle Tower ONE (LCT ONE)	No Change	No Change	No Change	No Change
Tamedia	Yes (required). Owner carried builder-owner third-party liability insurance and contractors' all risks insurance (see above)	Yes (Voluntary). Executing architect/ planner opted to separate policy from blanket coverage (see above)	No Change	No Change
Cenni di Cambiamento	No Change	No Change	No Change	No Change

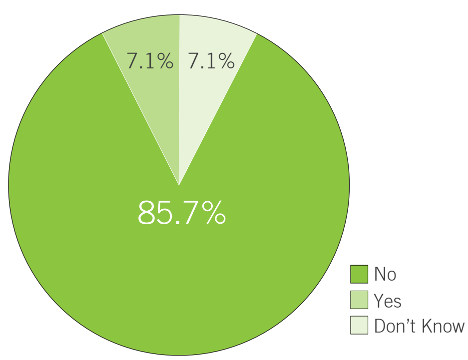
The majority of participants were not able to elaborate on the specifics of policy coverage, but were able to confirm that no additional insurance or modifications to existing policies were required as a result of pursuing design or construction work on a tall wood building. Only one stakeholder (Bridport House Construction Team) advised that they were required to inform the insurer of timber construction, although the policy premium was not increased.

Three stakeholders identified unique situations:

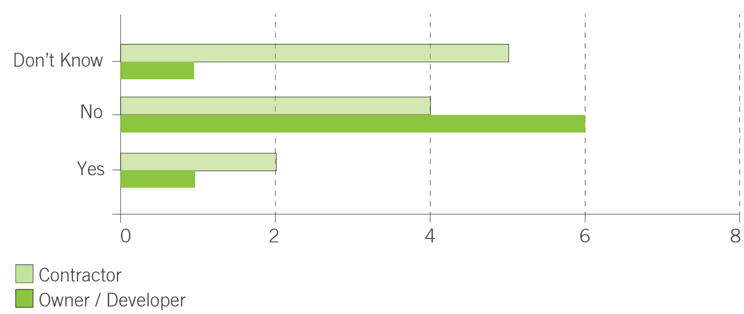
- The Course of Construction Insurance provider for the Earth Sciences Building required the Owner/Developer to carry the same policy as a light frame timber construction project, which represented a cost premium of 2.5 times more than the cost of the same insurance for a comparable concrete building. The perception of risk within the local insurance industry does not distinguish between mass timber construction and light frame timber construction.
- The Tamedia Owner carried Builder-Owner Third-Party Liability insurance and Contractors' All Risks insurance. The insurer charged higher premiums specifically due to the use timber given their lack of experience judging risk with this type of construction. The premium was nominal.
- The executing architect for the Tamedia project elected to arrange a separate insurance policy for this project, separating it from blanket professional insurance carried by the firm. Feedback from the participant stakeholder emphasized that separating the policy was not related to the use of mass timber, but rather the risk associated with developing a prototype design and collaborating for the first time with an international design architect. The cost of the policy was approximately 25% more than separate coverage for a conventional building, but the cost of blanket coverage was reduced by separating this project which brought the average cost of the policy down for all the projects covered.

Project Insurance: Online Questionnaire Participant Responses

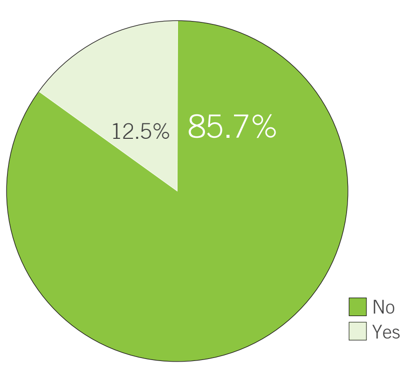
Design Team: Were you required to inform your insurance company that you were undertaking the work on an innovative project with a wood solution?



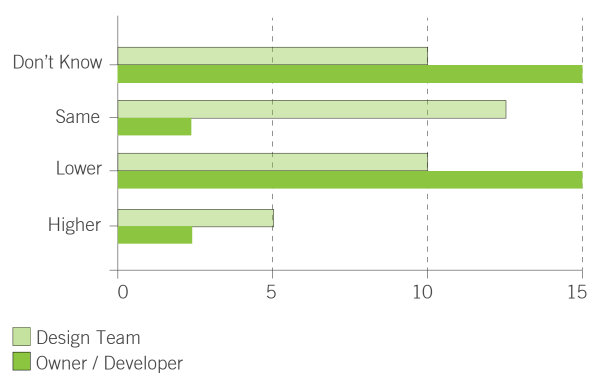
Was the required insurance coverage different from a conventional project?



Owner: Did the project face any barriers or challenges obtaining project insurance?



Were insurance premiums higher, lower or the same as a conventional project?



4.0 PROJECT FINANCING

Project financing questions were included as part of the Survey to determine if mass timber construction affected financing options or opportunities. Participants were asked to comment on how their project was financed, whether the process was different from other projects, if any limitations or premiums were placed on financing or if any advantages or incentives were accessed. Information was gathered as part of the online questionnaire and in-person interviews from the project owners or developers, and from design team members where applicable.

In all cases, within the context of each project's jurisdiction, no participants reported that any unusual financing protocols were required and no project experienced any challenges obtaining financing attributable to the use of mass timber. The most common method was self-financing, and some projects did access additional funding through incentive programs. A tabular summary is provided below in Table 3:

Table 3: Financing Summary

PROJECT NAME	FINANCING METHOD	ADDITIONAL FUNDING
E3	Traditional lending through Builder-Owner Collective	
Limnologen	2 buildings: Self-financed by the developer 2 buildings: Traditional bank lending	None.
Bridport House	Homes and Community Agency (National Government)	None.
3XGRÜN	Traditional lending through Builder-Owner Collective	
Holz8 (H8)	Self-financed by the developer	€120,000 incentive from German Federal Environment Program during planning phase
Forté	Self-financed by the developer	None.
Earth Sciences Building	Self-financed by the University of British Columbia	Canada Wood Council / NRCan Wood First incentive of $750,000 CAD.
LifeCycle Tower ONE (LCT ONE)	Self-financed by the developer	Received public funding for general innovation
Tamedia	Self-financed by the owner	None.
Cenni di Cambiamento	Government funded through government managed real estate investment fund (pension fund)	None.

There appears to be a relationship between self-financed projects and those approached as prototypes or pilot projects. Feedback from project developers for Limnologen, Holz8 (H8), Forté and LCT ONE clearly indicated that financing was approached as an investment in future development; these projects were undertaken to test design, systems, materials, process, performance and market uptake. Participants described the financial risk of a prototype approach to be within acceptable range given the perceived impact a successful built example of mass timber construction could have on the market.

Incentive funding was accessed by three Survey participants. In the case of the Earth Sciences Building, these additional funds were critical to the successful implementation of the solid wood design solution. A sum of $750,000 CAD funded fire modeling and alternative solution documentation, engineering, acoustic and vibration testing, in addition to augmenting project contingency. Both owner representatives and design team members described the acquisition of these additional funds as the critical factor in the decision to pursue a mass timber solution. In the case of Holz8 (H8), a €120,000 (~$180,000 CAD) incentive was accessed by the design team on behalf of the developer, from the German Federal Environment Program. While the sum contributed to offsetting some project costs, the design team indicated that the effort associated with preparing the documentation to apply for the funds was particularly onerous, reducing the significance and impact of the award. For Holz8 (H8), the additional funding opportunity did not play an important role in the project.

Builder-Owner Collective arrangements were established for both E3 and 3XGRÜN, a relatively common arrangement in Germany for residential development. Feedback from Survey participants for both projects indicate that Builder-Owner Collectives can easily obtain financing through traditional lending because lenders perceive buildings developed through this process to be more durable, actively maintained, and therefore retain high value. However, feedback from E3 indicated that property valuation on mass timber buildings is lower than comparable non-timber buildings in the jurisdiction by about 20% due to the perception in the marketplace that mass timber is less durable and carries a higher risk of fire.

Project Name: Forté
Photo credit: Lend Lease
Architecture by: Lend Lease

5.0 BUILDING PERFORMANCE

The Survey gathered information from project participants about building performance and operations in order to identify any unique issues, benefits or challenges of operating a tall mass timber building that arise after occupancy. Participants were asked to comment on building systems, any monitoring devices or programs in place, occupant concerns, operation costs, as well any positive or negative experiences with regular maintenance as compared to a building with a conventional structure.

Participants available to speak to operational aspects of the projects were limited in part by availability, as well as by the age of the buildings. The majority of projects have only recently been occupied and as such, operational experience and actual performance data is limited for most. Information was gathered as part of the online questionnaire and in-person interviews from the project owners or developers, and from design team members where applicable. In two cases, interviewers spoke to individual residential tenants, however, no participant specifically responsible for maintenance was available to contribute.

PERFORMANCE IN TALL WOOD

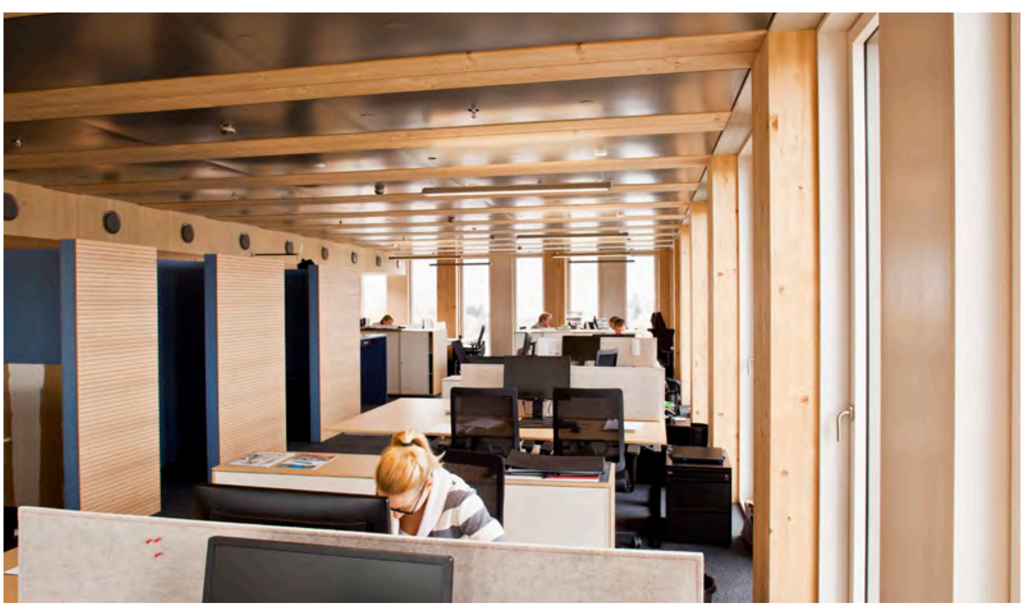
The information gathered from participants focused mainly on aspects of building performance rather than maintenance. For the purposes of this report building performance refers to building energy and water efficiency, ventilation and humidity control, air quality, as well as occupant satisfaction. It is important to note that good performance results from considering and implementing a range of complimentary and interdependent strategies and systems that respond to local climate and context, rather than one single mechanical, electrical or architectural system. Participant comments refer to issues of performance that they believe relate to the use of timber for the building structure.

Survey responses emphasized three performance issues more strongly than any other and include:

1) the benefits of mass timber for an efficient envelope;

2) the importance of occupant education in a mass timber structure; and

3) the high level of satisfaction and well-being reported by occupants.



Project Name: LCT ONE
Architecture by: Hermann Kaufmann ZT GmbH
Photo credit: www.creebuildings.com

Other common issues of performance raised include thermal comfort and ventilation. The following section summarizes the details of these common themes, and provides relevant project examples to best contextualize trends and unique scenarios.

- **Envelope**

  In all cases, participants indicated that mass timber was perceived as a beneficial material to support a high performing envelope. As a poor conductor of heat, it minimizes thermal bridging, improving the effectiveness of the insulation compared to many conventional envelope assemblies.

  In several instances participants identified the complementary advantage of achieving good airtightness owing to the precise cut and fit of prefabricated elements. These advantages were emphasized most by participants of buildings with panelized timber structures, where there are fewer joints, gaps and penetrations that require sealing as compared to other systems (3XGRÜN, Cenni di cambiamento, Bridport House, Limnologen).

  In the case of Tamedia where the mass timber post and beam structure is within a glazed envelope, achieving the code required air tightness and energy performance was identified as particularly challenging.

  In addition, Cenni di Cambiamento reports temperatures within the comfort range on hot summer days without operation of the mechanical system, confirming a thermally efficient envelope. Moreover, a cost analysis confirmed that while the project cost was 3-5% more expensive to build than a concrete building, the efficient envelope minimizes heating and cooling loads to result in an operational payback period of only eight years.

- **Occupant Education**

  In all cases, participants emphasized occupant education as an essential part of a robust maintenance plan that supports the best building performance. In several residential projects cases, training sessions for tenants and new owners were provided on how to effectively and efficiently operate their space. Participants reported this as a very effective strategy not only to facilitate efficient use of building systems, but also to foster appreciation for the unique aspects of the space among tenants, and encourage a community of care-takers.

Project Name: 3XGRÜN
Architecture by: Atelier PK,
Roedig Schop Architekten and Rozynski Sturm
Photo credit: Stefan Mueller

- **Quality of Space and Occupant Satisfaction**

  In all cases, participants reported high levels of occupant satisfaction, based in most cases on anecdotal feedback from residents or tenants. In the two cases where interviewers spoke to building occupants, feedback was overwhelmingly positive concerning thermal comfort, utility costs and their general feeling of well-being in the space. At Limnologen, only one noise complaint has been received in a complex of over 130 suites since the buildings were occupied.

- **Thermal Comfort**

  In several residential cases, participants indicated that spaces were very thermally balanced. The 3XGRÜN building reports that suites that are part of the concrete structure on the main floor experience slightly cooler temperatures in the summer time given the added mass from the concrete, however the suites above within the timber structure are still very comfortable and balanced.

  Cenni di Cambiamento reports that measurements conducted in the month of August, after project completion and before occupancy, indicated a comfortable indoor temperature of 24 degrees Celsius in suites with southern exposure, despite an outside temperature of 32 degrees Celsius.

- **Ventilation**

  To avoid any impacts of humidity in residential projects, several participants indicated that at least some humidity control through mechanical ventilation is prudent, rather than to rely completely on natural ventilation operated by occupants.

Project Name: Forté
Architecture by: Lend Lease
Photo credit: Lend Lease

As part of the Survey, participants were asked to elaborate on any systems or strategies included in the projects to enhance building performance. Information made available was not consistent for all projects, but in all cases buildings surveyed shared the complementary goals of optimizing energy performance and creating high quality spaces for occupants. The basic strategy of maximizing passive systems (efficient envelope, daylighting, natural ventilation) to minimize the requirement for active systems was common to almost all projects. Several projects noted design strategies were based on Passive House concepts, although only LCT ONE is attempting official certification.

For additional context, summaries of advanced systems details made available as part of the Survey are presented here for each relevant project:

- LCT ONE incorporates a range of advanced systems and monitors performance extensively, reflecting the prototype approach, and goal to test a wide range of technology and strategies and share experience and outcomes. LCT ONE is connected to a wood-waste fueled biomass district heating system, the building includes a photovoltaic array, heat recovery on ventilation systems, CO_2 sensors, LED lighting technology, occupancy sensors on lighting, and an intelligent building monitoring system.
- 3XGRÜN intentionally limited the application of advanced technology in the initial design in order to maintain the project budget; however, the team thoughtfully planned for future installation of systems where beneficial. The building is heated by a very efficient on-site biomass system, fueled by wood waste, and was designed to accommodate future photovoltaic panels on the roof to supply the majority of the building's electrical demand. Finally, to limit the cost of discharging stormwater to the municipal system, a portion of the roof includes a green roof system. The building is not currently monitoring performance, but plans to implement a monitoring program in the coming year.
- Cenni di cambiamento advanced systems include grey water reuse for water closets and garden irrigation, heat recovery on domestic hot water and continuous ventilation with air pollution filtration deliver high quality air to each suite.
- E3 is connected to a district heating system and includes rainwater collection for irrigation and photovoltaic panels to offset electrical demand.

Project Name: Cenni di cambiamento
Architecture by: ROSSIPRODI ASSOCIATI srl
Photo credit: Riccardo Ronchi

MONITORING TALL WOOD

Survey participants were requested to describe any building performance monitoring programs in place for their

projects. No consistent method of performance measurement or monitoring exists across the projects, and only two buildings report comprehensive post construction building performance monitoring programs:

LCT ONE plans to implement an extensive measurement and verification program, and to share data as part of the LifeCycle Hub

http://www.lifecyclehub.com/.

Forté: Moisture sensors are located within the CLT panels to monitor façade performance.

Limnologen: As part of the strong research partnerships established at the project outset, extensive research on structural systems, timber performance, energy and lifecycle analysis has been conducted and published for Limnologen. Completed studies can be accessed here:

http://www.cbbt.se/website3/1.0.3.0/31/FULLTEXT01.pdf

Ongoing monitoring includes energy performance, and Survey Participants report results of 50 kWh/m^2, close to Passive House performance and significantly better than the design goal to meet a target of 80 kWh/m^2. Limnologen is also monitoring humidity in the structure to determine if any moisture penetrates the envelope and if it affects long term durability of the timber structure. Approximately 25 sensors are located behind wall insulation on the surface of CLT panels, and around weak points such as window penetrations (refer to Lessons Learned bulletin, Appendix A for details).

LCT ONE Lifecycle Hub
Architecture by: Hermann Kaufmann ZT GmbH
Photo credit: www.creebuildings.com

6.0 CONCLUSION

This industry scan of ten international tall wood buildings demonstrates mass timber as a successful and emerging construction method. It can be concluded that all stakeholders involved in these projects, regardless of geographic region, are early adopters motivated by common goals of market leadership, innovation, carbon reduction, and improved building performance. Results also suggest where strong governing policies exist, particularly in Europe, that support low carbon construction, energy efficiency, or renewable resources the market for mass timber is developing more rapidly than in North America.

Although design and construction solutions are still evolving, there is a clear trend across the projects that design and construction teams, local authorities, and in some cases fabricators, are working collaboratively and early during the design process to plan complex details prior to construction, and resolve issues such as fire protection and acoustic performance. As a result of this early collaborative process, the majority of projects confirmed that they experienced overall construction schedule savings.

The majority of participants confirmed that no additional insurance or modifications to existing policies were required as a result of pursuing design or construction work on a tall wood building. Similarly, in all cases no unusual financing protocols were followed, and no project experienced any challenges obtaining financing attributable to tall wood projects. Finally, in all cases, participants reported they managed to overcome any design or construction obstacles without exceeding the project budget.

In summary, the results of the Survey reveal the experiences and leadership of a select number of stakeholders who are committed to building capacity, credibility and market acceptance in this emerging industry. Overall, the results confirm that a cost equivalent, high performing building with a timber structure is a viable option.

Project Name: E3
Architecture by: Kaden Klingbeil
Photo credit: Bernd Borachrt

APPENDICES

APPENDIX A - BULLETINS OF LESSONS LEARNED

BULLETIN OF LESSONS LEARNED

E3, BERLIN, GERMANY

This bulletin presents the lessons learned and experiences gathered from stakeholders who responded to an online questionnaire and/or participated in interviews.

OWNER/DEVELOPER
Builder-Owner Collective

DESIGN TEAM
ARCHITECT: Kaden Klingbeil Architekten, Berlin
STRUCTURAL ENGINEER: Bois Consult Natterer

AUTHORITY HAVING JURISDICTION
Untere Bauaufsicht Berlin-Pankow

CONSTRUCTION TEAM
Holzbau Merkle GmbH

Photo Credit: Architecture by Kaden Klingbeil, Photo by Bernd Borchardt

E3 is a 7 storey mixed-use commercial and residential building featuring office space on the ground floor and residential units above.

The building structure is comprised of glulam columns and beams connected with heavy steel fasteners, and two large concrete beams that span the building length. Structural infill walls are solid edge laminated dowelled wood panels, eliminating the need for adhesives, and therefore improving indoor air quality. Floor panels are a hybrid wood-concrete system with a fire-resistant finish applied to the underside of the wood deck. All suites in the building are accessed from the outside via an external free-standing concrete stairwell and bridging system.

The project was organised as a Builder-Owner Collective where Architects worked directly with the group of end-users throughout the design process. E3 was a ground breaking project in Germany, the first to use structural timber in a building exceeding 3 storeys.

PROJECT VITALS

LOCATION: Esmarchstraße 3 10407 Berlin, Germany
COMPLETION DATE: May 2008
OCCUPANCY TYPE: Commercial/Residential
CONSTRUCTION COST: €1,282/m² (~$1880/m² CAD)
TOTAL FLOOR AREA: 1, 270m²
NUMBER OF LEVELS: 7

TECHNICAL RESOURCES + LINKS

Technical details of the building systems can be accessed through the following resources:

Golden, Elizabeth. (2011) Berlin: Die Offene Stadt / The Open City, Part Two. *http://uwarch-belog.com/index.php/2011/08/berlin-die-offene-stadt-the-open-city-part-two/*

Jaeger, Falk. (June 2008) e3 - A Timber-Frame Building in "Stone-Built Berlin". Goethe-Institut e. V., Online-Redaktion *http://www.goethe.de/ges/umw/dos/nac/buw/en3468011.htm*

FrostBW. Esmarchstraße 3, Berlin *http://forstbw.de/wald-im-land/rohstofflieferant/bauen-mit-holz/urbanes-bauen/kapitel-5-dokumentation/esmarchstrasse-3-berlin.html*

Mayo, Joe. (July 2012) Wood Assemblies and Wood Buildings: Kaden Klingbeil. *http://timbercity.wordpress.com/2012/07/21/wood-assemblies-and-wood-buildings-kaden-klingbeil/*

LESSONS LEARNED

OWNER/DEVELOPER

- The project successfully demonstrated that a cost equivalent, high performing building with a mass timber structure is a strong alternative to other structural material in mid-rise residential development.
- Client collective (Baugruppen) project delivery creates buildings that are more responsive to client needs, and save costs by eliminating the role of the developer.

DESIGN TEAM

- Fire protection strategies were perceived to be excessive from an architectural perspective. Authorities have relaxed the requirements for subsequent projects, recognizing the benefits of combined fire protection strategies as well as the proximity of fire brigades in an urban context.
- By separating the exterior stair and bridge from the rest of the structure, the design eliminates the difficulty of detailing interfaces between different material types, and provides another facade to allow for more daylight in the suites.
- Construction carpenters must collaborate early to incorporate construction and installation requirements into the design.

AUTHORITY HAVING JURISDICTION

- Fire protection strategies have been simplified as a result of the procedure established by this first instance of construction with timber structure in a building over 3 storeys.

CONSTRUCTION TEAM

- Prefabrication of structural elements was key to accelerating the construction schedule and facilitating installation on the constrained urban site.

Photo Credit: Architecture by Kaden Klingbeil, Photo by Bernd Borchardt

THE OWNER / DEVELOPER

BUILDER-OWNER COLLECTIVE

A Builder-Owner Collective* of individual resident owners was formed, each of which contributed time and funds to the development process.

RATIONALE

- A commitment to the principles of sustainable design and realizing the embodied energy and carbon savings associated with timber construction.
- Demonstrate that timber is a practical structural material for buildings over 3 storeys.
- Benefit from the positive impact on indoor air quality provided by a timber structure.
- Develop a cost effective and easily customized residential typology.

PROCESS

- E3 was financed through a Builder-Owner Collective*.
- Some additional funds were accessed through a City of Berlin sustainable building and energy efficient construction program provided to projects with energy performance of 40 $kWhr/m^2$ or better.
- Flexible floor plans were prioritized to accommodate varied investment amounts from each suite owner.
- Despite the use of a novel structural system, total costs were kept low by applying the Builder-Owner Collective arrangement.

CHALLENGES

- Working with the authority to negotiate the fire protection strategy.

SUCCESSES

- Created residential spaces that responded to each tenant's needs, within each individual's budget.

Photo Credit: Architecture by Kaden Klingbeil, Photo by Bernd Borchardt

** Builder-Owner Collective In this document, the term refers to a method of organizing individual owners as a formal, legally recognized group for the purposes of acquiring land to design and construct a multi-family dwelling. This arrangement is relatively common in Germany. This arrangement eliminates the traditional role of Developer, and allows the group of individual owners to work directly with the design, often resulting highly customized suites.*

THE DESIGN TEAM

KADEN KLINGBEIL, BOIS CONSULT NATTERER

Kaden Klingbeil were the architects and Bois Consult Natterer completed the structural design.

RATIONALE

- A commitment to the principles of sustainable design and realizing the embodied energy and carbon savings associated with wood construction.
- Demonstrate that timber is a practical structural material for refined and affordable multi-family residential construction over three storeys.

DESIGN PROCESS

- E3 was the first tall wood project in Europe.
- The architectural team drew on extensive experience designing with timber frame, keeping the design phase relatively short.
- Timber-frame construction was considered, but structural analysis determined load bearing timber-skeleton system with timber infill walls and floors was the best solution for 7 storeys.
- The design team worked extensively with the fire authority throughout detailed design to negotiate the fire protection strategy.
- Fire testing was conducted by the Leipzig Institute for Materials Research and Testing (MFPA). All assemblies were fire tested to reach a 90 minute rating.
- The approvals phase was onerous; the authority having jurisdiction required 12 additional steps beyond the standard requirements for fire protection approval.
- Prefabrication of timber elements was prioritized to support a high quality and simplified construction process.
- To maintain costs and streamline construction, connection types were limited to three variations.

Photo Credit: Architecture by Kaden Klingbeil, Photo by Bernd Borchardt

DESIGN SOLUTIONS

STRUCTURE

- Concrete slab on grade.
- Heavy timber structural frame system of glulam post and beam and solid timber panel infill walls.
- The posts and beams measure 320mm x 360mm.
- Exterior walls and interior structural walls employ the Brettstapel system, whereby thin wooden boards are edge laminated and dowelled together, eliminating need for nails or glue.
- Floor structure features the hybrid Holz-Beton-Verbund (HBV) system, a combination of a wood deck with a layer of concrete poured on top. Floors are 160mm thick with a 100mm concrete topping.
- Floors span 6.5m, the full depth of each suite, eliminating the need for internal load bearing walls or columns, ensuring flexibility in layout and easy customization.
- Steel connections transfer loads from vertical and horizontal parts of the structure.
- Private balconies on the rear of the building are lightweight steel.

FIRE PROTECTION

- Timber elements were sized to include a char layer and are fire rated for 90 minutes, and wood-concrete floors create separate fire compartments between levels.
- Two layers of gypsum board encapsulate all structural wood products on the interior adding a further 60 minutes to the fire rating.
- Timber is only exposed on the ceilings where it is coated with paint with reduced flammability.
- A separate exterior concrete stair and elevator shaft create a short, smoke free escape route.
- Smoke detectors.
- Gridded window pattern limits the vertical flame spread from floor to floor.
- Non-combustible stucco cladding on the exterior.

ACOUSTICS + VIBRATION

- Acoustic separation and vibration controlled by the mass of the composite floor system.

MOISTURE PROTECTION + DURABILITY

- No timber is exposed to the exterior.
- Durable plaster façade protects the structure from moisture.

Timber structural frame
Photo Credit: Architecture by Kaden Klingbeil,
Photo by Bernd Borchardt

Brettstapel exterior walls in place.
Photo Credit: Architecture by Kaden Klingbeil,
Photo by Bernd Borchardt

Steel connections.
Photo Credit: Architecture by Kaden Klingbeil,
Photo by Bernd Borchardt

CHALLENGES

- Managing an onerous fire protection approvals process involving 12 additional steps beyond the standard requirements.

SUCCESSES

- Separation of the stair and bridging system to provide another façade for daylight.
- Exceptional energy performance achieved with high value insulation, no thermal bridging, heat recovery ventilation, a ground source heat pump, solar panels and rain water reuse for irrigation.
- Customized and flexible spaces.
- Reasonable cost.

Exterior concrete stair and elevator shaft.
Photo Credit: Architecture by Kaden Klingbeil, Photo by Bernd Borchardt

THE AUTHORITY HAVING JURISDICTION
UNTERE BAUAUFSICHT BERLIN-PANKOW

Authority representatives were not available to provide their perspectives, however the information presented here reflects feedback from other project stakeholders on the permissions and approvals process at E3.

At the time of construction the local building code of Berlin did not allow timber buildings above 3 storeys. The design and timber fabrication teams engaged directly with the fire authority to negotiate approvals based on custom strategies and variances to the code requirements. The timber fabricator accessed extensive fire testing research done at the University of Zurich and the Technical Universities of Munich, Karlsruhe, Stuttgart and Weimar to help convince the local Authority that acceptable strategies could be implemented to achieve satisfactory fire safety level. Fire testing was conducted by the Leipzig Institute for Materials Research and Testing (MFPA), and all assemblies were required to reach a minimum 90 minute rating. Approval of E3 led to regulatory changes, subsequently, allowing timber structures up to 13m tall.

Photo Credit: Architecture by Kaden Klingbeil, Photo by Bernd Borchardt

THE CONSTRUCTION TEAM

HOLZBAU MERKLE GMBH

Holzbau Merkle GmbH managed the construction process.

RATIONALE

- Prove a strong case for the use of structural timber products in new construction.
- Contribute to advancing construction techniques for tall wood structures.

PROCESS

- The timber supplier collaborated closely with the design team to establish the fire protection strategy.
- Design and construction process planning were done in parallel to ensure logistics and assembly were adequately detailed.
- Constrained construction site area necessitated immediate assembly of materials as they were delivered to the site.
- No cutting or fabricating happened on site.
- Four carpenters assembled the structure (excluding concrete components) and enclosed the building in eight weeks.
- Total construction time was nine months.

Aerial image during construction
Photo Credit: Architecture by Kaden Klingbeil, Photo by Bernd Borchardt

CONSTRUCTION SOLUTIONS

MOISTURE PROTECTION + DURABILITY

- Assembly of timber construction planned during favourable summer weather.
- Materials were delivered for immediate assembly.

CHALLENGES

- Managing deliveries and assembly on a constrained urban site.

SUCCESSES

- Prefabricated elements allowed for rapid construction.
- Timber elements were light-weight, affording fewer shipments with more materials to be delivered to the building site.

Installation of CLT floor panels
Photo Credit: Architecture by Kaden Klingbeil, Photo by Bernd Borchardt

BULLETIN OF LESSONS LEARNED

LIMNOLOGEN, VÄXJÖ, SWEDEN

This bulletin presents the lessons learned and experiences gathered from stakeholders who responded to an online questionnaire and/or participated in interviews.

OWNER/DEVELOPER
Midroc Property Development

DESIGN TEAM
ARCHITECT: Arkitektbolaget Kronoberg
STRUCTURAL ENGINEER: Martinsons Byggsystem KB

AUTHORITY HAVING JURISDICTION
City of Växjö

CONSTRUCTION TEAM
CONSTRUCTION MANAGER: Midroc Property Development
TIMBER FABRICATOR AND ERECTOR: Martinsons Byggsystem KB

Photo Credit: Midroc Property Development

Limnologen is a residential tenant-owned apartment complex with 4 buildings containing 134 residential units, common spaces, and a parking structure.

Each building is a wood structure, using cross laminated timber (CLT) panels for floors and exterior walls, with glulam columns and beams supporting the internal bearing loads. The first storey is reinforced concrete, and the cores above the first floor are constructed with CLT panels.

Limnologen is the first mass timber development of its size in Sweden and is part of the Välle Broar development, where the municipal government has been actively promoting and supporting wood building technology since 2006 to create 'The Modern Wooden City'. This master planning project is also a research and development partnership between the municipality, academic institutions, and industry with the goal of reducing environmental impact of buildings, improving construction quality, and supporting the timber industry. The Modern Wood City program asks all new projects to consider wood along with other construction material options, to ensure use is maximized in appropriate applications.

PROJECT VITALS

LOCATION: Sjöbågen 6B, 352 57 Växjö, Sweden
COMPLETION DATE: July 2009
OCCUPANCY TYPE: Residential
CONSTRUCTION COST: 320 million SEK (~$50.3M CAD)
TOTAL FLOOR AREA: 10,700m^2
NUMBER OF LEVELS: 8

TECHNICAL RESOURCES + LINKS

Technical details of the building systems can be accessed through the following resources:

Gustavsson et al, 2009. Limnologen Växjö – Lifecycle primary energy use and carbon analysis of an eight-storey building, Sub-project Report to Serrano, Erik (2009). *http://www.cbbt.se/website3/1.0.3.0/31/FULLTEXT01.pdf*

Serrano, E. (2009). Limnologen – Experiences From an 8- storey Timber Building. *http://www.forum-holzbau.ch/pdf/ihf09_Serrano.pdf*

Serrano, E. Växjö University. (December 2009). Documentation of the Limnologen Project: Overview and Summaries of Sub Projects Results. *http://www.cbbt.se/website3/1.0.3.0/31/FULLTEXT01.pdf*

Zeng Xiong Yu, Ren Su Xin, Omar Sabri, Växjö University. (June 2009). Vertical Displacements in a Medium-rise Timber Building — Limnologen in Växjö, Sweden. *http://www.diva-portal.org/smash/get/diva2:226491/FULLTEXT01*

TECHNICAL SUMMARY

STRUCTURE

- Exterior walls and structural floors – prefabricated 3-ply cross laminated timber (CLT) panels strengthened by T-shape glulam beams.
- Stair core and elevator shaft - 125-145mm thick CLT panels.
- Glulam columns and beams.
- Screwed connections.
- Steel tie-down rods.
- Concrete slab on grade and first storey.

SYSTEMS INTEGRATION

- Plumbing installed in the spaces located in the floor formed by the CLT panels and the glulam beams; ventilation, sprinklers and electricity services installed in the framed down ceiling space below the glulams.
- Except for electrical, services running parallel to the floor panels were preinstalled off-site.
- Services running perpendicular to the floor panels were installed on-site.
- All conduit connections installed on-site.

LATERAL RESISTANCE

- Tension rods anchored in the concrete extending to the top floor within interior walls.

ACOUSTICS + VIBRATION

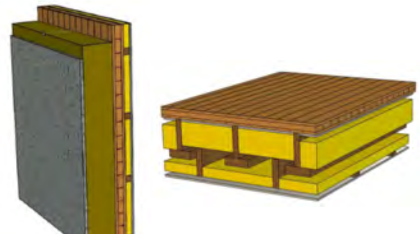
- Isolated and limited connections between floors and ceilings.
- Polyurethane acoustical insulation between the walls and the floor panels and around screws and washers connecting the floor and wall elements.

FIRE PROTECTION

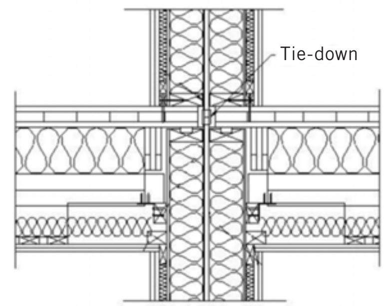
- Encapsulation with gypsum board.
- Automatic sprinkler system.
- Continuous/cantilevered balconies where wood cladding is installed to limit flame spread between levels.

MOISTURE PROTECTION + DURABILITY

- Climbing tent over the highest level under construction to protect working areas and crews.
- Use of breathable non-combustible cladding on top of mineral wool insulation in the exterior walls to allow moisture from the interior to escape.
- Vapour barrier extended 40-50 cm around windows on 3 of the 4 buildings; no vapour barrier on remainder of exterior walls.
- Exposed wood on underside of balconies only.
- Moisture sensors monitor exterior wall assemblies.



A) 3-ply CLT floor slab strengthened with T-shaped glulam beams.
B) 3-ply CLT exterior wall detail.
Detail Credit: Martinsons Bryggsystem KB



Location of tension rod through the interior wall and floor to assist with stabilization.
Detail Credit: Martinsons Bryggsystem KB

South façade showing uninterrupted balconies.
Photo Credit: Midroc Property Development

Movable, rising tent for weather protection during construction.
Photo Credit: Midroc Property Development

LESSONS LEARNED

OWNER / DEVELOPER

- The project has gained significant local industry recognition, could be a catalyst for developing capacity in the region and could encourage more construction of buildings utilizing materials with low carbon footprints.
- Information from research and development of structural timber products is important for demonstrating the value and benefits to building owners.
- Exceptional energy efficiency and high quality indoor residential environments can be created through well designed, specified and constructed wood structures.
- Successful projects lead to future construction opportunities.

DESIGN TEAM

- A strong integrated design process with the developer, authority having jurisdiction, and construction team, in addition to civic leaders, is essential to success.
- The use of wood significantly reduced environmental impacts; (Gustavsson et al. 2009) analysis of life-cycle primary energy use and carbon emissions.

AUTHORITY HAVING JURISDICTION

- Working closely with the design and construction teams helps the AHJ improve the understanding of fire protection strategies for mass timber solutions, resulting in simplified and practical fire protection strategy.

CONSTRUCTION TEAM

- Details in design for prefabricated components and very specific trade scopes are essential to realizing construction schedule benefits.
- Vulnerable areas, such as cantilevered balconies, require well considered and detailed designs and workable construction solution.

Photo Credit: Midroc Property Development

THE OWNER / DEVELOPER
MIDROC PROPERTY DEVELOPMENT

Midroc Property Development financed the project, secured the design team, managed construction and collaborated with local universities to document the Limnologen project process and building performance.

RATIONALE

- Encourage and comply with the City's commitment to use timber in new construction.
- Prove a strong, profitable business case for the use of mass timber products.
- Reduce embodied energy and carbon emissions associated with new construction, as well as comply with local environmental policies.
- Innovate and collaborate with Växjö University as part of a larger research and development program.

PROCESS

- Limnologen was self-financed by the developer for two of the four buildings; the remaining two used traditional bank financing.
- The developer held a design competition and awarded the project to Arkitectbolaget, in part for their previous experience in timber construction and their keen interest in timber innovation.
- Martinsons Byggsystem, a local Swedish timber product supplier approached the developer with a desire to begin producing mass timber products (including CLT) for the local market in Sweden.
- Identified risk included overall logistics, delays associated with delivery of timber panel products, moisture control and weather protection.
- The developer negotiated an agreement with the timber supplier that included responsibility for fabrication, delivery and assembly/erection on-site; ensuring a strong partner relationship with an important stake in the success and quality of the timber solution.
- The project was completed within the expected budget.
- No additional insurance or special policy consideration was required by the lender.
- The developer provided partial financing for the research and development program.

CHALLENGES

- Resolving fire protection issues.
- Developing and applying acoustic strategies and solutions.

SUCCESSES

- The project was the catalyst for developing local design and construction capacity for mass timber.
- Significant carbon savings realized by using mass timber solutions.
- Strong integrated design process involving not only the design and construction teams but also civic stakeholders and university partners was key.
- The weather protection tent was very successful not only as a timber structure protection strategy but also as a mechanism to improve the working environment for the trades.

THE DESIGN TEAM

ARKITEKTBOLAGET KRONOBERG, MARTINSONS BYGGSYSTEM KB

RATIONALE

- Respond to the municipal 'Modern Wood City' program dedicated to reducing carbon emissions and supporting local industry.
- Use timber in construction as a method to achieve a warm indoor environment with a sense of non-being, in residential buildings.
- Support the use of renewable materials.
- Innovate and evolve the design solutions and construction methodologies associated with mass timber construction.

PROCESS

- A concrete structure was considered; however, costs were high due to an active construction market at the time.
- Post and beam construction was also considered, but the narrow building footprint required more lateral stability; panelized, cross laminated timber provided a possible solution.
- The desire for a high level of prefabrication required extensive design detail and planning effort, and necessitated close collaboration with the timber supplier to accurately develop design documents.
- The structural engineer invested 30% more effort working on design details compared to a concrete structure.
- The timber supplier developed an in-house software program available for future use to support timber design.
- The use of conventional transportation vehicles limited the size of prefabricated panels to 10m x 3m.
- Acoustics and fire protection consultants provided expertise.

Photo Credit: Midroc Property Development

DESIGN SOLUTIONS

STRUCTURE

- Three types of walls (two 3-ply CLT and one double-stud) and floor panels were used on the project.
- Glulam columns and beams supplement the load bearing system.

SYSTEMS INTEGRATION

- Void spaces provided opportunities to conceal ventilation and plumbing.
- Fire protection sprinkler system.
- Hydronic heating system pipes milled in the prefabricated floor panels.

LATERAL RESISTANCE

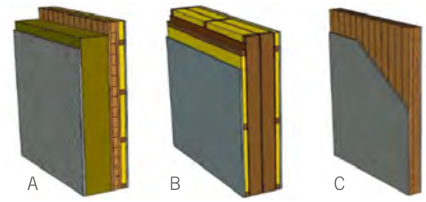
- Steel tie rods between interior wall elements. Each rod has a tightening mechanism to accommodate creep and shrinkage of wood and relaxation of the steel. Recent measurements after 2 years indicate only 10% of the rods have experienced a gap of 15mm or less and no adjustment to the tension is required (Refer to Yu et. al., June 2009 for results).

ACOUSTIC + VIBRATION

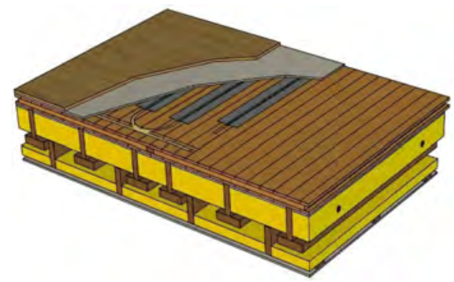
- Design goal for acoustics was to achieve excellent acoustic performance, which required exceeding the minimum code requirements.
- Extensive vibration testing was done in the laboratory and in-situ (Refer to Serrano 2009 for results).
- The timber supplier's previous experience led to the design strategy of isolating floors and ceilings.
- The walls and floors are not continuous across storeys, in order to reduce transmission of vibration.
- Logical suite layouts were prioritized, and the master bedrooms in each suite were completely soundproofed.

FIRE PROTECTION

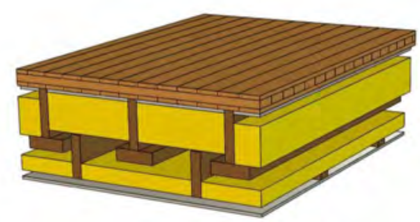
- Fire testing was done on a two-storey mock-up in the factory. Authorities required a 90-minute fire rating for walls and a 60-minutes fire rating for floors. Tests confirmed 140 minutes for both walls and floors.
- Interior fire protection is a combination of encapsulation of timber with gypsum board, an automatic sprinkler system and hard wired smoke detectors.
- On the exterior, non combustible cementitious cladding on the north façade, and uninterrupted balconies on the south façade limit flame spread.



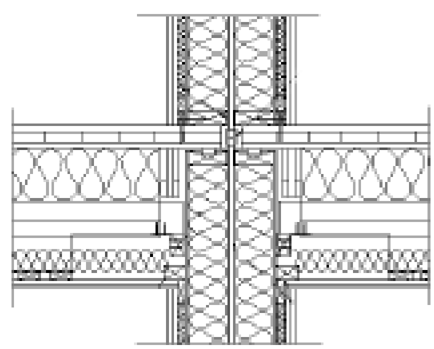
A) Exterior wall B) Separation wall C) Partition Wall
Detail Credit: Martinsons Byggsystem KB



Horizontal panel showing hydronic heating channels.
Detail Credit: Martinsons Byggsystem KB



Isolated floor detail.
Detail Credit: Martinsons Byggsystem KB



Detail showing a connection between interior wall and floor; the wall and floor elements are discontinuous at the joint.
Detail Credit: Martinsons Byggsystem KB

FIRE PROTECTION (CONTINUED)

- Sprinklers made it possible to use wood on the south façade, minimize the vertical distances between the windows on the north-west façade, and leave the exposed timber panels on the underside of the balconies.
- Fire protection strategy for void spaces where no fire barrier exists to isolate suites
- Cost for sprinklers was approximately 280 SEK/m^2 (~$44.00 CAD/$m^2$).

MOISTURE PROTECTION + DURABILITY

- Original design did not require a vapour barrier for the exterior wall assembly. However, this impacted air-tightness on the first building. To mitigate this impact on the remaining three buildings, a vapour barrier, extending 40–50 cm beyond edges of window openings was installed.
- Moisture sensors are strategically located in selected exterior and interior wall assemblies (Refer to Serrano 2009 for results).
- Balconies were originally designed and constructed with a cementitious topping. They were retrofitted with a waterproofed rubber mat covered by treated timber decking when concrete toppings began to crack.

CHALLENGES

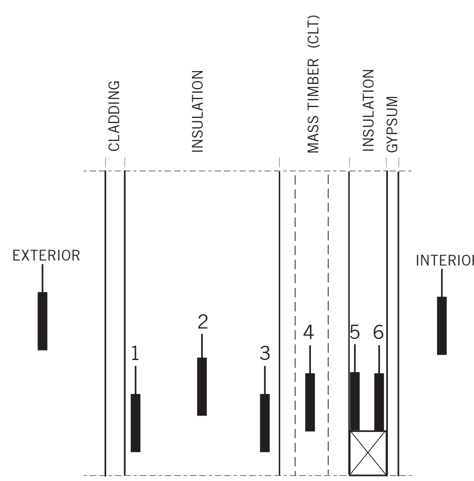
- Lack of experience and knowledge in the local design, manufacturing and construction industries about mass timber construction.
- Achieving an acoustical performance that exceeded the minimum requirement.
- Lack of understanding of all necessary fire protection detailing for mass timber floor and wall assemblies.

SUCCESSES

- Reduction of environmental impacts achieved with the extensive use of wood.
- The strong collaboration with the owner, consultants, and university partners helped overcome the major challenges of acoustics.
- After two years of occupancy, only one of 134 suites has complained about acoustics.
- A close working relationship that allowed for free flow of technical information between the fire officials and design team made it possible to reduce the amount of gypsum board used on two of the four buildings constructed in the complex, as the authority became more comfortable with sprinkling and smoke detectors as adequate fire protection.

Non-combustable exterior cladding, north facade.
Photo Credit: Midroc Property Development

Uninterrupted balconies, south facades.
Photo Credit: Midroc Property Development



Location of moisture sensors.
Detail Credit: Outstanding

THE AUTHORITY HAVING JURISDICTION

CITY OF VÄXJÖ

The City of Växjö oversees the long-term planning, land use regulations, licensing and permitting, and other programs related to the municipality's building programs.

RATIONALE

- Support the goal of becoming the 'Greenest City in Europe by 2020' by reducing embodied energy and carbon emissions in new construction.
- Increase demand for local forest and timber products.
- Facilitate a research and development partnership between the municipality, the developer and local universities.
- Transfer knowledge and improve industry capacity for timber solutions in construction.
- Demonstrate that timber is a cost competitive alternative.

PROCESS

- Harmonization of Swedish building code with the European Union made approvals for the use of structural wood possible.
- The approval process was not different from other projects delivered within the same jurisdiction; the project was only required to demonstrate compliance with the building code.
- The developer and design team relied on expert consultants to support and create fire protection and acoustics strategies and solutions.
- No independent third party review was required.
- No special expertise to support the AHJ was accessed beyond the project partners and consultants.
- The fire authority worked closely with the project developer, fire protection consultant and construction team to identify concerns and collaborate on appropriate solutions.
- Full scale fire testing of wall and floor panels was required to demonstrate a 90-minute fire resistance rating for walls and 60-minute rating for floors; results achieved 140 minutes for both panel types.
- Wood shake cladding was proposed for a specific part of the exterior wall but was not implemented as a result of negative results from an additional fire test. An improved understanding of the efficacy of fire protection strategies resulted from the close collaboration with the design and construction teams.
- In the first two buildings constructed, all interior timber elements were required to be encapsulated with fire-rated gypsum boards. In the next two buildings constructed, some exposed wood elements in the wall and ceilings were allowed.
- All four buildings were required to have sprinkler systems and hard-wired smoke detectors.

CHALLENGES

- Overcoming fire protection issues was the biggest challenge.
- On-site inspections revealed gaps and inconsistencies between design and construction.

SUCCESSES

- The collaborative and open process improved the understanding of fire protection strategies for mass timber buildings.

THE CONSTRUCTION TEAM

MIDROC DEVELOPMENTS, MARTINSONS BYGGSYSTEM

The developer managed construction and sub-contracted Martinsons Byggsystem for timber structural engineering, fabrication and erection.

RATIONALE

- Support the City's commitment to use timber in new construction.
- Prove a strong, profitable business case for the use of mass timber products.
- Further expand expertise and capacity of local design, manufacturing and construction industries for mass timber applications.

PROCESS

- Prefabricated timber components from Martinsons Byggsystem's facility in northern Sweden were delivered for just-in-time installation. During transportation, wall elements were poly-wrapped and floor elements were simply stacked; all were covered with tarps.
- More off-site prefabrication was proposed but not carried out because no product guarantees were provided by the exterior cladding supplier.
- A mobile, 3.3-ton overhead crane was sufficient for the project.
- Construction erection time took ten days per storey.
- In one instance, trades experienced faster installation times due to unfamiliarity with timber installation techniques.
- The project was completed within the expected budget.

Photo Credit: Midroc Property Developments

CONSTRUCTION SOLUTIONS

STRUCTURE

- Prefabrication of timber components maximized the opportunity to realize gains in the construction schedule.

SYSTEMS INTEGRATION

- Extensive and detailed planning in design made systems installation relatively smooth.
- In addition to channels cut during prefabrication, additional milling for the hydronic heating system was done on-site.

FIRE PROTECTION

- The fire official was on-site weekly to inspect progress; construction and design teams worked closely with them to resolve issues quickly.

MOISTURE PROTECTION + DURABILITY

- An independent climbing tent structure anchored to a separate footing was erected over each building during construction to provide weather protection
- The budgeted cost of the climbing tent system for all 4 buildings was ~8M SEK ($~1.3M CAD)

Photo Credit: Martinsons Byggsystem KB

CHALLENGES

- The erection of the weather tent was time consuming and required appropriate stabilization against wind loading.
- Pre-cut grooves in the floor panels for the hydronic heating in some cases had to be re-milled on-site; sawdust generated by the process slowed construction.
- A lack of familiarity with timber construction led to the overestimation by subcontractors of the time and effort needed to complete the required work.
- Erection of this type of structure was new to the timber supplier/erector; Martinsons Byggsystem invested in training of their crew using two specialists.
- Trade scopes were not fully detailed.

SUCCESSES

- The extra effort spent on working out design details before construction led to time saving during construction.
- For some trades, significant reduction in installation time was realized. For example, exterior insulation was completed 40% faster than anticipated.
- The weather protection tent was very successful in creating warm and dry working conditions.
- Fire authority, design consultants and the construction team worked closely together to create acceptable alternative solutions for fire protection.

Photo Credit: Midroc Property Development

BULLETIN OF LESSONS LEARNED

BRIDPORT HOUSE, HACKNEY, LONDON, ENGLAND

This bulletin presents the lessons learned and experiences gathered from stakeholders who responded to an online questionnaire and/or participated in interviews.

OWNER/DEVELOPER
London Borough of Hackney

DESIGN TEAM
ARCHITECT: Karakusevic Carson Architects
STRUCTURAL ENGINEERS: Peter Brett Associates (concrete)
EURBAN and Pirmin Jung (timber)

AUTHORITY HAVING JURISDICTION
London Borough of Hackney

CONSTRUCTION TEAM
GENERAL CONTRACTOR: Willmott Dixon Group
TIMBER FABRICATOR: Stora Enso
TIMBER ERECTOR: EURBAN


Photo credit: Willmott Dixon Group

Bridport House is an eight storey residential social housing development comprised of 41 units, built to replace and rehouse tenants from the existing 1950s four-storey residential block.

The structure from the ground floor upwards, including the elevator shaft is comprised of cross-laminated timber (CLT) panels. Below ground level, the foundation is reinforced concrete. Bridport House is the first project in the UK to use cross-laminated timber (CLT) for the entire multi-storey structure of this height, including the ground floor. Bridport House is the first phase of the five-hectare regeneration of the London Borough of Hackney's Colville Estate which underwent an extensive local resident engagement process over an 18-month time period. The project is built to Code for Sustainable Homes level four and won the Mayor's Housing Design Guide Award and Community Consultation Award in 2012.

PROJECT VITALS

LOCATION: Bridport Place, London, N1 5DG, England
COMPLETION DATE: September 2011
OCCUPANCY TYPE: Residential
CONSTRUCTION COST: ~£1,422/m^2 (~$2,488/m^2 CAD)
TOTAL FLOOR AREA: 4,220m^2
NUMBER OF LEVELS: 8

TECHNICAL RESOURCES + LINKS

Technical details of the building systems can be accessed through the following resources:

Willmott Dixon Group. (2011) Bridport House - The Contractors View. *http://www.buildingcentre.co.uk/slideshow/wd_rethinking-clt_presentation_v8.pdf*

Stora Enso project report (2013). Bridport House, London, UK – Faster, Greener, Neater and More Accurate Building with CLT. *http://www.storaenso.com/products/wood-products/success-stories/bridport/Pages/default.aspx*

Willmott Dixon Group (2012) Bridport House, Case Study. Uk's largest cross-laminated timber residential scheme. Willmott Dixon Group. *http://www.willmottdixongroup.co.uk/assets/b/r/bridport-house-case-study.pdf*

LESSONS LEARNED

OWNER/DEVELOPER

- Building with CLT reduces the impact of carbon and embodied energy associated with new construction.
- Stakeholder management and education are key to changing public opinion about mass timber buildings for residential purposes.

DESIGN TEAM

- The use of CLT allows for floor plan flexibility during design and easy modifications in the future.
- Design details must be established early to inform panel prefabrication.
- Tender packages must be specific and detailed to ensure no scope gaps between contracts.
- Industry resources must be accessed and relationships developed early in the project to ensure an effective integrated design process.
- 3D modelling software significantly improves the efficiency of the design process.

AUTHORITY HAVING JURISDICTION

- The use of CLT does not compromise code fire-safety requirements.

CONSTRUCTION TEAM

- Early coordination and engagement of trades is key.
- A mass timber building can be erected at a competitive cost and more quickly than a conventional building.
- Identified efficiencies in construction process will inform future CLT applications.
- Sequencing of material deliveries must be carefully planned and coordinated.
- A set down area for materials is essential in a city context to alleviate pressure on material delivery schedules.
- Building with mass timber provides more certainty in terms of erection time, compared to the construction of conventional buildings which are more weather dependant.

Metal frame balconies.
Photo credit: Willmott Dixon Group

THE OWNER / DEVELOPER

LONDON BOROUGH OF HACKNEY

Hackney Council, the local government authority for the London Borough of Hackney in Greater London, UK, financed the project. The Borough's housing strategy aspires to make the best possible use of existing housing and new homes to help address local housing needs, and build sustainable communities.

RATIONALE

- A desire to realize the embodied carbon savings associated with wood construction.
- Existing site conditions included a large Victorian era storm sewer necessitating a light structure, making timber an optimal choice.
- Requirement for an increased site density with no net load increase demanded a lightweight structural solution.
- The Homes and Community Agency contributed £3.4 million of the £6 million project, conditional on completion to a specified deadline, so a fast-track schedule was essential.

PROCESS

- A design competition was launched by the London Borough of Hackney's Architectural Framework Panel to select the design team.
- The Architect worked closely with the London Borough of Hackney and the existing tenants over an 18 month consultation period, including presentation of a number of large scale models to portray the building and unit types.
- The extensive consultation period resulted in a high level of buy-in from the residents who responded well to the opportunity for direct input into design choices.
- The design brief specified a façade which portrayed a conventional building structure, to limit negative public perception of timber buildings.
- The construction contractor initiated a study with the Cambridge University Engineering Department Centre for Sustainable Development to calculate the building's embodied energy in comparison to a reinforced concrete frame structure. The study revealed that the mass timber solution realized savings of 892 tonnes of carbon, equivalent to 29 years-worth of operational energy at Bridport House. A local regulatory requirement for new buildings to offset operational carbon emissions was reduced by 50% based on the study results.

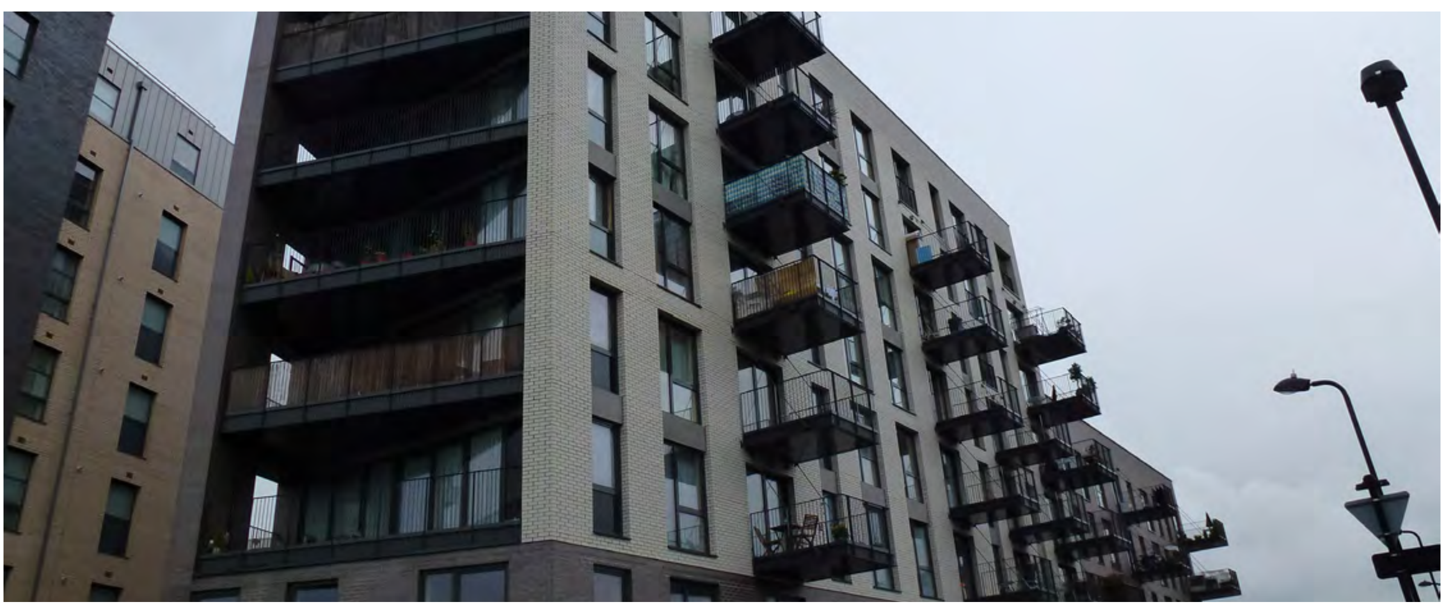


Photo credit: Peter Brett Associates

CHALLENGES

- Relocation, temporary tenure and management of existing building residents.
- Overcoming residents' perception of fire risk in timber buildings. Significant effort was invested to educate residents.
- The need for a lightweight structure after a survey revealed that the site is underlain by a 2.5-metre diameter Victorian era storm sewer.

SUCCESSES

- The embodied carbon in the wood structure reduced the project's renewable energy requirements imposed by the local government for all new buildings by 50%.
- The finished building demonstrated a successful example of a mass timber building for residential purposes.
- The use of a light, mass timber structure made it possible to double the useable floor area while increasing the overall weight of the building by only 10% on this load sensitive site.

Interior of residential suite.
Photo credit: Willmott Dixon Group

THE DESIGN TEAM

KARAKUSEVIC CARSON ARCHITECTS, PETER BRETT ASSOCIATES, EURBAN AND PIRMIN JUNG

Karakusevic Carson Architects completed the architectural design, Peter Brett Associates were the structural engineers for the concrete support structure, and EURBAN in association with Pirmin Jung were responsible for the structural design of the timber structure.

RATIONALE

- The need for a lightweight structure after a survey revealed that the site is underlain by a 2.5-metre diameter Victorian era storm sewer.
- A desire to use natural materials to provide a comfortable, clean and warm occupant experience.
- Demonstrate the environmental merits and potential for embodied carbon savings in wood construction.
- The need to create a structural system to support a cost effective and flexible layout.

DESIGN PROCESS

- The decision to use wood was made prior to design by the Owner.
- Design team was selected through a design competition.
- Initial designs considered a Glulam frame in combination with different structural materials; however, a CLT panelized system was selected for its lightweight quality, ease of erection, and to eliminate difficulties of accommodating variations in tolerances between materials.
- The timber manufacturer completed fire testing and used 3D modelling software to support design.

Photo credit: Peter Brett Associates

DESIGN SOLUTIONS

STRUCTURE

- Concrete slab on grade.
- Prefabricated CLT panels form the above grade stair core and elevator shaft, walls and floors.
- A concrete topping is applied on-site to the floor panels to address fire protection and acoustics.
- The thickness of CLT wall panels is reduced in the upper storeys for the lighter loads supported:
  - The wall panels are 138mm – 5 ply and 161mm – 5 ply.
  - The floor panels are 182mm – 5 ply and 223 mm - 7 ply.
  - The roof panels are 165mm – 5 ply and 182mm - 5 ply.
- The CLT floor and wall panels were fabricated with an interlocking keyed edge to transfer vertical loads end grain to end grain, eliminating the problem of shrinkage by avoiding loading through cross grain.
- Balconies are metal frames secured to the exterior.
- Brick cladding was chosen to provide a solid appearance and address residents' negative perception of wood construction.

LATERAL STABILITY

- The lateral load resistance is borne entirely by the load-bearing CLT walls in each direction.
- Shear resistance is provided at each floor by the interlocking key detail.
- Tie down connections consist of custom gang nail steel plates at each floor joint and at the base of the walls.

SYSTEMS INTEGRATION

- Ventilation ductwork is routed between two layers of gypsum board in the ceiling to accommodate systems.
- Penetrations for the electrical systems were cut in CLT panels on-site.

ACOUSTICS + VIBRATION

- 55mm concrete screed topping installed on floor panels reduces sound and vibration transfer.
- Two layers of 15 mm gypsum on walls and one layer of 12.5mm gypsum wallboard on the ceilings contributes to the acoustic strategy.
- Edge glued CLT boards were selected to contribute to acoustic and fire performance as well as increased air-tightness. A 3-ply edge glued board provides the same airtightness value as a non-edge-glued 5-ply board. Edge glue also protects board end-grains from weather prior to installation.
- Floor and ceiling assemblies are isolated from each other via a cavity which varies from 87mm to 128mm, to limit sound and vibration transfer between units.
- An acoustic insulation layer between the walls and ceiling further reduces sound transmission.

Interlocking keyed edge of each floor and wall panel.
Photo credit: Willmott Dixon Group

CLT floor panels and walls secured with custom gang nail steel plates.
Photo credit: Willmott Dixon Group

Building systems are routed through a ceiling void created with gypsum board.
Photo credit: Willmott Dixon Group

FIRE PROTECTION

- CLT floor, wall and core panels are encapsulated with gypsum to achieve a 90 minute fire rating.
- All wall and floor panels were oversized to provide a sacrificial char layer.
- Staircase was built in steel, the stair core is CLT.
- Brick cladding to create non-combustible facade.

MOISTURE PROTECTION + DURABILITY

- Mechanical ventilation system with heat recovery helps to eliminate moisture during occupancy.
- Building is clad with a brick façade. No timber structure is exposed to the exterior.

CHALLENGES

- Managing the budget where material cost of CLT represents a slight increase over concrete.
- Investing more time in the initial project stages to finalize the details of a prefabricated solution.
- Addressing the variation in floor plans between the ground floor and upper levels which required complex structural design solutions.
- Distributing the building load to protect the Victorian era storm sewer system.
- Managing residents' perceived fear of fire risk.
- Managing authority's perception of mass timber and fire risk.
- Integrating and coordinating disciplines to execute design details.
- Developing design solutions to address shrinkage and lateral stability in a mass timber building.
- Achieving Code of Sustainable Homes Level 4 with few precedents to follow.

SUCCESSES

- Collaboration was effective between design team and other stakeholders.
- Fire code consultants have become more familiar with the approvals process for mass timber buildings.
- Actual building performance exceeded projections for airtightness.
- Embodied carbon assessment demonstrated offsets for the first 29 years of operations, equivalent of more than 30 tons of sequestered carbon.
- Embodied carbon savings reduced the regulatory renewable energy requirement by 50%.
- Building achieved level 4 of the Code for Sustainable Homes

Exterior brick cladding.
Photo credit: Willmott Dixon Group

THE AUTHORITY HAVING JURISDICTION
LONDON BOROUGH OF HACKNEY

Borough representatives were not available to provide their perspectives, however the information presented here reflects feedback from other project stakeholders on the permissions and approvals process at Bridport House.

- Overall, approvals process was straightforward due to the Borough's commitment to carbon benefit of timber construction, and experience with previously completed local projects such as Murray Grove Stadhaus.
- Fire testing was required and completed by the timber manufacturer.

Photo credit: Willmott Dixon Group

THE CONSTRUCTION TEAM

WILLMOTT DIXON GROUP, EURBAN, STORA ENSO

Willmott Dixon Group managed the construction process, Eurban assembled the structure and Stora Enso manufactured and supplied the CLT.

RATIONALE

- A desire to compare and assess the embodied carbon associated with a CLT frame versus and reinforced concrete frame.
- The ambition to improve construction productivity and efficiency with a prefabricated approach.
- An interest in pursuing and being a part of a unique, innovative project.

PROCESS

- Early discussions and consultations were held to identify the optimal acoustic, cladding and thermal bridging solutions.
- CLT panels were sourced from Austria, and took ten weeks to fabricate.
- 1,100 CLT panels (~1,576 m^3) were transported to site over 30 deliveries to correspond with the sequence of assembly.
- A crew of seven erected the timber structure.
- Scaffolding was erected in tandem with the CLT installation to allow for the manual installation of the façade.
- Brick cladding, windows, insulation, gypsum board finishes were installed on-site.

Façade enclosed during construction.
Photo credit: Willmott Dixon Group

CONSTRUCTION SOLUTIONS

SYSTEMS INTEGRATION

- Early involvement of trades and specific training allowed for efficient systems integration.
- Electrical trades cut additional penetrations in timber panels at the construction site.

FIRE PROTECTION

- Gypsum encapsulates timber panels, providing a 90 minute fire rating.

MOISTURE PROTECTION + DURABILITY

- Sequenced delivery of panels reduced panel exposure to weather.
- CLT panel end-grain was covered on the construction site.
- Scaffolding wrap used during façade installation to protect from wind.

CHALLENGES

- Coordinating panel delivery from Austria to fit construction schedule, the erection sequence and to avoid double handling. Dealing with periods of strong winds which, combined with the size of the panels and building height, delayed the assembly process and created delivery backups.
- Coordinating erection with only one crane, but crew of seven.
- Managing gaps between trade scopes of work. The nature of new construction processes associated with wood identified unexpected tasks that were not accounted for within any particular trade scope.
- Having internal trades with no prior experience of building with mass timber led to conservative pricing to allow for learning curve.

SUCCESSES

- Construction was fast, taking only 12 weeks to erect the timber structure, 6 weeks less than a traditional wood-frame construction.
- Industry familiarity of CLT product has increased and created more competitive prices.
- CLT panels were edge glued, contributing to an airtightness of $3m^3$/hour, 60% better than the UK building regulations require.
- The construction site was clean, dry and offered a comfortable working environment.
- Limited disturbance and a clean environment was experienced in the surrounding community.
- The relationships between the erectors and the fabricators were excellent and led to an efficient construction timeframe with no delivery delays.

Cross laminated timber panels stored on-site
Photo credit: Willmott Dixon Group

The solid external wall panels are ideally suited to helical brick ties.
Photo credit: Willmott Dixon Group

BULLETIN OF LESSONS LEARNED

3XGRÜN, BERLIN, GERMANY

This bulletin presents the lessons learned and experiences gathered from stakeholders who responded to an online questionnaire and/or participated in interviews.

OWNER/DEVELOPER
Builder-Owner Collective

DESIGN TEAM
ARCHITECT: Atelier PK, Roedig Schop Architekten, Rozynski_Sturm Architekten
STRUCTURAL ENGINEER: IFB

AUTHORITY HAVING JURISDICTION
Untere Bauaufsicht Berlin-Pankow

CONSTRUCTION TEAM
GENERAL CONTRACTOR: Anes Berlin GmbH
TIMBER FABRICATOR: Merk Timber GmbH
TIMBER ERECTOR: A-Z Holzbau Zimmerei GmbH

Photo credit: Stefan Mueller

3XGRÜN is a residential apartment building containing 13 units, with shared amenity spaces. The building's structure includes a concrete basement and ground floor, with two precast concrete stair and elevator cores.

Above grade side walls are also precast concrete. Structural interior columns, beams and floor slabs above grade are a combination of laminated veneer lumber (LVL) beams, glulam columns and cross laminated timber (CLT) panel floors.

The architectural team collaborated with the Technical University of Braunschweig to research and design 3XGRÜN as the first prototype of a prefabricated structural timber building. The prototype is part of a larger effort termed 'fertighauscity5+ research project' begun in response to the recently revised German building code that changed to allow timber structures up to 13m tall. The Deisgn Team worked with a Builder-Owner Collective, an arrangement where legally recognized groups form to jointly acquire land to design and construct dwellings. The goal of the prototype project is to encourage designers to build creatively with wood and to engage the end user by creating a flexible system that can easily accommodate changes to suit individual needs, while providing all the benefits of single family living in multi-family construction.

PROJECT VITALS

LOCATION: Görschstraße 48/49 in 13187 Berlin, Germany
COMPLETION DATE: October 2011
OCCUPANCY TYPE: Residential
CONSTRUCTION COST: €1,375/m² (~$2,013/m² CAD)
TOTAL FLOOR AREA: 2,900m²
NUMBER OF LEVELS: 5

TECHNICAL RESOURCES + LINKS

Technical details of the building systems can be accessed through the following resources:

Rozynski, Daniel. (2008) Fertighäuser für die Innenstadt. Sondemeh Urbanes Wohntn Issue 6/ 2008, p19: *http://www.roedig-schop.de/presse/3xgruen_Die_Wohnungswirtschaft_06_2008.pdf*

Roedig, Christoph. (2011) Grüne in Berlin. Bauen Mit Holz Issue 3/2011, p14-18: *http://www.roedig-schop.de/presse/3xgruen_Bauen_mit_Holz_03_2011.pdf*

Ballhausen, Nils. (2012) Den Holzbau Radikalisieren. Bauwelt Issue 21/2012, p36-42: *http://www.roedig-schop.de/presse/3xgruen-bauwelt_2012_21_0036-0043.pdf*

Hoeft, Markus. (2012) Ein Bauherr statt dreizehn. Bauen Mit Holz Issue 5/2012, p48-51: *http://www.roedig-schop.de/presse/3xgruen-bauen-mit-holz-berlin-pankow-2012-05.pdf*

LESSONS LEARNED

OWNER/DEVELOPER

- Engage a facilitator to represent and coordinate the Builder-Owner collective.
- Choose fire protection consultants early in the research and design process to facilitate a positive and collaborative relationship that supports innovation.
- Focus on passive performance strategies at the outset of the project to simplify services and keep costs low. Prepare the building for more complex technology to be added in the future (i.e. solar PV or cooling system).

DESIGN TEAM

- Create an effective, collaborative and integrated design process early in the project.
- Choose fire code consultants who are supportive of innovation with structural timber.
- In a Builder-Owner collective scenario, employ a facilitator or project manager to coordinate ideas.

AUTHORITY HAVING JURISDICTION

- Some exposed timber on the interior was allowed, given a 60 minute fire rating was achieved through a combination of other strategies.
- In a city context fire brigades arrive within short timeframes, which should be considered as part of the overall fire protection strategy.

CONSTRUCTION TEAM

- Consider the construction plan in parallel with the design process to reduce changes during construction.
- Prefabrication of both concrete and wood elements was highly advantageous.
- CLT panels can withstand rain and weather without consequence, as long as they are allowed to dry before encapsulating or sealing. Other timber components are more vulnerable.
- A pure wood structure, including the core, would have been more advantageous to eliminate the details and precision required to coordinate and execute interfaces between materials.

Photo credit: Stefan Mueller

THE OWNER / DEVELOPER

BUILDER-OWNER COLLECTIVE

Institute for Urban Timber was created as a joint venture between the University of Braunschweig and four professional architects - Atelier PK, Roedig Schop Architekten, Rozynski Sturm - to research, develop and implement a prototype for a residential timber building in the city centre. A Builder-Owner collective* of individual resident owners was formed, each of which contributed time and funds to the development process.

RATIONALE

- Prove a business case for multi-storey and multi-family residential timber development.
- Develop a high quality, multi-tenant residential typology with the feeling of single family homes, for all tenant types.
- Develop a flexible, prefabricated timber construction system comparable to the cost of steel or concrete.
- Demonstrate the potential of timber to contribute to environmentally sound construction practices, especially to reduce embodied energy and carbon emissions associated with wood construction.

PROCESS

- Joint research undertaken with the university to investigate how to apply prefabricated, high quality, sustainable residential timber construction in a city centre context.
- Building codes in Berlin changed to allow timber construction up to 13m (4-5 storeys).
- The site was acquired by the Builder-Owner collective from a single property owner.
- The project was self-financed by the tenant-ownership group, each member contributing to the design process and providing funds toward the purchase of their suite.
- Collaborated with the research institution on developing prototypes and options for materials and connections.
- A full wood solution including the core and side walls was evaluated before arriving at the final solution.
- A facilitator was engaged to manage the process on behalf of the tenant-ownership group and consulting team.

Photo credit: Stefan Mueller

** Builder-Owner collective in this document, refers to a method of organizing individual owners as a formal, legally recognized group for the purposes of acquiring land to design and construct a multi-family dwelling. This arrangement is relatively common in Germany and eliminates the traditional role of Developer, allowing the group of individual owners to work directly with the design, often resulting highly customized suites.*

- Space was negotiated among the tenant-ownership group according to individual need and funds available for investment.
- The team adopted a simplified approach to systems to reduce initial costs as much as possible.
- Timber suppliers collaborated with the design team to test structural and fire protection options.
- Two independent code consultants were engaged to facilitate and obtain approvals from the authority having jurisdiction.

CHALLENGES

- Keeping cost within comparable range of other structural materials.
- Managing the changing needs and desires of multiple stakeholders over the course of the project.
- Educating potential owners about the characteristics of mass timber to address negative perceptions that pre-fabricated systems represent low quality buildings.

SUCCESSES

- The large group of individual stakeholders were managed effectively through a complex prototype design and construction process.
- The success of the prototype was demonstrated in relation to cost, appeal and performance.
- This building represents the practical implementation of new standards that are now available as a technological planning instrument for all successive engineers, architects, building contractors and clients.

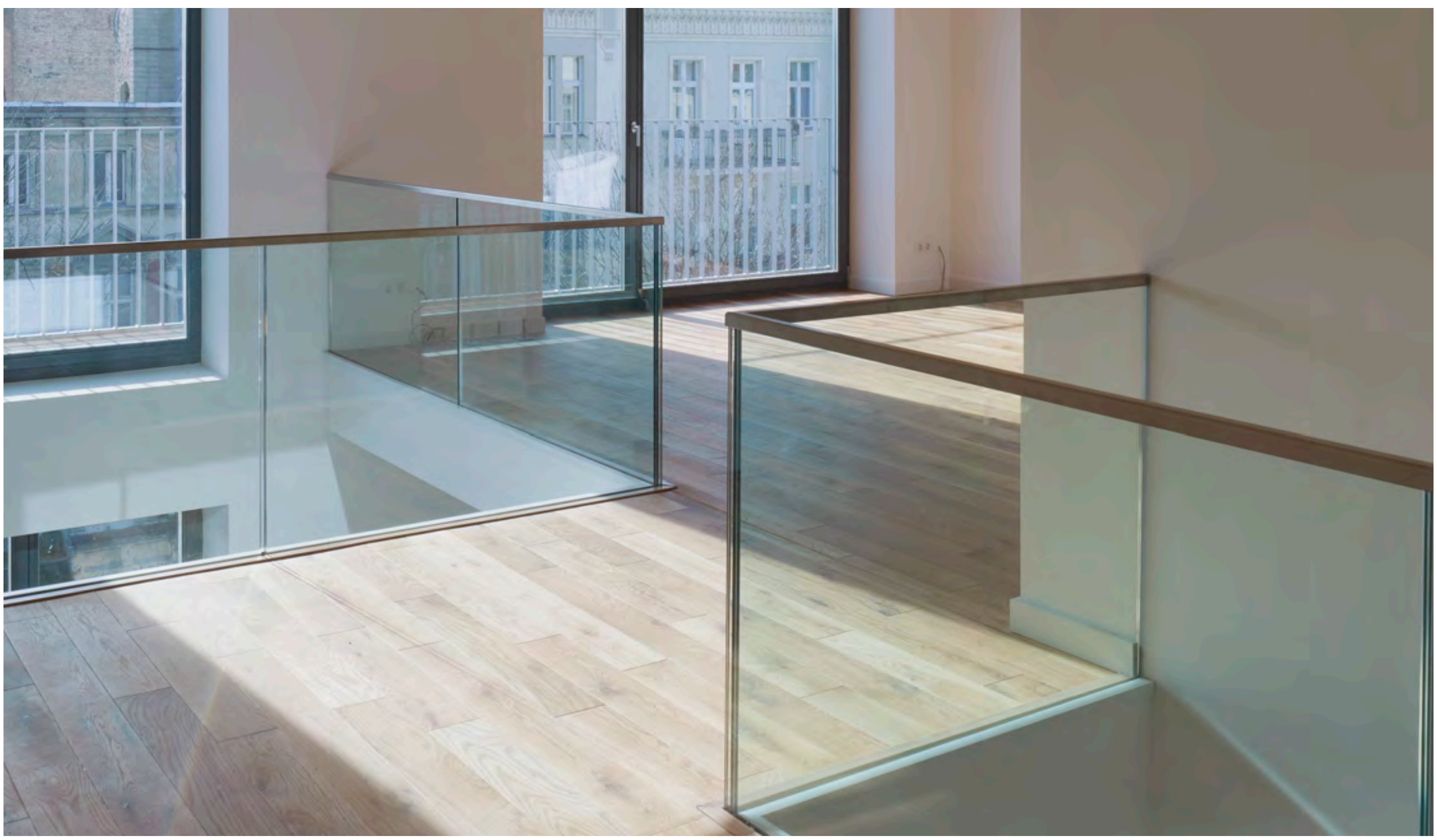


Photo credit: Stefan Mueller

THE DESIGN TEAM

ATELIER PK, ROEDIG SCHOP ARCHITEKTEN, ROZYNSKI_STURM ARCHITEKTEN, IFB

Four architects; Atelier PK, Roedig Schop Architekten, Rozynski_Sturm Architekten worked with the Technical University of Braunschweig on the architectural design. The structural design was developed by IFB.

RATIONALE

- Prove a business case for multi-storey and multi-family residential timber development.
- Develop a high-quality, multi-tenant residential typology with the feeling of single family homes, for all tenant types.
- Develop a flexible, prefabricated timber construction system comparable to the cost of steel or concrete.
- Demonstrate the potential of timber to contribute to environmentally sound construction practices, especially to reduce embodied energy and carbon emissions associated with wood construction.

DESIGN PROCESS

- Collaboration with the Technical University of Braunschweig and timber supplier to test structural design options and fire protection strategies.
- A modular approach to the floor plan allows for easy modification within suites over the life of the building.
- Pursuing a structural timber solution required an estimated 10% more effort in design than a steel or concrete structure.
- Initial structural design considered a concrete core with steel beams and steel connections between wood elements, with two layers of gypsum board encapsulating interior spaces to address fire protection.
- Testing on the initial connection detail indicated an unacceptable 7cm of compression.
- In an effort to address compression, reduce materials, keep costs low and simplify design, a pure wood solution was mocked-up and tested with successful results.

Photo credit: Rozynski_Sturm Architekten

DESIGN SOLUTIONS

STRUCTURE

- Direct end-grain contacts between vertical timber elements were used to reduce compression.
- Grooved joints between vertical and horizontal panels were used to eliminate the top grain compression problems related to wood structure load transfer between vertical and horizontal structures.
- Angled screws secure horizontal and vertical panels at the joint.

FIRE PROTECTION

- Exterior side walls directly adjacent to neighbouring buildings are precast concrete.
- Precast concrete stair and elevator cores.
- Timber elements have 30 minute fire rating; one layer of gypsum board increased the wall and ceiling assemblies to 60 minutes.

ACOUSTICS + VIBRATION

- Isolated floor and ceiling elements.
- A sand layer within the floor assembly to add mass and limit vibration and sound transfer.

MOISTURE PROTECTION + DURABILITY

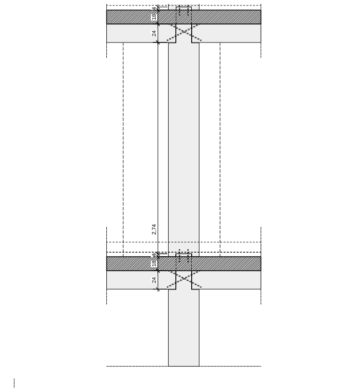
- Concrete for the basement and ground floor protect the structure from moisture.
- Concrete façade protects timber structure from weather; timber is exposed on the underside of balconies only.
- Mechanical ventilation provided in suites to remove humidity.
- Tenants were educated on appropriate operational practices to optimize performance and maintain comfort in all seasons.

CHALLENGES

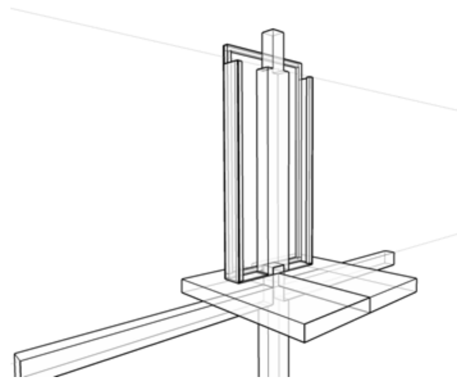
- Managing the changing needs and desires of the many resident stakeholders over the course of the project.

SUCCESSES

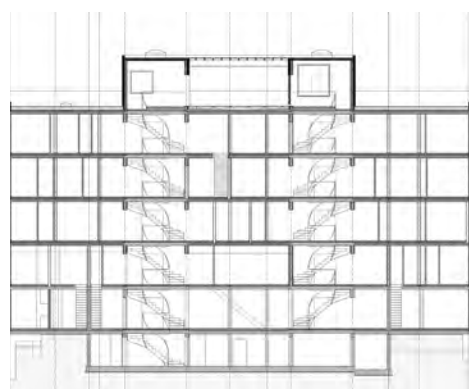
- Completely open floor plans surrounding the cores to facilitate flexible layouts on each level.
- Customized suites, successfully respond to the social and economic needs of each tenant-owner.
- Energy efficient building performance was achieved; 30% better than required.
- The interior space achieved a warm and high quality space.
- New work was secured as a result of the overall success of this project.
- The project was completed within the expected budget.



Detail of floor-wall connection.
Detail credit: Rozynski Sturm Architekten



Interlocking wood structure
Detail credit: Rozynski Sturm Architekten



Elevation view
Detail credit: Rozynski Sturm Architekten

THE AUTHORITY HAVING JURISDICTION
UNTERE BAUAUFSICHT BERLIN-PANKOW

Authority representatives were not available to provide their perspectives, however the information presented here reflects feedback from other project stakeholders on the permissions and approvals process at 3XGRÜN.

During the early stages of research for 3XGRÜN, the local building code was amended to allow a timber structure for buildings of 5 storeys, or 13m in height or less. The building code change was a direct result of the successful approval of the seven storey, mass timber E3 building in the same jurisdiction. 3XGRÜN benefited greatly from the onerous process experienced by the E3 team, and reported that the approvals process was relatively smooth in comparison.

As per the requirements of the AHJ, the 3XGRÜN design and timber fabrication teams engaged directly with two independent fire protection consultants to establish acceptable strategies and liaise directly with the fire authority to negotiate approvals. The team was required to conduct fire testing for proposed timber connections and assemblies, but the approvals process in general was reported to be efficient and straightforward.

Photo credit: Stefan Mueller

THE CONSTRUCTION TEAM

ANES BERLIN GMBH, A-Z HOLZBAU ZIMMEREI GMBH, MERK TIMBER GMBH

Anes Berlin GmbH managed the construction process, A-Z Holzbau assembled the structure and Merk Timber GmbH manufactured the timber.

RATIONALE

- Further expand their expertise and develop industry capacity for mass timber projects.
- Invest and expand skilled labour for future mass timber projects.

PROCESS

- Design and construction plan was developed early in the design phase.
- Careful planning avoided costly and time consuming changes during construction phase.
- Total construction time was three months; timber erection was one week per storey.
- Concrete elements and wood elements arrived on-site together and were installed simultaneously, floor by floor rather than core first, followed by timber structure.
- Skilled carpentry labour was readily available.

Photo credit: Rozynski Sturm Architekten

CONSTRUCTION SOLUTIONS

MOISTURE PROTECTION + DURABILITY

- Strategic and timely delivery of materials reduced exposure of CLT panels to weather.
- A movable roof protected the structure from weather exposure.

CHALLENGES

- Managing weather protection for the combination of concrete and the wood, particularly during high winds.
- Managing with limited material storage and staging space in the dense, city-centre location.

SUCCESSES

- The extent of prefabrication resulted in an extremely short construction phase.
- Simultaneous erection of precast concrete and timber elements worked well on-site.

Installation of CLT floor panels
Photo credit: : Rozynski Sturm Architekten

Installation of precast concrete panels
Photo credit: Rozynski Sturm Architekten

BULLETIN OF LESSONS LEARNED

HOLZ8, BAD AIBLING, GERMANY

This bulletin presents the lessons learned and experiences gathered from stakeholders who responded to an online questionnaire and/or participated in interviews.

OWNER/DEVELOPER
B&O Gruppe
DESIGN TEAM
ARCHITECT: SCHANKULA Architekten
STRUCTURAL ENGINEER: Bauart Konstruktions GmbH & Co.
AUTHORITY HAVING JURISDICTION
County of Rosenheim
CONSTRUCTION TEAM
GENERAL CONTRACTOR: B&O Gruppe
TIMBER FABRICATOR: Binderholz and Huber & Sohn
TIMBER ERECTOR: Huber & Sohn


Photo credit: Huber&Sohn

Holz8, or "H8", is an 8 storey residential apartment building containing 15 rental suites as well as commercial office space on the ground floor. The building includes a concrete stair and elevator core, and uses a customized panelized mass timber product for walls, and Cross Laminated Timber (CLT) panels for floors. All structural components were prefabricated and the building was designed to offer the most flexible layout possible by reducing the number of interior load bearing walls.

Holz8 is a pilot project intended to test the merits of mass timber construction and energy efficiency, and is part of a larger mixed-use redevelopment of a former military base. The site is planned to accommodate 400 people and use energy from renewable sources only. As a prototype project for the developer, the design and construction process relied on innovative strategies researched in close collaboration between the developer, design team and several research institutions including the Technical University of Munich (TUM), the Rosenheim University of Applied Sciences and the Institute for Window Technology in Rosenheim.

PROJECT VITALS

LOCATION: B&O Parkgelände, Bad Aibling, Germany
COMPLETION DATE: June 2011
OCCUPANCY TYPE: Commercial/Residential
CONSTRUCTION COST: €2.4million (~$3.6million CAD)
TOTAL FLOOR AREA: 1740m^2
NUMBER OF LEVELS: 8
HEIGHT ABOVE GRADE: 21m

TECHNICAL RESOURCES + LINKS

Technical details of the building systems can be accessed through the following resources:

Binderholz Bausysteme GmbH. (2013) 8-Storey Timber Building, Bad Aibling. *http://www.binderholz-bausysteme.com/fileadmin/books/en/Case%20study%20Bad%20Aibling%20GB/files/assets/downloads/publication.pdf*

Angela, T. & Schäfer, W. (December 2011), Herausragend Auch Im Detail. Bauen Mi Holz, Issue 12/2011 *http://www.huber-sohn.de/bilder/Allgemein/04_Presse/04_PDFs/H8_Bauen-mit-Holz_12-2011.pdf*

Holzma. (July 2012) Wooden Town Hits The Heights. *http://www.holzma.com/en-en/references/referencedatabase/weinmann/Pages/Woodentownhitstheheights.aspx*

Burk, Maike. (September 2012) Hoch Hinaus Mit Holz. *http://architektur.mapolismagazin.comschankula-architekten-holz-8-bad-aibling*

LESSONS LEARNED

OWNER/DEVELOPER

- Consultants must be engaged early to ensure collaborative and detailed planning throughout the design process.
- Detailed project planning is critical to avoid complications and costly changes during installation of mass timber products.
- Combining a mass timber structure with a precast concrete core was beneficial in a number of ways including satisfying the fire authority's requirement for a non-combustible exit, schedule gains offered by a precast product, and structural stability.
- The use of precast concrete panels helps maintain a clean, less disruptive construction site.

DESIGN TEAM

- Close collaboration with the fire authority on design strategies can successfully overcome perceived barriers of fire risk and mass timber structure.
- It is important to work with experienced and progressive consultants and engineers to facilitate innovative solutions.
- Close coordination with mechanical and electrical team is critical where prefabricated components are used, to avoid costly and difficult changes after components are manufactured.

AUTHORITY HAVING JURISDICTION

- Fire testing is required to confirm acceptable design conditions for each unique timber panel type.

CONSTRUCTION TEAM

- Prefabrication decreases construction time and requires a smaller crew.
- Consider timber for stair and elevator core to avoid difficulties of incompatible tolerances between concrete and wood.
- Simplify the drawing detail process by sharing files and staff between timber fabricators.
- A timber fabrication service package that includes design, fabrication, installation and post-construction consideration to ensure material integrity, is essential to successful and high quality results.

Photo credit: Huber&Sohn

THE OWNER / DEVELOPER
B&O GRUPPE

B&O self-financed the building as a research project on mass timber design and construction techniques. B&O secured the design team, managed construction and collaborated with local universities to assist with research and technical innovation.

RATIONALE

- Demonstrate that mass timber is the future of residential construction to benefit from energy efficiency in operation, and reduced carbon emissions.
- Build company capacity by adopting innovative approaches and conducting research before applying it in the marketplace.

PROCESS

- The architectural team was engaged based on a previous successful collaboration.
- Huber & Sohn was contracted to erect the building, and fabricate the wall panels. Binderholz was contracted to fabricate and install the floor panels in collaboration with Huber & Sohn.
- A research partnership was formed with local universities to investigate structural options, fire protection and acoustic strategies.
- The developer perceived the greatest risk to be the process of learning new construction techniques and design solutions, rather than meeting code requirements for fire protection or acoustics.
- No additional or special insurance policies were required.

Photo credit: SCHANKULA Architekten / Photographer: Arthur Schankula

CHALLENGES

- Handling the learning process for everyone involved.
- Meeting the acoustical requirements.
- Controlling higher costs associated with timber construction due mostly to the lack of established standards, machinery and methods.
- Managing the shortage of qualified timber trades people.

SUCCESSES

- Timber erection time was fast; two days per storey.
- The building quality impressed the owner and residents.
- The collaboration process among all team members was very smooth and cohesive.

External concrete corridors provide smoke free escape route pictures.
Photo credit: SCHANKULA Architekten / Photographer: Arthur Schankula

THE DESIGN TEAM

SCHANKULA ARCHITEKTEN, BAUART KONSTRUKTIONS GMBH & CO.

RATIONALE

- Respond to the regional regulatory requirement to reduce the environmental impact of new construction.
- Create a highly energy efficient building.
- Explore the benefits of fully prefabricated structural elements.
- Demonstrate the benefit of a lighter structural material for other project types, such as, renovations and additions.
- Support and broaden the use of timber in residential construction in Germany to respond to the need for high quality housing.

DESIGN PROCESS

- The design team collaborated with local universities to research acoustics, fire protection and explore structural options.
- Significant effort was expended by the design team to coordinate and procure a nominal incentive of €120,000, awarded through the Federal Environmental Program.
- Extensive collaboration occurred with timber fabricators to create robust design details.
- Architectural design time spent on detailing was approximately double compared to a conventional project of the same size.
- Significant research on exterior or cladding finishes was completed to address fire protection while maintaining a timber look to the building.

Photo credit: Huber&Sohn

DESIGN SOLUTIONS

STRUCTURE

- Concrete slab on grade.
- Precast concrete panels form the stair and elevator cores.
- Walls are a customized panel product constructed from timber posts measuring 80mm x 80mm to 160mm x 160mm and timber top and bottom plates.
- To account for lighter loads at the top of the tower, the thickness of the timber in the wall panels is reduced in the upper storeys.
- Floors are 5-ply cross laminated timber (CLT) panels.
- Floor elements are connected to concrete core with a steel bracket.

SYSTEMS INTEGRATION

- Concrete chases were provided in the floor for mechanical and electrical systems.

LATERAL RESISTANCE

- Shear wall overturning resistance is achieved by steel tension rods anchored in the slab on grade, extending to the top floor within the interior walls.
- A complex cross screw technique is used to connect the floor elements to the wall panels.

ACOUSTICS + VIBRATION

- Local acoustic standards do not provide acceptable prescriptive requirements for mass timber construction; academic research partners proposed and tested unique acoustic strategies for walls and floors to reduce flanking noise.
- Floor assemblies are isolated between suites and include a layer of dry screed, a layer of sound impact insulation and a layer of cement screed.
- Two layers of gypsum board are attached to all ceilings with the exception of living room spaces, further limiting sound transfer between suites.
- Acoustic performance exceeds the minimum local code requirements.

FIRE PROTECTION

- Suites are accessed via external corridors in the concrete staircase and elevator core, creating a smoke free escape route.
- Two layers of gypsum encapsulate timber panels on walls and all ceilings except in living rooms.
- Metal flashing is installed at the ceiling level of each storey on the exterior to prevent fire from spreading on the front of the building where timber cladding is used.
- Integrated dry risers, and smoke alarms are connected directly to the fire department.

Steel bracket used to connect wood floor panels to concrete core.
Photo credit: Huber&Sohn

Cross screw technique used to connect floor and wall panels.
Photo credit: Huber&Sohn

Metal flashing between each storey prevents the spread of fire.
Photo credit: Huber&Sohn

MOISTURE PROTECTION + DURABILITY

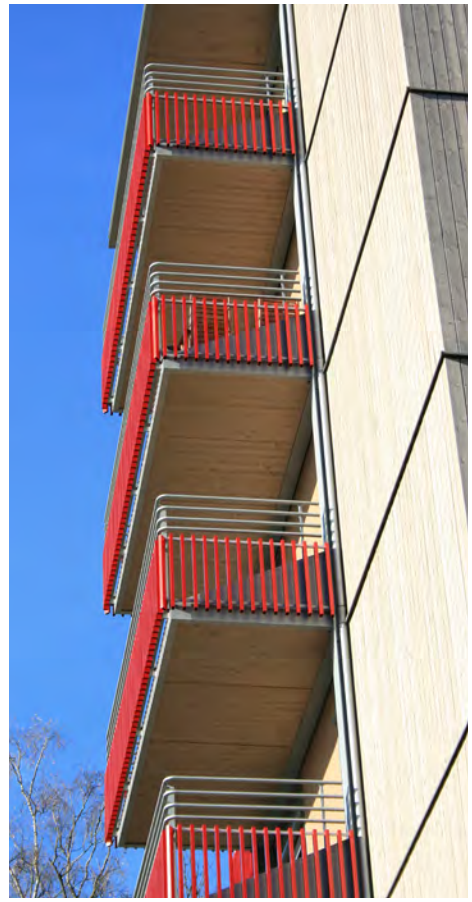
- Wall panels were delivered entirely prefabricated with windows, doors and cladding already installed.
- Mass timber panels are used for the balconies and sit within a steel frame to protect them from direct exposure to weather; exposing timber on the underside only.
- Humidity from the interior is regulated through a mechanical ventilation system.

CHALLENGES

- Adjusting the design process to address unfamiliar construction processes that are specific to mass timber construction.
- Ensuring wood is prominent and visible on the building in order to showcase the mass timber construction.
- Finding a solution to address required acoustical measures and humidity control.

SUCCESSES

- Project specific solutions demonstrated innovation in the use of mass timber technology.
- Construction time was faster than a conventional building.
- There was a high degree of collaboration between the research, design and construction team members.



Timber balcony panels enclosed by steel frame
Photo credit: naturally: wood

THE AUTHORITY HAVING JURISDICTION
COUNTY OF ROSENHEIM

County representatives were not available to provide their perspectives, however the information presented here reflects feedback from other project stakeholders on the permissions and approvals process at Holz8.

- County policies favour timber construction and encourage low carbon, low energy buildings and renewable energy systems.
- Fire testing was required to confirm a 90 minute fire rating for all load bearing timber components.
- The stair and elevator core was required to be concrete to provide a non-combustible exit.
- New testing data now exists to support future mass timber projects.

Photo credit: B&O Gruppe / Photographer: Walter Wehner

THE CONSTRUCTION TEAM
B&O GRUPPE, HUBER & SOHN, BINDERHOLZ

B&O Gruppe managed construction and contracted Huber & Sohn and Binderholz for timber fabrication and erection.

RATIONALE

- Encourage and comply with the County's commitment to use timber in new construction.
- Prove a strong, profitable business case for the use of mass timber products for low carbon residential buildings.
- Further expand expertise and develop industry capacity for mass timber projects.
- Refine and simplify the process of design detailing to facilitate smooth construction process and high quality outcomes.

PROCESS

- Timber fabrication was shared by two fabricators; Binderholz supplied the floor panels, Huber & Sohn supplied the wall panels.
- Wall panels were completely prefabricated including windows, doors, insulation and exterior cladding.
- Concrete panels for the stair and elevator core were assembled in advance of the timber erection.
- The timber erection time was 16 working days, or two days per level.

Left: Prefabrication of wall panels. Right: Timber erection time took 2 days per level.
Photo credit: Huber&Sohn

CONSTRUCTION SOLUTIONS

STRUCTURE

- Gaps in the façade were used to avoid cracking of interior finishes as movement occurs between different materials.

LATERAL RESISTANCE

- Dual-axis angular pilot holes were drilled into the CLT floor panels in the factory to accommodate the screw connections.

MOISTURE PROTECTION + DURABILITY

- Floor panels were protected with plastic prior to installation and with a waterproof membrane immediately after installation.
- Construction was scheduled to take place during a favourable weather season.

CHALLENGES

- Educating trades on the proper techniques associated with mass timber construction.
- Considering the screw connection pilot holes in advance of construction phase.
- Installing the connections between concrete and timber elements.

SUCCESSES

- The drawing and detailing processes were streamlined by collaborating with the design team early, and sharing resources between timber fabricators.
- Very few obstacles were encountered during construction and site management was very effective.
- The fully prefabricated solution was extremely successful.

Floor panels covered with waterproof membrane after installation.
Photo credit: Huber&Sohn

Prefabrication process.
Photo credit: Huber&Sohn

Prefabrication process.
Photo credit: Huber&Sohn

BULLETIN OF LESSONS LEARNED

FORTÉ, MELBOURNE, AUSTRALIA

This bulletin presents the lessons learned and experiences gathered from stakeholders who responded to an online questionnaire and/or participated in interviews.

OWNER/DEVELOPER
Lend Lease

DESIGN TEAM
ARCHITECT: Lend Lease
STRUCTURAL ENGINEER: Lend Lease

AUTHORITY HAVING JURISDICTION
Melbourne Certification Group, City of Melbourne

CONSTRUCTION TEAM
GENERAL CONTRACTOR: Lend Lease
TIMBER FABRICATOR: KLH UK


Photo credit: Lend Lease


Photo credit: Lend Lease

Designed and constructed by Lend Lease, Forté is a residential boutique apartment building containing 23 units, located in Melbourne, Australia. Certified with a 5 Star Green Star residential rating, Forté features one bedroom, two bedroom and penthouse apartments, all designed with dual aspect to maximize sunlight and natural ventilation.

Forté is the first residential building in Australia to use Cross Laminated Timber (CLT) as a structural solution. With the exception of the first storey which is concrete, the remaining nine storeys are constructed with CLT panels, including the walls, floors, stair shafts and the elevator core.

Lend Lease has a long history of landmark innovations in sustainable construction. Forte was undertaken as a pilot to test new processes and technologies in the local context, to further Lend Lease's commitment to informing high quality and low impact future development.

PROJECT VITALS

LOCATION: 791 Bourke Street, Victoria Harbour, Melbourne, VIC 3008, Australia
COMPLETION DATE: December 2012
OCCUPANCY TYPE: Commercial / Residential
CONSTRUCTION COST: $11 million AUS ($10.4 million CAD)
TOTAL FLOOR AREA: 2, 890m²
NUMBER OF LEVELS: 10
HEIGHT ABOVE GRADE: 32.17m

TECHNICAL RESOURCES + LINKS

Technical details of the building systems can be accessed through the following resources:

Lend Lease. (2013) Forté Creating the World's Tallest Timber Apartment Building: The 10-story Forté. *http://woodworks.org/wp-content/uploads/CLT-PATTERSON.pdf*

Lend Lease. (2013) Forté: Building Australia's First Timber High-Rise. *http://woodworks.org/wp-content/uploads/2013-WSF-ATL-Collins.pdf*

LESSONS LEARNED

OWNER/DEVELOPER

- Significant carbon savings are possible with mass timber even when procuring non-local materials.
- Industry preconceptions about timber construction, such as structural integrity, fire protection, construction complexity, and durability were successfully addressed.
- Construction time savings are significant.
- The learning process was challenging, but ultimately led to a robust assessment of the commercial impacts of using a mass timber system.
- A structural wood solution can be cost competitive compared with more conventional building materials such as concrete or steel.
- Be bolder with the use of timber on future projects.

DESIGN TEAM

- Consider the structural solution from the outset.
- Close collaboration is required across the design and delivery team to realize an optimal outcome.
- Change the design delivery process to finalize details earlier to avoid on-site detail changes.

AUTHORITY HAVING JURISDICTION

- Extensive fire testing data on solid timber panels is now available for future projects.
- Continue to undertake a large number of inspections during construction, until the industry becomes familiar and confident with product and construction tolerances.
- Effective training of all contractors is essential.

CONSTRUCTION TEAM

- Invest the time to understand the system and processes early.
- Ensure there is an integrated design process.
- Plan for efficient logistics.
- Educating subcontractors on the benefits of a mass timber solution is essential to build awareness and capacity in the market.

Photo credit: Lend Lease

THE OWNER / DEVELOPER
LEND LEASE

Lend Lease, an international property and infrastructure group, financed the project, and managed the design and construction process. Principles of sustainability and innovation, along with market leadership, are integral to Lend Lease's business practice.

RATIONALE

- A commitment to sustainable design, market leadership, and innovation.
- Assess embodied carbon and life cycle impacts associated with wood construction.
- Desire to demonstrate the reduced impact on the surrounding community during construction.
- Improve productivity and efficiency with a prefabricated approach.
- Advocate for new construction technology in the market.
- Poor site soil conditions necessitated a light structure, making timber an optimal choice.

PROCESS

- Forté was self-funded by the developer; no external funding was provided.
- A three year due diligence process was undertaken, including comprehensive fire testing.
- Extensive research to learn from European experience was conducted, including field trips to mass timber projects in the UK and CLT fabrication plants in Austria.
- Forté was approached as a pilot project to test the market for mass timber construction in a residential application.
- Exposed timber is used selectively so as not to influence potential buyers or occupants with preconceptions about timber construction. Each apartment has a CLT feature wall and the fire stair case is entirely exposed CLT.
- Thorough cost assessment and logistics planning were undertaken to ensure procuring timber products from Europe was feasible given the limitations of long distance shipping, and impact on embodied energy.

Photo credit: Lend Lease

- The Royal Melbourne Institute of Technology (RMIT) was commissioned to complete a Life Cycle Analysis study to independently assess and understand the life cycle benefits and challenges of mass timber as applied at Forté.

CHALLENGES

- Addressing perceived risk surrounding market acceptance of timber buildings.
- Demonstrating commercial viability.
- Managing logistics in procuring and shipping timber products from Europe.

SUCCESSES

- All residential units were sold quickly and positive feedback was received from the occupants about their investment.
- Forté achieved 5 star Green Star as built rating and carbon savings.
- Speed of construction was faster than a conventional building.

Photo credit: Lend Lease

THE DESIGN TEAM
LEND LEASE

RATIONALE

- A commitment to sustainable design, market leadership, and innovation.
- Assess embodied carbon and life cycle impacts associated with wood construction.
- Improve productivity and efficiency with a prefabricated approach.
- Advocate for new structural technology in the market.

DESIGN PROCESS

- The design team accessed external structural and erection expertise from KLH UK.
- Design team invested additional time and resources to research and execute design solutions.
- Relevant European codes and standards along with FP Innovation's CLT Handbook were consulted as resources.
- Multiple structural wood options were considered during the due diligence period, before the final solution was selected.
- The design of walls and floors was based on evaluated European test data and computer simulation. Lab and prototype testing of locally adapted details were used to confirm performance targets.
- The project elected to use fully prefabricated bathroom pods to simplify systems integration and accelerate building assembly. Bathroom pods were built and delivered by Project Modular in Brisbane.
- 3D modelling in Auto-CAD was used for design.
- Installation sequencing, crane calculations and logistics and delivery planning were undertaken in design phase.

Photo credit: Lend Lease

DESIGN SOLUTIONS

STRUCTURE

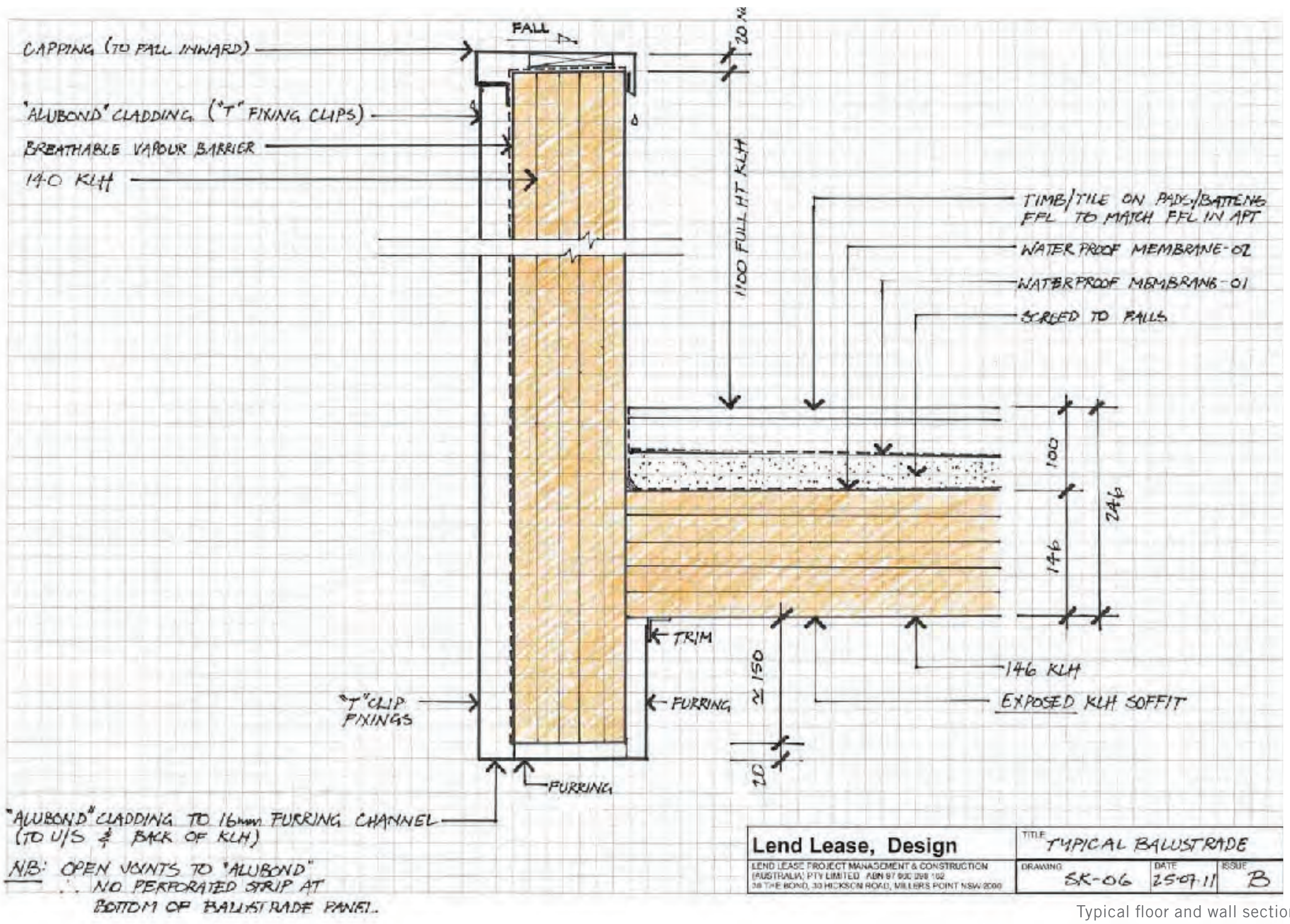
- Pile foundation with concrete slab on grade and ground floor.
- 5 ply CLT panels for load bearing walls and floors slabs from level 2 upward.
- Final design includes 759 custom CLT panels.
- Joints are fastened with screws and angled steel connection plates.

FIRE PROTECTION

- Fire testing passed based on Structural Adequacy, Integrity and Insulation. Three scenarios were tested and accepted:
  - FR 90/90/90: 128mm wall panel with 13mm fire grade plasterboard direct fixed.
  - FR 90/90/90: 158mm wall panel – bare.
  - FR 120/120/120: 146mm floor panel with 2 layers 16mm fire grade plasterboard directly fixed.

ACOUSTICS + VIBRATION

- Acoustic performance was prioritized and the goal for both walls and floors was to exceed the current code requirement. Low frequency vibration performance was a focus and 70mm of non-structural cementitious screed in the floor topping was included to address this.



Typical floor and wall section
Detail credit: Lend Lease

MOISTURE PROTECTION + DURABILITY

- A rain screen façade is utilized to control moisture ingress.
- Moisture in the exterior wall assembly was measured prior to sealing building.
- Moisture detector sensor rods are strategically located within the CLT panels to monitor façade performance.
- Termite risk is mitigated with concrete structure at ground floor level, a proprietary termite barrier (Termimesh) installed between the concrete structure and timber and a regular inspection regime at various access points.

SERVICES INTEGRATION

- Plumbing penetrations and rough-in for mechanical and electrical components were completed during prefabrication at the factory.
- Bathroom pods were completely prefabricated and installed as modular components.

Angled steel connection plates and screws.
Photo credit: Lend Lease

CHALLENGES

- Changing process and mind-set from typical planning, design and construction methodology.
- Using a new structural system.
- Undertaking significant analysis and effort to demonstrate how the design solutions applied within the Australian building code framework.
- Resolving details to the highest extent possible, as early as possible.

Completed bathroom.
Photo credit: Lend Lease

SUCCESSES

- A high level of precision was achieved while maintaining design flexibility and opportunity for customization.
- 1,451 tonnes of carbon saved through use of mass timber.
- Data from fire testing will be applied to future projects.
- The market has responded well, all units were sold and positive feedback has been received from new homeowners.

THE AUTHORITY HAVING JURISDICTION
MELBOURNE CERTIFICATION GROUP, CITY OF MELBOURNE

RATIONALE

- Timber buildings taller than 3 storeys are not explicit in the Building Code of Australia, as such, an alternative solutions path was pursued with the appeals board at the City of Melbourne.

PROCESS

- The developer and design team engaged with the authority early to facilitate collaboration and knowledge transfer as the team explored solutions and options.
- To document the alternative solution, the City of Melbourne required only standard documentation from the design team. In addition, they requested the FPInnovation's CLT Handbook from Canada and the applicable available European codes and standards as reference documentation.
- The team completed a fire engineering assessment to demonstrate the proposal would meet the applicable performance provisions.
- Significant effort was expended to conduct fire testing on key timber elements, including the walls, floors, service penetrations, fire rated doors and lift landing doors.
- Each level was inspected multiple times to identify issues to be verified for compliance by the design engineers or corrected on-site.

CHALLENGES

- Coordinating and managing more intensive inspections than would typically be completed for a conventional project.

SUCCESSES

- Approval process successfully demonstrated that proposed construction materials met the relevant performance requirements.
- Follow-up inspections provided reassured confidence that required standard was met.
- Inspections and approvals related to CLT product, process and delivery have paved the way for future mass timber structures.

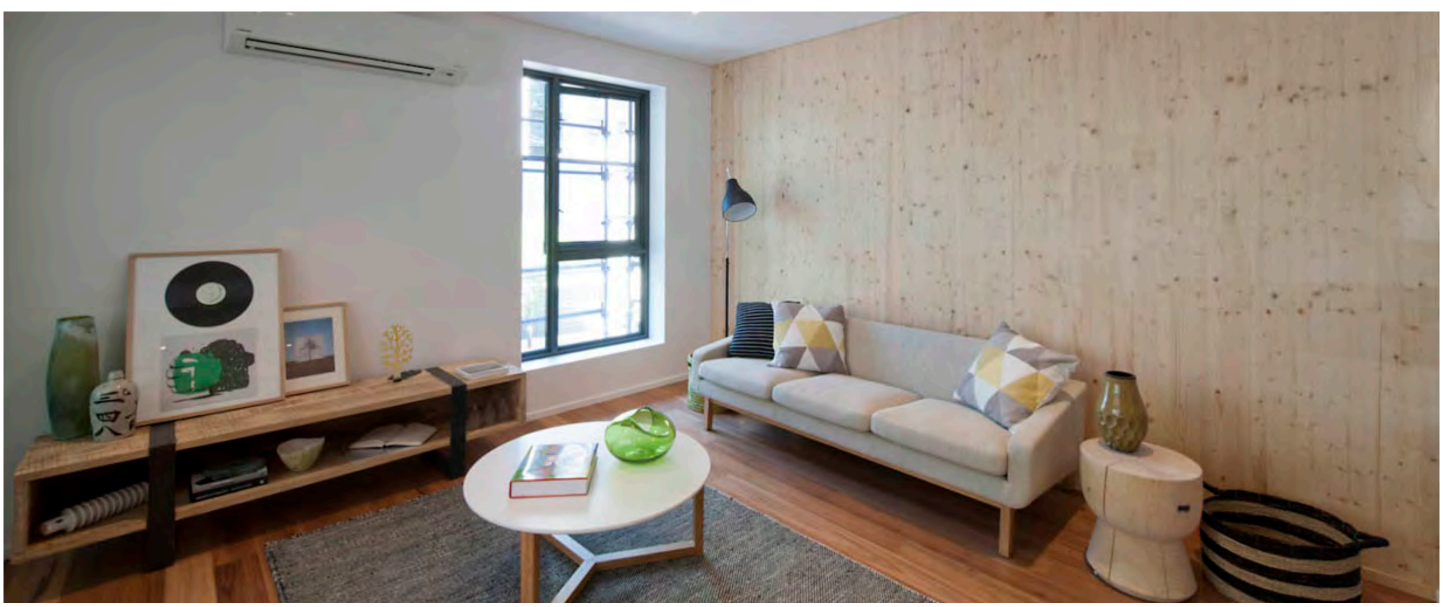


Photo credit: Lend Lease

THE CONSTRUCTION TEAM
LEND LEASE, KLH UK

RATIONALE

- A commitment to sustainable design, market leadership, and innovation.
- Assess embodied carbon and life cycle impacts associated with wood construction.
- Desire to demonstrate the reduced impact on the surrounding community during construction; timber is quicker, cleaner and quieter.
- Improve construction productivity and efficiency with a prefabricated approach.
- Advocate for new construction technology in the marketplace.

PROCESS

- Construction manager and foreman spent time in the UK to work on building sites using CLT prior to commencing Forté.
- Installation sequencing, crane calculations and logistics and delivery planning were undertaken in design phase.
- A new installation crew and erection team was formed under the direction of an experienced site supervisor from the UK who was present on-site for the initial weeks of construction.
- No special tools were used during construction except for a ratchet clamp to hold walls together during installation.
- Total construction time was 11 months which is significantly faster than the average 14 months for a similar concrete building.

Installation of CLT elevator core
Photo credit: Lend Lease

CONSTRUCTION SOLUTIONS

SYSTEMS INTEGRATION

- Speed of construction was enhanced because systems integration was considered early. Penetrations for plumbing and roughs-in for mechanical and electrical systems were completed at the factory.

MOISTURE PROTECTION + DURABILITY

- CLT panels were stored in a shed near the construction site prior to installation.
- End grain sealant was applied to the base of the wall panels.
- Polyethylene 'black sheet' was utilized to protect visually exposed panels from UV exposure.
- Moisture in the wall assembly was tested prior to sealing the building.

CHALLENGES

- Coordinating the detailed and extensive pre-planning for construction.
- Adapting to new systems and techniques of mass timber construction for the first time.
- Managing the delivery and logistics of prefabricated bathroom pod integration
- Ensuring precision and speed of installation of panels.

SUCCESSES

- Two apprentices were trained in the construction techniques required for CLT installation, developing industry capacity.
- Working with structural timber provided a high quality environment for workers on-site.
- Estimated construction time savings of 30% over a similar concrete structure.
- On-site waste was minimized.
- Installation errors were minimized given the number of prefabricated components by developing a template that enabled panels to be marked for locations.

Dust protection sheet surrounding the scaffolding.
Photo credit: Lend Lease

Photo credit: Lend Lease

Installation of prefabricated bathroom pod
Photo credit: Lend Lease

BULLETIN OF LESSONS LEARNED

UBC EARTH SCIENCES BUILDING, VANCOUVER, CANADA

This bulletin presents the lessons learned and experiences gathered from stakeholders who responded to an online questionnaire and/or participated in interviews.

OWNER/DEVELOPER
The University of British Columbia Properties Trust

DESIGN TEAM
ARCHITECT: Perkins+Will
STRUCTURAL ENGINEER: Equilibrium Consulting Inc.

AUTHORITY HAVING JURISDICTION
UBC Campus + Community Planning

CONSTRUCTION TEAM
GENERAL CONTRACTOR: Bird Construction TIMBER FABRICATOR: Structurlam, Weyerhaeuser Corp. TIMBER ERECTOR: Nicola Logworks


Photo Credit: Martin Tessler

The Earth Sciences Building (ESB) at University of British Columbia (UBC) houses multiple faculties of Science and Mathematics. The building comprises teaching, and research spaces, a wet laboratory, office spaces and three lecture theatres.

The five-storey complex is organized into two wings linked by an open-concept atrium with a free-floating, cantilevered, glulam-composite staircase. The north office-classroom wing and the atrium use wood as the primary structural material. The structure of the office-classroom wing comprises glulam columns and beams, and a hybrid floor system of laminated strand lumber (LSL), polystyrene insulation and concrete topping; the roof of the north wing and atrium are constructed with cross laminated timber (CLT). The south wing accommodates the laboratories and is a concrete structure complete with a CLT canopy.

The use of glulam beam and columns in a 5 storey building, the hybrid wood composite floor panels, significant CLT elements and an elegant cantilevered glulam staircase make ESB a unique project in Canada, effectively raising the bar for the use of wood in large-scale, high performance buildings.

PROJECT VITALS

LOCATION: 2207 Main Mall, University of British Columbia, Vancouver, V6T 124 British Columbia, Canada
COMPLETION DATE: August 2012
OCCUPANCY TYPE: Institutional
CONSTRUCTION COST: \$3,672/m^2 CAD
TOTAL FLOOR AREA: 15,794m^2
NUMBER OF LEVELS: 5
HEIGHT ABOVE GRADE: 22.1m

TECHNICAL RESOURCES + LINKS

Technical details of the building systems can be accessed through the following resources:

Canadian Wood Council. (June 2012) Innovating with Wood: A Case Study Showcasing Four Demonstration Projects, 3-13 *http://www.cwc.ca/documents/case_studies/Four%20demonstration%20Case%20Study_May_30.pdf*

Naturally Wood. (June 2012) Mass Timber and Wood Framing, New and Traditional Approaches Reduce Cost and Meet Code for Mid-Rise Construction, Case Study 5, 6-9 *http://continuingeducation.construction.com/crs.php?L=324&C=946*

Karsh, Eric. (April 2013) Building the Earth Sciences Building at the University of British Columbia. *http://www.kenilworth.com/publications/cc/de/201304/files/8.html*

TECHNICAL SUMMARY (NORTH WING & ATRIUM)

STRUCTURE

- Engineered wood and hybrid wood elements with typical and proprietary embedded connectors.
- Glulam columns and beams; a Holz-Beton-Verbund™ (HBV) composite floor system (89mm LSL panels, 25mm polystyrene insulation and 100mm lightly reinforced concrete); cross laminated timber (CLT) roof panels and canopies.
- Special long-span, composite wood-steel trusses at one level.
- Glulam chevron braces with steel connectors, and a concrete elevator core.

SYSTEMS INTEGRATION

- Electrical conduit for power and other services embedded within the insulation layer of the composite floor assembly and surface mounted on ceilings.
- Hydronic heating pipes embedded in concrete topping of the floor system.
- Recesses in glulam to accommodate sprinklers for the cantilevered stair

LATERAL RESISTANCE

- Seismic Force Resisting System (SFRS): concrete core and glulam chevron braced frame.

ACOUSTICS + VIBRATION

- Acoustic separation provided by the polystyrene insulation within the HBV composite floor system; vibration controlled by the mass of the composite floor system.

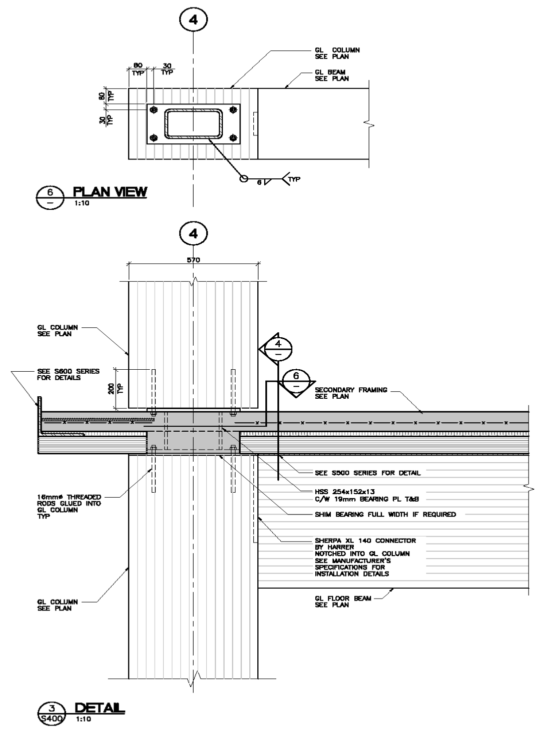
FIRE PROTECTION

- Automatic sprinkler system.
- Fire retardant applied to wood components at the exits.
- Compartmentalization of interior spaces.
- Charring of structural elements considered in design.

MOISTURE PROTECTION + DURABILITY

- Pre-installed partial roofing membrane protecting CLT roof panels during construction.
- Sealers and stains applied to exposed wood in the factory and onsite.
- Polystyrene insulation layer protecting LSL panels from moisture absorption during application of concrete topping.
- Building envelope designed to protect all interior structural wood elements.
- Exterior glulam columns on raised-bases.
- Preventive maintenance program for all exposed exterior wood elements.

Exposed view of glulam chevron braces.
Photo Credit: Equilibrium Consulting Inc.



Detail Credit: Equilibrium Consulting Inc.

LESSONS LEARNED

OWNER / DEVELOPER

- Overall project experience was successful and despite the project complexities, it was seamless, delivered on time, and is highly appealing to occupants and users.
- Implementing a difficult wood solution is worth the effort once it could be seen how the project goals and objectives were achieved.
- A construction management contract is an effective arrangement that allows for engagement by an owner/developer in the all phases of the project and for a good level of project control.

DESIGN TEAM

- The decision to use wood should be made early in the design development process to optimize and integrate systems, materials and services and to avoid delays in design and construction schedules.
- An estimated additional 15% more effort was required by the structural engineer to resolve issues that typically do not fall within the engineering scope; issues include vibration, sound transmission and fire engineering.
- Designing for prefabrication is only effective when construction implications are fully understood by the design and construction team and fully embraced by subcontractors and trades.
- In order to better accommodate mechanical and electrical services attached to exposed wood surfaces, alternate service zones or chases need to be considered.

AUTHORITY HAVING JURISDICTION

- In order to propose appropriate options for occupancy, egress and fire protection, requesting building specifics from the owner/developer and the design team is important.
- In order to identify the necessary fire-fighting requirements, construction safety plans and fire-fighting capabilities, including on-site installations such as standpipes and security cameras, need to be clearly understood.
- An inspection schedule that takes into account the key construction sequences and tasks for innovative alternative solutions should be developed to coordinate field reviews with the design consultants and the construction team.
- Information developed collaboratively between the design team and the peer reviewers in addition to any required testing results would increase the comfort of the authority having jurisdiction regarding the use of wood in large and complex structures designed with alternative solutions.

CONSTRUCTION TEAM

- A crew trained in heavy-timber erection is crucial to successful project delivery.
- Coordination of the scheduling and operation of the crane with all other trades is essential to capture the advantage of schedule savings offered by building with large, prefabricated timber components.
- The construction schedule must be carefully planned to avoid moisture related damage to timber elements from long-term exposure to inclement weather.
- If practical, coatings on exposed wood members should be applied after installation.
- There are limitations to where glulam beams can be penetrated to accommodate services.

Photo Credit: Martin Tessler

THE OWNER / DEVELOPER

UNIVERSITY OF BRITISH COLUMBIA (UBC) PROPERTIES TRUST

UBC Properties Trust is a private company owned by the University of British Columbia. It is responsible for the acquisition, development and management of real estate on the UBC campus. As such, UBC Properties Trust acted as the Owner and oversaw the development and construction processes for the Earth Sciences Building.

RATIONALE

- Desire to create a space for various complementary science disciplines to collaborate.
- Demonstrate UBC's commitment to its Mission statement and its Living Laboratory concept by showcasing innovation in wood construction technology.
- Contribute to institutional sustainability goals to reduce carbon emissions by specifying and utilizing sustainably harvested, locally manufactured wood products.
- Opportunity to align the project with the Wood First Policy of the province of British Columbia.
- Capture an opportunity presented by the Government of Canada Economic Action Plan through the Natural Resources Canada (NRCan) Wood Demonstration Project Initiative, a program supporting the Canadian wood industry.
- Create research partnerships with existing organizations on campus such as the Faculty of Forestry Centre for Advanced Wood Processing and FPInnovations.
- Advance the application of mass timber technologies in Canada.

PROCESS

- Standard design team selection process (Expression of Interest, Request for Proposal, interview, fee proposal, and competitive bid process).
- Design team members selected based on timber and institutional project experience.
- Financed by the University of British Columbia, with funding grants from the federal and provincial government programs and private donors.

Photo Credit: Martin Tessler

PROCESS CONTINUED

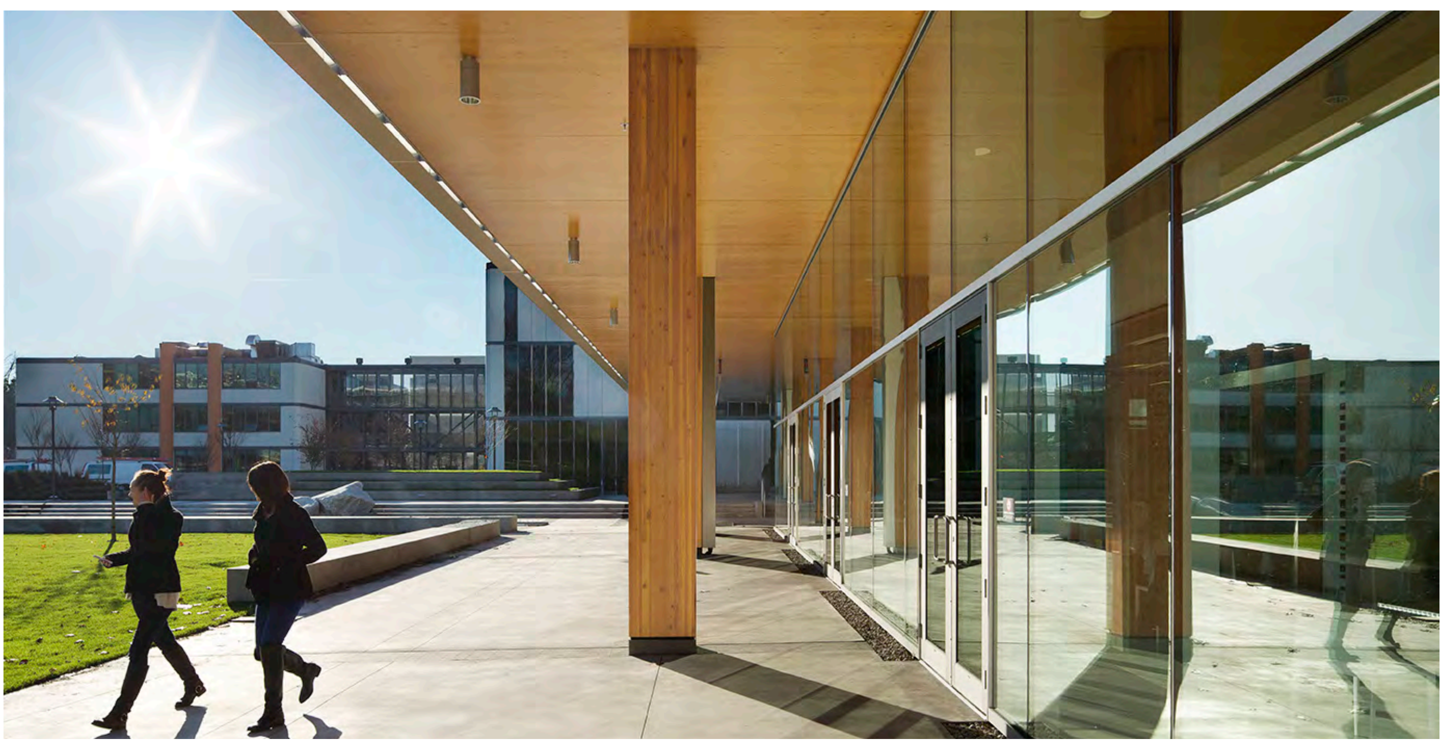
- Higher cost initially estimated by the project construction manager for the wood north wing, compared to the concrete south wing.
- Estimated incremental construction cost for the north wing covered by the NRCan Wood Demonstration Project Initiative.
- The owner's need to cover the estimated incremental cost and the owner's need to increase the project contingency in order to mitigate any risk associated with the innovative aspects of project delivery satisfied by the incentive funding.
- Full-scale HBV panel system tests performed by FPInnovations in cooperation with the design team and the peer reviewers to confirm predicted design performances.
- Wrapping the building for weather protection explored but not undertaken because of the high estimated cost.
- Course of Construction insurance cost same as that for light wood-frame buildings (about 2.5 times the costs of the same insurance for a 'non-combustible' building).

CHALLENGES

- Maintaining the project design and construction schedule to meet the occupancy date due to lack of clarity on availability of and delivery times of CLT components, unknown performance characteristics of LSL in large component construction and possible delays in accessing qualified erection expertise.

SUCCESSES

- Project completion on time.
- Project objectives and target budgets met.
- Complex yet manageable design development, approval process, and construction.
- Confidence gained to pursue more complex wood structures.



South Wing Canopy
Photo Credit: Martin Tessler

THE DESIGN TEAM
PERKINS+WILL, EQUILIBRIUM CONSULTING INC.

RATIONALE

- Desire to innovate, use new technologies, and demonstrate leadership in high quality structural wood construction by addressing and eliminating typical performance and operational concerns such as vibration, noise transfer and load capacity for structural spans.
- Contribute to complementary institutional sustainability goals of using local materials with low embodied energy, and reduce the carbon footprint of the building.
- Expose wood throughout the interior to reflect a warm but modern aesthetic.
- Reflect the building program of earth systems research by using timber, a natural, and renewable material.
- Stimulate a local market for solid wood panel construction.
- Access available Federal and Provincial funding incentives to encourage all of the above.

DESIGN PROCESS

- In order to explore the possibility of a structural wood solution but adhere to the project schedule, two designs were carried forward in parallel: one for structural concrete for both the north and south wings, and one for concrete on the south only, with timber structure for the north wing.
- A funding application for the NRCan Wood Demonstration Project Initiative was made and an incentive was secured and a portion was applied towards additional efforts required to support the design and construction process.
- The final wood solution incorporating the LSL panels and glulam elements was resolved approximately five months into the design process when physical testing and peer review verified the innovative wood aspects of the design.
- The design team used 3D modeling software, Revit, as the main design tool.
- A Building Code Alternative Solution compliance path was followed, rather than adhering to the prescriptive requirements of the local building code to gain approval of wood as the main structural element.

Detail Credit: Equilibrium Consulting Inc.

DESIGN SOLUTIONS

STRUCTURE

- LSL panels were specified for the floors because a local supply of CLT could not be confirmed within the design schedule. CLT was used for roof panels and canopies only. Consideration was given to wood-concrete composite with CLT and other panel products, as well as CLT with non-composite concrete topping.
- Three full size panel samples were tested at FPInnovations laboratory at UBC, as the composite system had never been used before with LSL panels.
- The design team reached out to access expertise where available and appropriate.
- The structural team developed a new, unique approach for chevron braces.
- A solid timber, free-floating cantilevered staircase employs the Holz-Stahl-Komposit-System (HSK-System)™, a rigid composite of wood with glued-in steel HSK-connectors.

SYSTEMS INTEGRATION

- Limited options for beam penetrations required some electrical conduit to be installed through the insulation layer for a concealed effect.
- Notching was provided in the timber stair to recess automatic sprinkler piping and power lines within the wood.

ACOUSTICS + VIBRATION

- Ambient Vibration Testing (AVT) testing was performed to confirm analytical results. Results demonstrated favorable design performance.
- Extensive structural, economic and feasibility research was done on the HBV-System to ensure it met the project's rigorous performance requirements. This solution was selected because it met the vibration performance, and is 50% lighter than a solid concrete floor structure.

FIRE PROTECTION

- Compartmentalized design of the building limits the risk of flame spread.
- The structural team raised discussions about fire code early given fire protection strategies are not typically part of the structural discipline scope.
- Structural elements were dimensioned to resist the prescribed post-fire gravity loads with a section reduced by the required one hour of char.
- Some metal components of the timber connections were concealed within the glulam columns and beams, and the exposed components were protected with intumescent coating to ensure sustained load transfer during a fire.

MOISTURE PROTECTION + DURABILITY

- All timber is either on the interior, or protected from direct rain and sun exposure within a 3m canopy overhang. Panel edges are fully flashed around the canopy. Exterior columns bases are raised 100mm off grade, and set back from the canopy edge.

STRUCTURAL CONNECTIONS

- The tops of interior columns are slotted to allow for the beams to run continuously. Beams terminate at inside face of exterior columns. Columns at the atrium are continuous from foundation to roof to minimize cumulative shrinkage.

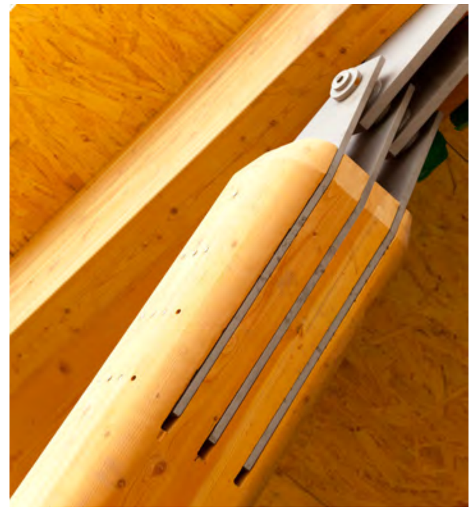


Photo Credit: K. K. Law

Lifting of CLT panel.
Photo Credit: Nicola Logworks

Composite floor panel used for testing.
Photo Credit: Equilibrium Consulting Inc.

CHALLENGES

- Coming to the design solutions for acoustics and vibration was challenging given these are not typically responsibilities associated with structural engineering scope. At the time of design, there was no testing available in North America for vibration and acoustics of concrete composite flooring.
- Integration and layout of mechanical services in the office wing due to dropped beams and exposed structure.
- Increased effort was required during construction administration and shop drawing review due to complexity of shop drawings.

SUCCESSES

- Extensive effort associated with exposing wood on the interior was a clear success for the design team; it offers a sense of warmth and complements the urban surrounding and regional character.
- ESB serves as a benchmark for other buildings to demonstrate that timber structures can perform as well or better than conventional concrete/steel structures.
- Unique approaches for vibration, sound transfer and complex bracing were developed by the team – the opportunity to design and test new solutions and innovate was exceptional.

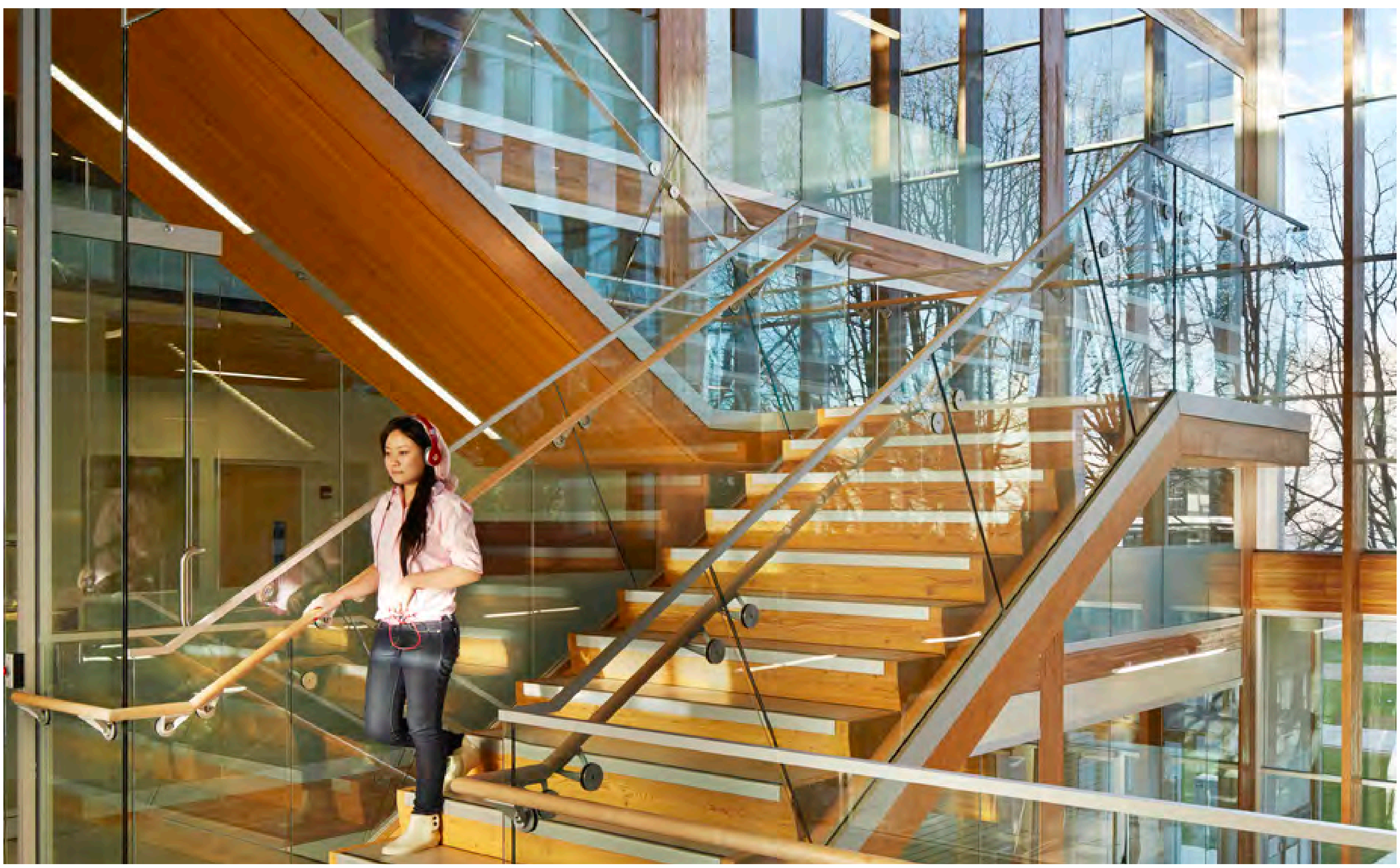


Photo Credit: Martin Tessler

THE AUTHORITY HAVING JURISDICTION

UBC CAMPUS + COMMUNITY PLANNING

UBC Campus + Community Planning is the department that oversees the long-term planning, land-use regulations, licensing and permitting, and other programs related to building programs on campus. As the Authority Having Jurisdiction, it oversaw the approval process for the Earth Sciences Building at UBC.

RATIONALE

- Ensure safe buildings while supporting the University`s pursuit of innovation, carbon reduction goals and Living Laboratory objectives.

PROCESS

- The Alternative Solution compliance path within the building code was required for the project when the wood structural option was proposed:
  - extensive engineering assessment, testing and documentation
  - peer reviews by third-party structural consultant and code consultant with expertise in fire engineering
  - coordinated and collaborative inspection and on-site resolution processes between the design team, the third-party consultants and the construction team

CHALLENGES

- A lack of wood manufacturing industry testing and documented results in the local jurisdiction for fire as well as for vibration and acoustics.
- Reliance of alternative solutions on knowledge and consensus of registered professionals to achieve the optimum and compliant design presenting the best available solution.

SUCCESSES

- A smooth and effective process created by regular monthly meetings between the design team, the third-party code consultants, the construction team, and the campus authority provided an objective opinion of the design.

Photo Credit: Martin Tessler

THE CONSTRUCTION TEAM

BIRD CONSTRUCTION, STRUCTURLAM WOOD PRODUCTS, NICOLA LOGWORKS, WEYERHAEUSER CORP.

Bird Construction was the lead contractor for the project under a construction management contract. Structurlam was subcontracted by Bird to supply and install glulam beams and columns, CLT panels and the prefabricated glulam stairs components. Weyerhaeuser supplied the LSL panels. Nicola Logworks was subcontracted by Structurlam as a specialist to oversee the erection of the timber structural components and the cantilevered staircase.

RATIONALE

- Enter into an negotiated construction management agreement with owner-developer.
- Gain experience building with mass timber products through an alternative solution compliance path.

PROCESS

- Significant amount of time and effort was dedicated to pre-planning.
- Erection was scheduled during late spring and summer months to minimize weather impacts on wood components.
- Construction delays minimized and construction administration improved when an experienced timber erection specialist was engaged to work in parallel with the installation crew.
- Limited prefabrication of structural wood elements at Structurlam:
  - Perforated steel fins for the HBV connections between the beams and the composite floor system were attached.
  - Perforated steel fins for the HSK stair connection were attached.
  - A roof membrane vapour barrier was applied to a part of the CLT roof panels.

Photo Credit: K. K. Law

CONSTRUCTION SOLUTIONS

STRUCTURE

- Atypical bracing, scaffolding and crane-time required.
- Normal construction sequence reversed.
  - Bracing of the LSL panels to support the loads resulting from pouring of the concrete topping; pouring of concrete incorporating rough-ins started at the highest floor level, moving down to the lowest suspended floor.
- Specialized rigging and slings to minimize potential damage to the wood members during handling.
- Heavy-timber erection and installation tools required.
- To manage the variation in tolerances between the concrete, steel and wood elements, bi-weekly meetings held with the wood supplier, installer, structural steel contractor (connections) and forming contractor.
- Close attention to detail required for HBV connectors to the LSL panels and glulam beams and the pre-installed HSK connectors for the cantilevered stair.

SYSTEMS INTEGRATION

- Although there are limitations to where beams can be penetrated, it was generally easy to conceal systems even where structure was exposed.
- Suspended wood ceilings were added in some areas where services were unsightly.
- Electrical conduit for lighting and power was installed within the insulation layer of the floor assembly.

MOISTURE PROTECTION + DURABILITY

- Glulam beams and CLT panels shipped wrapped and stored outdoors, off the ground.
- Pre-applied vapour barrier to the CLT roof panels.
- Tarping of the opening in the roof above the atrium as required.
- Concrete topping for all floors poured after the roof and its substrate were installed.
- Refinishing of select wood members from exposure to weather during construction.

Significant scaffolding required on site.
Photo Credit: K. K. Law

The ‘free-floating’ staircase connection to the landing using the Holz-Stahl- Komposit-Systeme (HSK-System)™. This system uses glue to connect the steel members to the wood.
Photo Credit: Equilibrium Consulting Inc.

Installation of HSK perforated steel connectors.
Photo Credit: Equilibrium Consulting Inc.

CHALLENGES

- Limited availability of local trades with the qualifications, skill set, and experience required to install and effectively erect and detail a complex wood structure.
- Detailing surface mounted services for aesthetics.
- Accurately squaring CLT panels without access to a computer numerical control (CNC) machine.
- Lack of clarity between trade scopes.
- Trades required more supervision during construction to avoid compromising wood structure with procedures that might be acceptable with other materials, but negatively affect wood in various ways (drilling, staining etc.).
- Selection and operation of cranes impacting site coordination and construction schedule variation of acceptable tolerance between wood, concrete and steel installations where materials connected, with trades often unaware of narrow tolerances and high level of accuracy required for timber elements.
- Attaching the perforated steel fins for the HBV system to the glulam beams in the plant.
- Slotting the glulam beams and the LSL panels and applying the adhesive correctly to accept the perforated steel fin.

SUCCESSES

- Efficient construction achieved through collaboration, motivation and positive attitudes and an effective construction management contract.
- Broad learning experience for all supervisors and trades.

Photo Credit: Equilibrium Consulting Inc.

Photo Credit: Nicola Logworks

BULLETIN OF LESSONS LEARNED

LIFECYCLE TOWER ONE, DORNBIRN, AUSTRIA

This bulletin presents the lessons learned and experiences gathered from stakeholders who responded to an online questionairre and/or participated in interviews.

OWNER/DEVELOPER
Cree GmbH, a division of the Rhomberg Group

DESIGN TEAM
ARCHITECT: Architekten Hermann Kaufmann ZT GmbH
STRUCTURAL ENGINEER: Merz Kley Partner Zt GmbH

AUTHORITY HAVING JURISDICTION
Region of Vorarlberg

CONSTRUCTION TEAM
Cree GmbH, a division of the Rhomberg Group

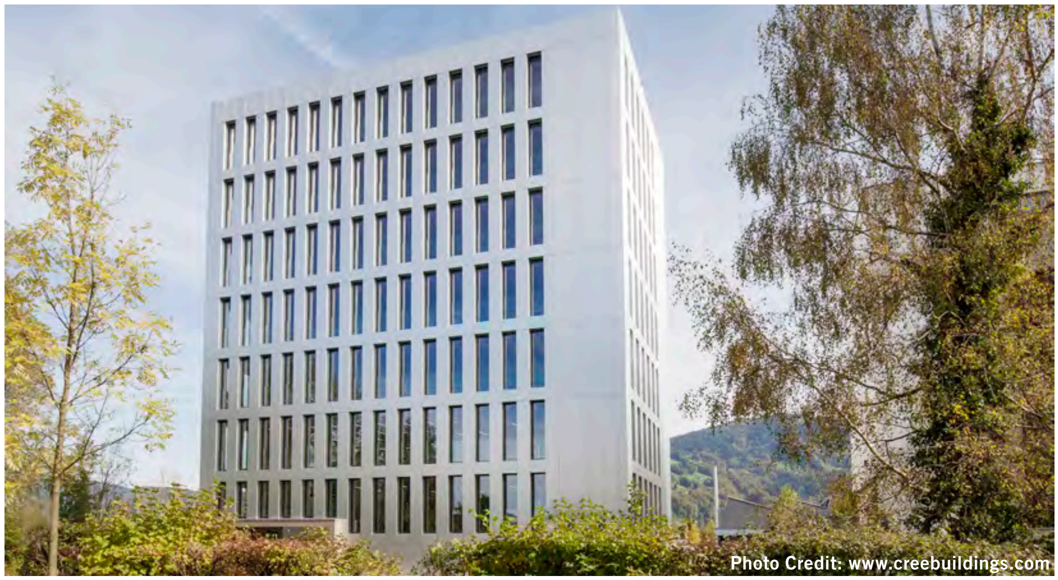


Photo Credit: www.creebuildings.com

The LifeCycle Tower ONE (LCT ONE) is an 8 storey commercial office tower developed by Cree GmbH. The building serves as a living educational laboratory to build industry capacity and transfer knowledge about the benefits of mass timber building.

LCT ONE was a prototype project to develop and test a structural system using mass timber, with a systemized and prefabricated design and construction approach. This building system was conceived as modular, a kit of parts, consisting structural components (slabs, columns, façade) and of mechanical and electrical systems that can be prefabricated and arranged to suit individual requirements.

LCT ONE uses glulam wood beams as the primary building material, combined with concrete. Structurally, the system relies upon hybrid wood-concrete slabs supported by glulam posts at the building's perimeter and by the central concrete core and interior post and beam frame on the interior. The slabs span 9m, maintaining an open floor plan that can be easily customized.

The timber post/slab configuration resists earthquake and fire damage without losing strength, while reducing material weight by 30% over a concrete building of similar size. The curtain wall system was engineered to maximize R-value and reduce thermal bridging, allowing the building to meet Passive House requirements.

PROJECT VITALS

LOCATION: Färbergasse 17, 6850 Dornbirn, Austria
COMPLETION DATE: September 2012
OCCUPANCY TYPE: Commercial Office
CONSTRUCTION COST: €4.5 million (~$6.8 million CAD)
TOTAL FLOOR AREA: 1,600m²
NUMBER OF LEVELS: 8
HEIGHT ABOVE GRADE: 27m

TECHNICAL RESOURCES + LINKS

Technical details of the building systems can be accessed through the following resources:

Cree Buildings. (2013) Cree Buildings Information Brochure. *http://www.creebuildings.com/files/CreeBrochure.pdf?PHPSESSID=ea7665320e71c5f167122d5562e442fc*

Tahan, Nabih. (2012) LCT ONE: Case Study of an Eight-story Wood Office Building. *http://woodworks.org/wp-content/uploads/C-WSF-2012-NABIH-LCT-1.pdf*

LESSONS LEARNED

OWNER/DEVELOPER

- Engage the fire protection authority early in the research and design process to facilitate a positive and collaborative relationship.
- Smart, passive energy strategies require less building services installations.
- Choose a prefabricated concrete core, rather than cast-in-place concrete, to avoid losing the schedule gains offered by the other prefabricated components.

DESIGN TEAM

- Access industry resources and develop relationships early in the project to ensure an effective integrated design process.
- Specify precast concrete core elements instead of cast-in-place concrete to gain the advantage of precision and schedule.
- Simple design concepts support a high quality, modular approach.
- Prefabrication is key to a structurally pre-defined solution and minimizing complex design details being realized on site.
- Fire testing informed a simplified approach for demonstrating the fire-integrity of the LCT system in future projects.
- Collaboration between the design team and the fire authority was central to obtaining approval for the building.

AUTHORITY HAVING JURISDICTION

- Work directly with the design team to resolve fire protection in collaboration.

CONSTRUCTION TEAM

- Encourage a collaborative and integrated design process early in the project.
- Select a prefabricated concrete core instead of cast-in-place to align speed of concrete installation with speed of timber erection.
- Confirm a strategy for coordinating trade sequencing to minimize damage to work previously completed, and maintain site cleanliness as the project progresses.
- Communicate effectively between disciplines to assess and select suppliers that are committed to quality, innovation and understand the prefabricated approach.

Photo Credit: www.creebuildings.com

THE OWNER / DEVELOPER

CREE GMBH (RHOMBERG GROUP)

Cree GmbH, a division of the Rhomberg Group, was responsible for the design, development and construction of LCT ONE.

RATIONALE

- Prove a business case for the use of mass timber products in construction.
- Develop a flexible, prefabricated construction system as a new, independent product compliant with technical and economic requirements of modern real estate markets and adaptable to international requirements.
- Demonstrate the combined effectiveness of Passive House technologies and mass timber.
- Gain a competitive advantage over conventional concrete and steel buildings in anticipation of a future carbon tax.
- Realize systematic improvement of resource and energy efficiency, and reduction of embodied energy and carbon emissions associated with new construction, thereby proving a case for environmentally sound buildings, based upon the following research conclusions:
    - Compared to a reinforced concrete building, tall high-performance timber buildings can reduce Carbon emissions and shorten construction times significantly.
    - When considering the embodied energy to produce wood, as well as the “end of life” potential to generate energy from the wood, a timber building would use 39% fewer resources during its lifetime.
- Test and develop a prototype building.

PROCESS

- LCT ONE was self-financed by the Rhomberg Group.
- Additional incentive funding of 400,000 Euros (~$640,000 CAD) was secured from The Austrian Research Promotion Agency (FFG) to support additional research requirements.

Photo Credit: www.creebuildings.com

- Joint research, focused on life cycle assessment and performance, was undertaken through collaboration with Cree's parent company (Rhomberg Bau), the Berlin office of the global engineering firm Arup, and renowned Austrian architect Hermann Kaufmann.
- A mock-up was built to test structural integrity to help overcome any preconceived risks associated with the mass timber solution.
- Design was informed and fire protection concerns were addressed early by working closely with the fire authority and conducting several fire tests in a full-size fire chamber.

CHALLENGES

- Justifying project financing given that timber represents slightly higher costs over concrete/steel structures.
- Investing additional time to research and secure funding streams.
- Educating product suppliers on how to work with an unfamiliar prefabricated approach, whilst maintaining a focus on precision and durability.
- Coordinating large visitor groups during installation to minimize interruption and scheduling delays.

SUCCESSES

- LCT ONE validated proof of concept for the LCT system and feasibility of mass timber buildings.
- The LCT ONE precedent demonstrated that wood buildings can safely exceed building code height requirements with innovative structural and fire protection solutions.
- Construction completed at the rate of one storey per day, confirmed the effectiveness of prefabricated tall mass timber buildings.
- International recognition and feedback from industry stakeholders has generated future business opportunities.
- Integration of the LifeCycle Hub exhibition in the building supports experiential knowledge sharing and education.

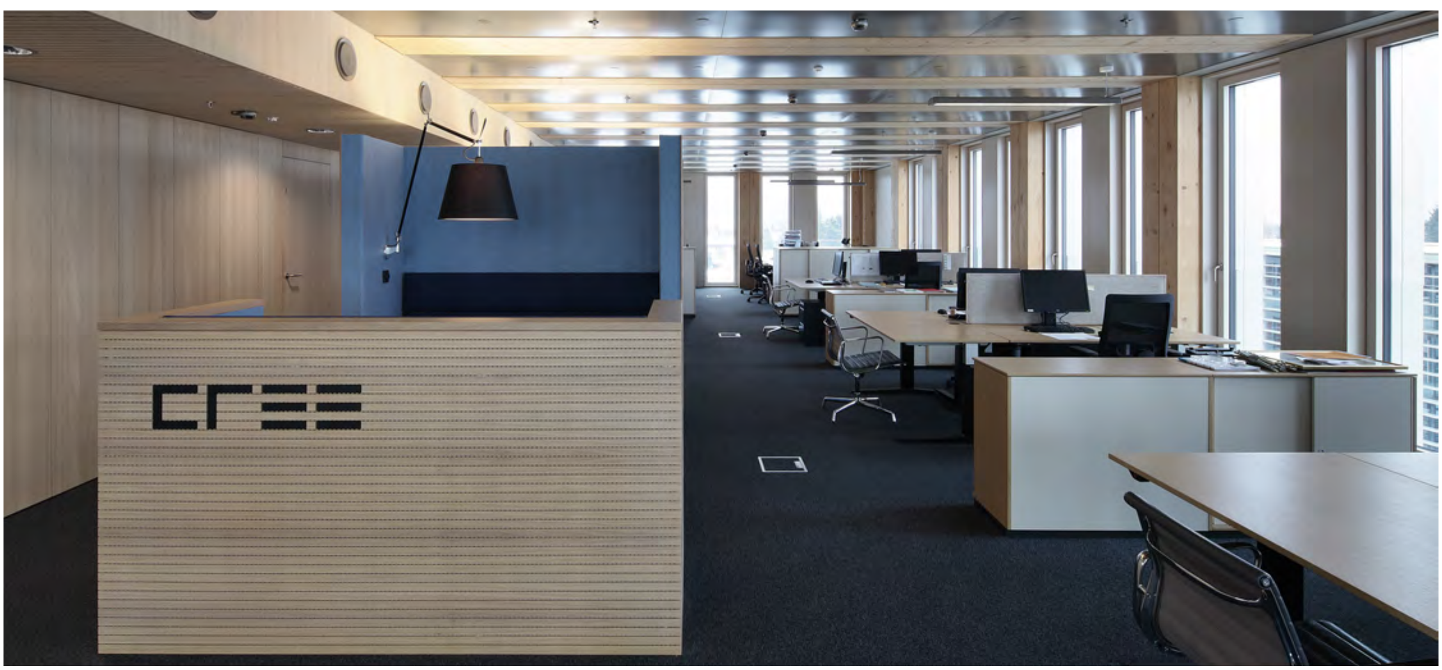


Photo Credit: www.creebuildings.com

THE DESIGN TEAM

HERMANN KAUFMANN ZT GMBH, MERZ KLEY PARTNER ZT GMBH

Hermann Kaufmann ZT GmbH completed the architectural design and Merz Kley Partner ZT GmbH were the structural engineers.

RATIONALE

- Respond to client vision for a timber solution.
- Expand the use of mass timber in tall buildings.
- Develop the existing methods of wood construction to achieve large scale precision, building capacity in the local carpentry industry.

DESIGN PROCESS

- Decision to use wood was made by the Owner, prior to design.
- Design team selection was based on their previous experience with timber design and construction.
- LCT ONE is the proof of concept for Cree's Lifecycle Tower (LCT) system developed as a research project which proposes a resource efficient, modular, 20 storey building.
- Structural design focuses on solving shrinkage issues by using a wood/concrete hybrid slab, strictly avoiding cross grain pressures.
- The structural system prioritizes simple design and straight forward engineering focused on standardization of key elements and modularity.
- The criteria for selecting technologies were based on the fastest and most replicable solutions.
- Different hybrid slab options tested included up to 20cm of concrete topping. Fire testing confirmed only 8cm could achieve the required fire rating and contribute significantly to limiting noise transfer between floors.
- Structural design effort was double that of a concrete building.
- More detailing and pre-construction planning was required as compared to conventional construction process.

Installation of prefabricated wall panels.
Photo Credit: www.creebuildings.com

DESIGN SOLUTIONS

STRUCTURE

- Concrete basement and ground floor.
- Each storey and associated technical services are accessed via one centralized concrete access core which serves as the lateral load resisting element of the building. Cast-in-place concrete was used for core construction.
- The exterior walls consist of load bearing glulam posts, and a curtain wall building envelope.
- The floor system is a hybrid wood/concrete slab approximately 9m long and 3m wide.
- Walls and floor slabs were prefabricated and brought to site for installation.
- Connections between the concrete core and hybrid slabs are made with angled steel brackets
- Mortise and tenon joints address lateral forces between the hinged columns and the hybrid slabs.
- Structural solution was developed as a kit of parts to facilitate a prefabricated, modular system which minimized complexity during construction.

FIRE PROTECTION

- Fire was perceived as the primary project risk.
- Design solutions depended heavily on results of the fire testing phase.
- The concrete core addresses the requirement for a non-combustible egress route.
- Smoke alarms wired directly to the fire department are strategically located.
- Exposed wood structure triggered the requirement for a sprinkler system, which was determined to be redundant by the authority having jurisdiction after installation. Although sprinkler infrastructure is in place, it is not connected to the water mains.
- The hybrid slabs were tested in a full-size fire chamber; initial floor slab fire tests failed, achieving only a 30 minute rating. The concrete mix was then revised and subsequent tests earned a 120 minute fire rating.
- Concrete topping on the wood panels addresses fire separation between each floor with no wood-to-wood contact.
- Timer members are oversized to provide a char layer.
- Elimination of cavities and penetrations within walls to reduce potential risk of fire spread.

ACOUSTICS + VIBRATION

- Extensive acoustical testing was done for several design scenarios.
- The concrete topping on the floor slab addresses noise transfer and vibration between floors, and testing was done with 12cm and 8cm. Tests confirmed that in combination with the wood members, 8cm of concrete topping was adequate to meet code requirements.
- Metal panels installed between the wood beams to conceal the building systems also improved the acoustics in the space.

Modular system of interlocking prefabricated components with centralized concrete access core.
Detail Credit: www.creebuildings.com

Hybrid floor slab features wood-concrete composite rib construction.
Photo Credit: www.creebuildings.com

Hybrid floor slab and double wood columns comprise the load-bearing timber structure
Detail Credit: www.creebuildings.com

MOISTURE PROTECTION + DURABILITY

- The concrete foundation in the basement and ground floor protects the timber structure from moisture.
- No structural timber elements are exposed to the exterior, all are protected within the envelope.
- Prefabricated wall elements result in a weather tight enclosure as soon as they are installed.
- Insulation and structural elements are kept separate to accommodate variations in material lifecycles: insulation can be easily replaced after 20 years, while structural components are designed to last more than 100 years.

SYSTEMS INTEGRATION

- Systems were integrated into the available ceiling spaces between each glulam beam and concealed with aluminum facing panels, eliminating the need for a deeper dropped ceiling.

CHALLENGES

- Understanding and predicting the behavior of the hybrid slab over time.
- Determining the variations in precision and tolerances between concrete and timber.
- Planning for systems integration was a challenge due to fragmented work split among several design disciplines, leading to late design changes on-site.
- Managing the extensive testing that was required to meet the acoustic requirements.

SUCCESSES

- The hybrid slab production process was improved to eliminate concrete formwork.
- Seamless integration of systems eliminated the need for dropped ceilings.
- Large floor spans and a 2.80m floor-to-ceiling height created flexibility to support many floor plans.
- Prefabrication allowed for easy customization of floor layout.
- The prefabricated modular system created pre-defined solutions which eliminated execution of complex details during construction.
- Low energy building designed to meet Passive House* requirements.
- Minimal use of concrete led to a lighter structure with up to 90% less CO2e emissions than a conventional concrete building.
- No additional architectural resources, design time or tools were required throughout the design process.
- Flexible, open floor space achieved by using concrete girders in combination with timber elements allows for easy conversion and reconfiguration, extending the building lifetime.

Angled steel brackets connect hybrid floor slabs to concrete access core.
Photo Credit: www.creebuildings.com

Angled steel brackets connect hybrid floor slabs to concrete access core.
Photo Credit: www.creebuildings.com

Systems are concealed behind aluminum panels within ceiling cavities.
www.creebuildings.com

*Passive House is a rigourous, voluntary energy performance standard for buildings, which aims to reduce the requirement for space heating and cooling, whilst also creating excellent indoor air quality and comfort levels.
www.passivehouse.ca

THE AUTHORITY HAVING JURISDICTION
REGION OF VORARLBERG

Authority representatives were not available to provide their perspectives, however the information presented here reflects feedback from other project stakeholders on the permissions and approvals process at LCT ONE.

RATIONALE

- Structural timber is not explicit in the local building code; LCT ONE required an exception to obtain approval.

PROCESS

- The process was unique in that the project team worked closely with the fire authority to research, test, and prove final concept.
- The fire authority was engaged in evaluating the fire risk associated with the hybrid system, monitoring the assembly on-site, and determining the final approval of the building.
- Extensive fire testing was required.

CHALLENGES

- Several fire tests were undertaken to determine acceptable solutions.

SUCCESSES

- Collaboration between the design team and the fire authority led to an acceptable solution.
- Quality and simplicity of building structure reduced fire risk and confirmed the level of fire safety performance for the authority having jurisdiction, consequently allowing the requirement for sprinklers to be removed.

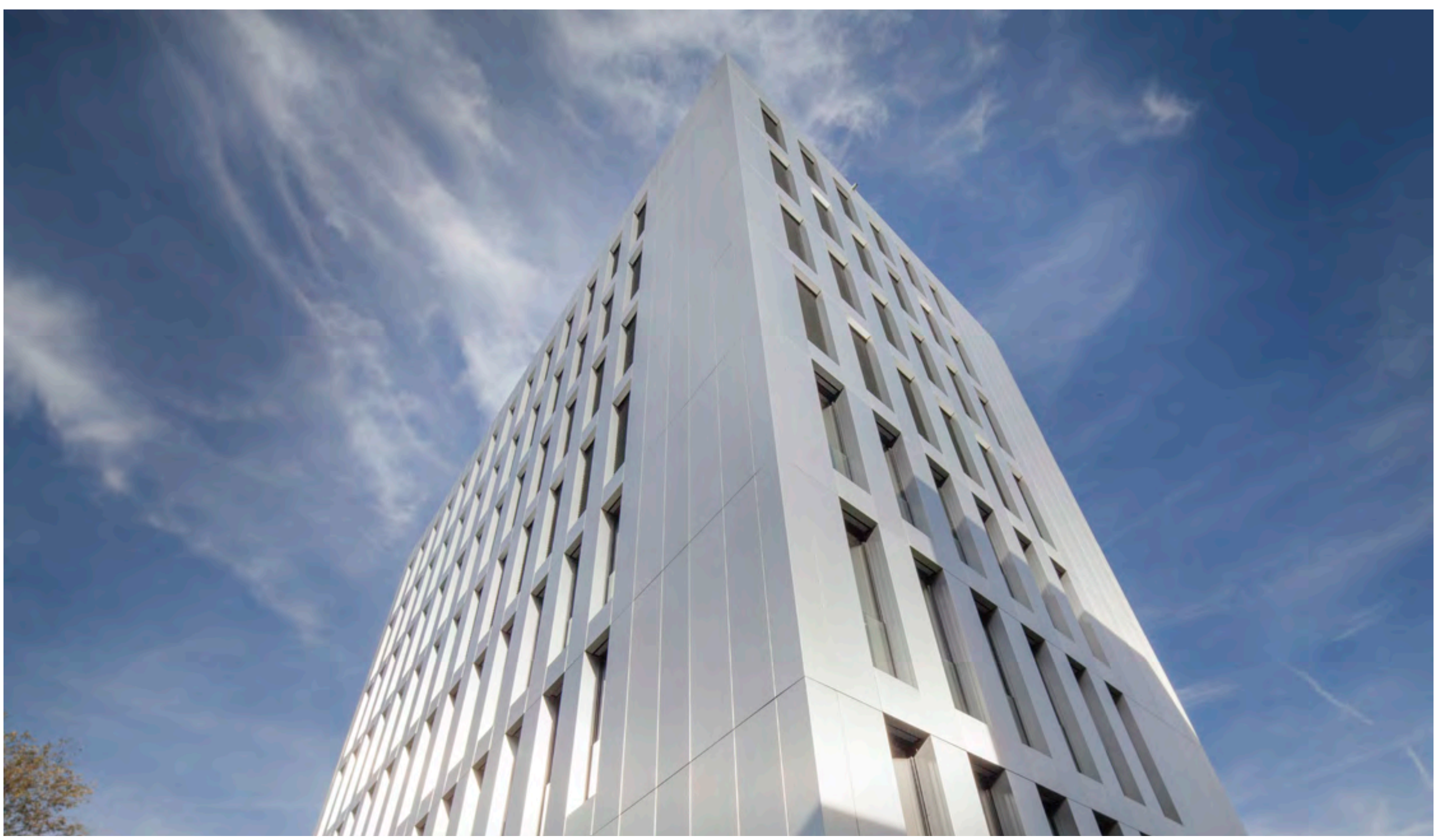


Photo Credit: www.creebuildings.com

THE CONSTRUCTION TEAM

CREE GMBH (RHOMBERG GROUP)

Cree GmbH, a division of the Rhomberg Group, managed the construction process and supplied the LCT hybrid system.

RATIONALE

- Prove a strong, profitable business case for the use of mass timber products in construction.
- Further expand expertise and develop industry capacity for mass timber projects.
- Invest and expand skilled labour for future mass timber projects.

PROCESS

- Cree provided on-site training for the crew to learn to install the prefabricated elements.
- Meticulous planning and prefabrication greatly reduced changes made during construction.
- The concrete core was cast-in-place and completed before any other building assembly.
- Total erection time for the timber elements was eight days, two days for the first level and one day for each remaining level.
- Efficient scheduling and delivery planning were essential to support successful assembly of prefabricated elements.
- Construction team and trades were regularly informed of the fabrication timelines to assist with construction phase scheduling.

Photo Credit: www.creebuildings.com

CONSTRUCTION SOLUTIONS

STRUCTURE

- Concrete core was cast-in-place, and completed before the building was assembled around it.
- The installation crew took the time to learn proper assembly techniques on the first floor; assembly of subsequent levels was much quicker.

MOISTURE PROTECTION + DURABILITY

- An emergency, temporary plywood roof was constructed which required 1.5 hours to put in place over the building footprint, and was used only once due to sustained dry weather during construction.

CHALLENGES

- Finalizing architectural, structural and mechanical details well in advance of prefabrication.
- The scheduling advantage of modular construction was reduced with the curing time required for the cast-in-place concrete core.
- Educating trades about protecting the exposed wood surfaces from physical damage and staining as they progressed through the sequence of finishing.
- Delayed procurement decisions by the owner challenged the panel fabrication timeline and construction schedule.

SUCCESSES

- Overall speed of construction was faster than a conventional building; completing at the rate of one storey per day.
- Noise and dust pollution were reduced during the construction phase.
- Prefabrication minimized errors on-site
- Local trades were trained in structural timber and modular construction techniques, increasing industry capacity.

Efficient scheduling and delivery planning were essential for a smooth construction phase.
Photo Credit: www.creebuildings.com

Installation of hybrid floor slab.
Photo Credit: www.creebuildings.com

BULLETIN OF LESSONS LEARNED

TAMEDIA HEADQUARTERS, ZURICH, SWITZERLAND

This bulletin presents the lessons learned and experiences gathered from stakeholders who responded to an online questionnaire and/or participated in interviews.

OWNER/DEVELOPER
Tamedia

DESIGN TEAM
ARCHITECT: Shigeru Ban Architects
GENERAL PLANNER AND EXECUTING ARCHITECT: IttenBrechbühl
STRUCTURAL ENGINEER: Creation Holz GmbH

AUTHORITY HAVING JURISDICTION
City of Zurich

CONSTRUCTION TEAM
GENERAL CONTRACTOR: HRS Real Estate AG
TIMBER FABRICATOR AND ERECTOR: Blumer-Lehmann

Photo Credit: Didier Boy de la Tour

The Tamedia Headquarters is an office redevelopment project at the Stauffacher media hub in Zurich. In an effort to consolidate several satellite offices, the project included renovation of an existing building, and a new addition.

The addition was designed with a unique wood structure system that makes use of 2,000 cubic meters of pre-fabricated spruce wood columns and beams precision milled to interlock without glue or joint hardware. Continuous 23 meter-tall mass timber columns extend from the ground to roof, and the structure is exposed and visible from the exterior through the glazed façade. A double skin façade along the east side of the building creates an intermediate space that spans the full height of the building. This space creates internal balconies, where circulation space is combined with lounge and meeting areas that can be opened to the exterior and passively ventilated by means of lifting airtight elements of the façade. The pure wood structural solution responds to the owner's desire for a sustainable building by drastically reducing the embodied energy associated with construction, and eliminating operational emissions through a heating and cooling system that utilizes groundwater to regulate temperature. Building operations are carbon neutral.

PROJECT VITALS

LOCATION: Werdstrasse 21, Postfach, 8021, Zurich, Switzerland
COMPLETION DATE: July 2013
OCCUPANCY TYPE: Commercial Office
TOTAL FLOOR AREA: 8,905m^2
NUMBER OF LEVELS: 6
HEIGHT ABOVE GRADE: 23m

TECHNICAL RESOURCES + LINKS

Technical details of the building systems can be accessed through the following resources:

Lalutea, Ines. (2013) Metalocus. The New Tamedia Building by Shigeru Ban. *www.metalocus.es/content/en/blog/new-tamedia-building-shigeru-ban*

Tamedia AG (2013). The New Tamedia Building. *www.tamedia.ch/en/company/tamedia/the-new-tamedia-building/*

Shigeru Ban Architects (2013). Tamedia office building. *http://www.shigerubanarchitects.com/works/2013_tamedia-office-building/index.html*

LESSONS LEARNED

OWNER/DEVELOPER

- Engage a design team that shares and respects the project aspirations.
- Engage only the best, highly skilled trades to ensure successful construction.
- Late design changes lead to extra costs where prefabricated elements are used.

DESIGN TEAM

- Use wood only when it is the most appropriate design solution.
- Choose technical experts with a shared vision and collaborative approach from the beginning.
- Collaboration between architectural and engineering teams are key to success.
- Engage timber engineers and erectors with whom you have a strong working relationship to minimize learning curve.
- Protect timber elements from the impacts of weather by enclosing within the envelope or providing canopies for exposed components.
- Use of 3D design software by the timber manufacturer is essential to detail interfaces between different materials.
- Project specific insurance is recommended when delivering a prototype project to mitigate potential risks of new design solutions.

AUTHORITY HAVING JURISDICTION

- Collaborate with the team to resolve fire protection strategies.

CONSTRUCTION TEAM

- Implement efficient communication between parties involved in the delivery process.
- Be clear with the team at the outset that extensive prefabrication demands detailed management and logistics planning.
- Design and construction solutions should aim to reduce complexity as much as possible.
- Resolve as many issues as possible in the pre-design phase.
- Pre-fabricate as many components as possible. Construction is more efficient as an assembly process.
- Allow time to focus efforts on the interface between different materials.
- Accept that timber will show some effects of construction, protecting it from every mark or stain is not practical.

Photo Credit: Didier Boy de la Tour

THE OWNER / DEVELOPER
TAMEDIA

Tamedia is a leading Swiss media group that includes daily and weekly newspapers, magazines, online platforms and a printing facility.

RATIONALE

- Desire to create a building that represents Tamedia's spirit of innovation and leadership that offers a flexible, high quality work environment.
- Commitment to use sustainable and low carbon construction materials.
- Opportunity to showcase the use of a common material applied in an unusual and creative way.
- Commitment to creating a landmark for the neighbourhood.

PROCESS

- Tamedia self-financed the project.
- A commitment to quality and detail was established at the project outset.
- The Owner ensured that cost and investment were carefully balanced with the desire for innovation.
- The Owner created an unusual contract arrangement where three direct contracts were arranged with the design architect, executing architect/general planner and general contractor, permitting a good balance of owner influence on technical details.
- A lengthy process was required to obtain approval from the City for the mass timber structure due to concerns that the aesthetic quality would not be consistent with Zurich's architectural tradition.
- A cost consultant was hired to help assess various prototype solutions.
- The structural wood solution required slightly higher insurance premiums.

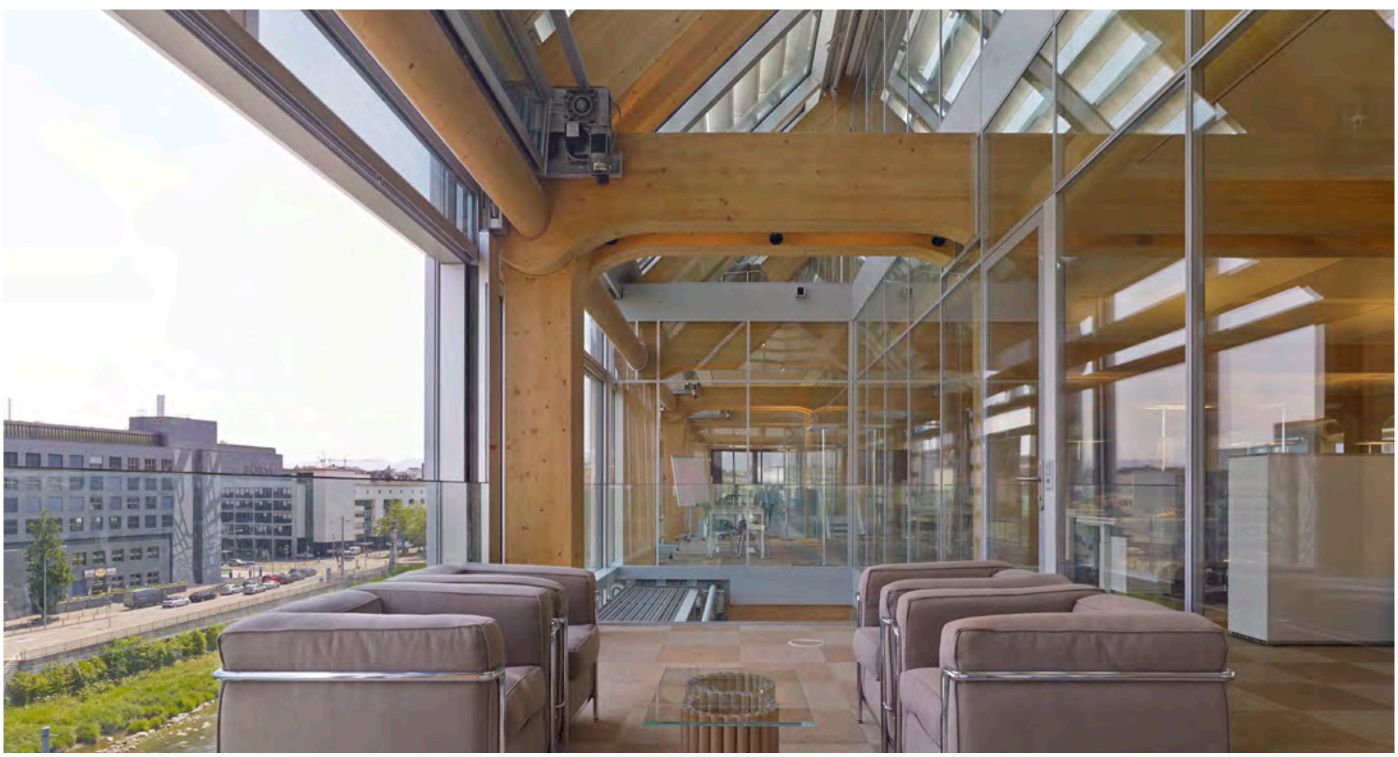


Photo Credit: Didier Boy de la Tour

CHALLENGES

- Gaining authority approval for architectural quality and fire protection was complex and lengthy.
- Managing cost was challenging given the exceptional level of detail and precision required to execute this prototype approach.
- Managing a complex project contract, where three separate direct contracts were arranged with the design architect, executing architect and general contractor.

SUCCESSES

- High quality design responded to the expectations of the Tamedia family and shareholders.
- The building has created an exceptional working environment for Tamedia employees.
- The design showcased timber in a sophisticated application.

Photo Credit: Didier Boy de la Tour

THE DESIGN TEAM

SHIGERU BAN ARCHITECTS, ITTENBRECHBÜHL, CREATION HOLZ GMBH

Shigeru Ban Architect completed the architectural design, IttenBrechbühl was the general planner and executing architect and Creation Holz GmbH was the structural engineer.

RATIONALE

- Respond to the owner's desire for an iconic office building with flexible floor area and a pleasant working environment that reflects a warm and sophisticated quality at a reasonable cost.
- Use a low carbon and natural material to respond to the owner's commitment to sustainability.
- Design a creative and iconic building that inspires building occupants and the public.
- Benefit from the highly developed timber technology and engineering capacity in Switzerland, particularly computer-controlled 3D machinery.

Photo Credit: Blumer Lehmann

DESIGN PROCESS

- A mass timber solution was presented by the design architect to the owner group for consideration, and approved. The decision to propose mass timber was based on the architect's longstanding experience designing with wood.
- A local, executing architect and general planner was engaged at the completion of conceptual design.
- The local architect was key to navigating permissions and approvals with the authority having jurisdiction. The approvals process for fire protection took 10 months, and the strategies were vetted by an independent fire protection specialist.
- A close collaboration between the owner, design team, timber manufacturer and erector, and construction contractor was established to facilitate and execute this complex project.
- 80% of the building was designed and detailed for prefabrication.
- Testing of design solutions was paramount and as conducted 6-12 months before preparing tender documents:
- A 1:1 mock-up was built to test the oval beam connections with steel as well as wood dowels.
- A smaller mock-up was used to assess aesthetic quality of wood species.
- Intensive fire testing and stiffness tests were undertaken.
- Testing for the internal glazed façade surrounding the stair was required to demonstrate a 60 minute fire rating to protect the primary timber structure.
- More than 200 detailed drawings were done to ensure accurate building assembly.
- Emphasis was placed on closely aligning engineering and systems requirements with structural design.
- No additional effort was invested by the design architect.
- The executing architect estimates 50% more effort was invested to manage the detailed design process, the collaborative effort between the two architectural disciplines, and obtaining approvals and permissions from the City.
- The executing architect carried a separate insurance policy to cover any perceived risk associated with innovative design solutions and new professional collaborations.

Photo Credit: Blumer Lehmann

DESIGN SOLUTIONS

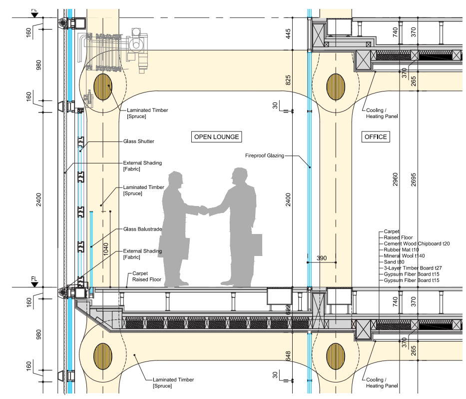
STRUCTURE

- Concrete basement, ground floor and elevator core.
- 23m long single piece glue laminated spruce columns sandwich each floor beam.
- Connections between columns and beams are accommodated by an intricate, interlocking oval node that penetrates the three elements, preventing it from rotating, and completely eliminating compression perpendicular to grain.
- Connections are pure wood and do not include glue or other mechanical connection devices.
- The exterior is fully glazed; no timber members are exposed to the exterior.

Interlocking oval pure wood connection.
Photo Credit: Shigeru Ban Architects

SYSTEMS INTEGRATION

- A raised access floor accommodates mechanical and electrical services.
- Sprinklers are installed within the floor slabs and penetrate the ceilings of the level below.
- 3500 penetrations were cut on-site to accommodate systems, requiring an exceptional level of effort and precision to execute.



Detail of raised floor and exterior glazing
Detail Credit: Shigeru Ban Architects

ACOUSTICS + VIBRATION

- Floor assembly includes a sand layer to absorb noise and vibration.
- Acoustic ceiling panels and acoustic wall paneling in multi-occupant spaces such as the cafeteria.

FIRE PROTECTION

- Fire rated glass around the stair and intermediate zone.
- Where the timber beams penetrate the fire-rated glazing in the intermediate zone, timber interfaces are notched and layered with gypsum to create a non-combustible barrier, then covered with wood veneer to maintain the aesthetic quality of the timber.
- Timber columns and beams were oversized by 40mm to provide a char layer.
- Automatic sprinkler system and smoke detectors.
- Two layers of gypsum on the underside of each floor assembly.
- Limited furnishings in the intermediate zone to reduce fire risk.

Notched interface conceals non-combustible barrier on timber beams
Detail Credit: Rebecca Holt

MOISTURE PROTECTION + DURABILITY

- Temporary movable roof was used during construction.
- Timber structure is protected by the building envelope, no structural elements are exposed to the exterior.

CHALLENGES

- Extreme level of precision and limited tolerances required to execute the interfaces between different materials, for example, where timber penetrates the internal glazing.
- Identifying and managing 3,500 complex penetrations in the slabs to accommodate systems.
- Significant increase in execution effort in order to manage complex details and disciplines.
- Obtaining authority approval for design and fire protection.
- Resolving interfaces between materials was particularly time consuming.

SUCCESSES

- Distinctive and unique aesthetic quality was achieved, clearly responding to the client's desire for a creative, warm, and sophisticated space.
- Exceptional execution of precision and high quality result.
- The local architect was successful in navigating permissions and approvals with the authority.

Photo Credit: Didier boy de la Tour

THE AUTHORITY HAVING JURISDICTION
CITY OF ZURICH

Permissions and approvals from the local Authority for building design and construction methodology required significant effort. Local design guidelines in the City of Zurich are in keeping with the historic vision for the city, maintaining continuity of building and block heights, volumes, façades and materials to reflect a distinct local characteristic and quality. The unusual aesthetic achieved by exposing the timber structure within a glazed façade required extensive discussion and negotiation between the design team and local authority, some design compromises were made, and final approval for the timber structure was based on reduced height, preserving solar access for adjacent buildings and a roof line that reflects the city's vernacular.

The fire protection strategy was approved as a unique exception to the local code. Significant testing was required to demonstrate the proposed strategies provided a minimum 60 minute fire rating, and a collaborative relationship between the executing architect, building owner and fire authority was essential to developing the final solution. Several revisions to the design were required to meet fire protection requirements, representing about 20% additional effort for the design team.

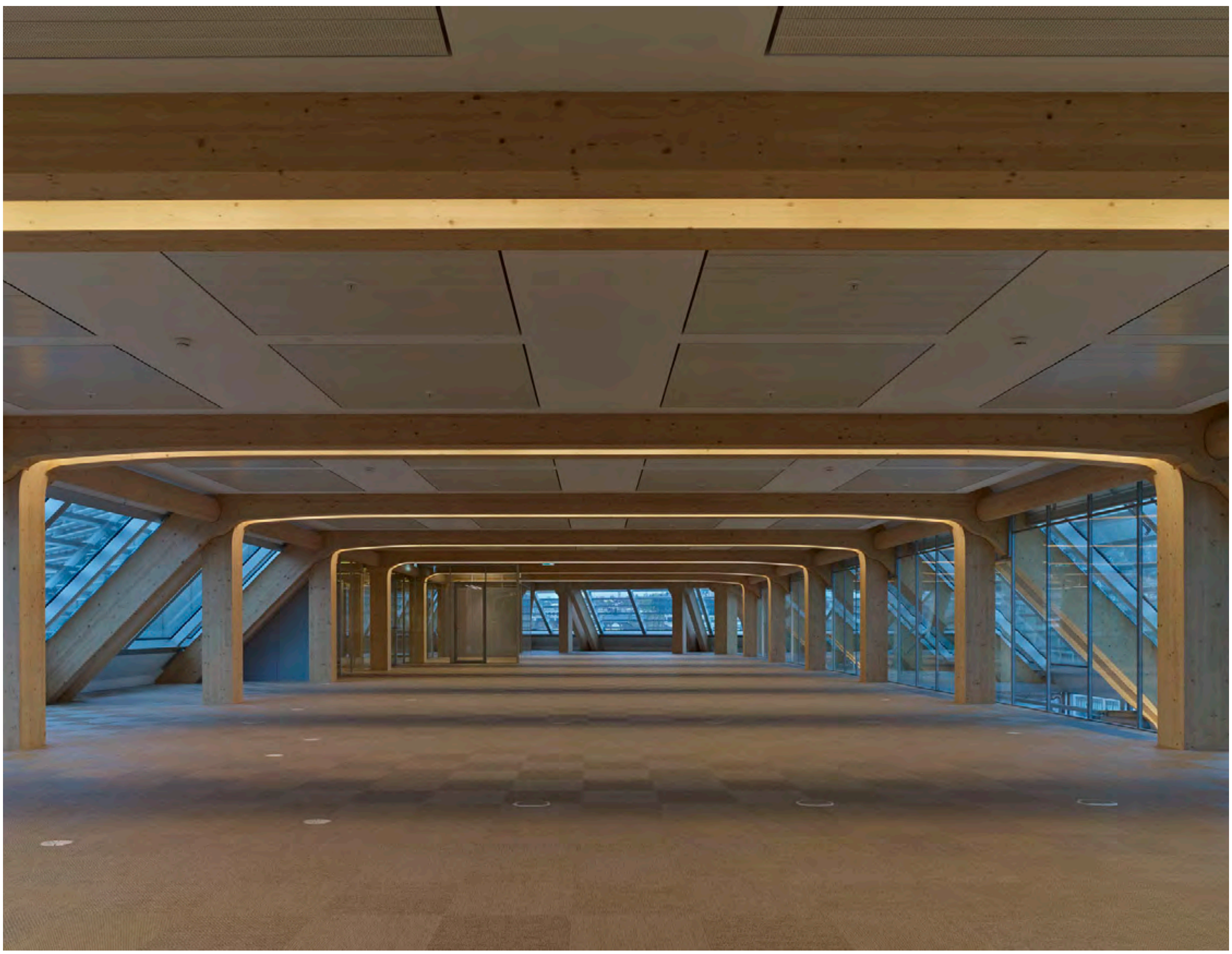


Photo Credit: Blumer Lehmann

THE CONSTRUCTION TEAM

HRS REAL ESTATE AG, BLUMER-LEHMANN

HRS Real Estate AG acted as the General Contractor and Blumer Lehmann fabricated and assembled the wood structure.

RATIONALE

- Collaborate on a leading, prototype mass timber project.
- Opportunity to innovate and demonstrate potential of mass timber in commercial applications in Switzerland.
- Commitment to low carbon, sustainable construction materials.

PROCESS

- The construction team collaborated closely with the design team to execute extensive detailing required for prefabricated elements.
- The construction contractor worked with the timber engineer to finalize design concepts for the building.
- A 1:1 mockup of the post and beam connection was built to test dimensions and assembly process.
- All timber components were prefabricated, only the concrete elevator core and foundation were constructed on-site (cast-in-place).
- Concrete curing process for the elevator core and foundation was the most time intensive part of construction.
- The level of precision demanded by the design could only be achieved through prefabrication, using 3D modeling and precision, computer controlled cutting equipment.
- Erection of the timber structure took six months, and was assembled one bay at a time, beginning from the back of the addition at the connection to the existing building.
- The installation of the envelope was started after the entire timber structure was complete.

Photo Credit: Blumer Lehmann

CONSTRUCTION SOLUTIONS

STRUCTURE

- 3D modeling software used to support precision timber cutting.

SYSTEMS INTEGRATION

- Locations for all 3,500 systems penetrations were identified on all timber elements during fabrication, and cut on-site to maintain some flexibility of location during installation.

MOISTURE PROTECTION + DURABILITY

- Timber members were stored in a warehouse in advance of delivery to site for immediate installation.
- A temporary roof was used during assembly to cover completed blocks before the envelope was installed.
- A screen was used to reduce the intensity of rain and wind along the façade of the structure, but did not completely sheltered it from the weather.

CHALLENGES

- Reconciling varied tolerances between materials.
- Sequencing and management of trades.
- Cutting a significant number of penetrations on-site for services integration in the wood structure.
- Mitigating unwanted weathering of the exposed timber during construction.
- Investing additional effort using 3D design software and timber cutting technology.
- Coordinating a large volume of change orders during construction, significantly increasing complexity of assembly.
- Organizing process, logistics and sequencing of assembly given a portion of the work involved an addition and renovation to an occupied building.
- Managing owner expectations during the construction process.

SUCCESSES

- Collaboration between the architecture, engineering and project delivery teams.
- A high quality of construction in a very complex and unique context was achieved, representative of Swiss expectation for value, quality and durability.
- Successfully exposing the mass timber structure in an office typology, making the innovative design visible from the interior and exterior.

Temporary roof over timber structure
Photo Credit: Shigeru Architects

Photo Credit: Shigeru Ban Architects

Photo Credit: Didier boy de la Tour

Forestry Innovation Investment

BSLC

BULLETIN OF LESSONS LEARNED

CENNI DI CAMBIAMENTO, MILAN, ITALY

This bulletin presents the lessons learned and experiences gathered from stakeholders who responded to an online questionnaire and/or participated in interviews.

OWNER/DEVELOPER
Polaris Real Estate SGR SpA

DESIGN TEAM
ARCHITECT: ROSSIPRODI ASSOCIATI Srl.
STRUCTURAL ENGINEER: Borlini & Zanini SA

AUTHORITY HAVING JURISDICTION
Ministry of Infrastructure and Transport

CONSTRUCTION TEAM
GENERAL CONTRACTOR: Carron TIMBER SUPPLIER: MakHolz TIMBER FABRICATOR: StoraEnso TIMBER ERECTOR: Service Legno


Photo Credit: Riccardo Ronchi

Cenni di cambiamento is a social housing apartment complex with four 9-storey towers and 2-storey connector buildings between towers. The complex contains 124 units, common amenity and social spaces, gardens and some commercial office and retail units to accommodate social services.

All buildings in the complex are timber structure using cross laminated timber (CLT) for floors, walls, elevator cores, stair cores and balconies. Two complex connection systems are employed at the joints of the CLT panels to ensure seismic stability.

The complex offers high quality housing to low-income families within three lease options including a lease-to-own option resulting in ownership after only 8 years. It is currently the largest completed residential project in Europe constructed with a mass timber structure and was the catalyst for a revised approvals process in Italy that now allows structural timber solutions for new construction over 3 storeys.

PROJECT VITALS

LOCATION: 15 - 17 Via Gabetti, Milan, Italy
COMPLETION DATE: November 2013
OCCUPANCY TYPE: Commercial / Residential
CONSTRUCTION COST: €1,000/m² (~ $1,525/m² CAD)
TOTAL FLOOR AREA: 17,000 m² gross built floor area
NUMBER OF LEVELS: 9

TECHNICAL RESOURCES + LINKS

Technical details of the building systems can be accessed through the following resources:

Bernasconi, Andrea. (June 2012) Timber construction in the city of Milan - 4 residential buildings with 9 storey. http://www.traeblog.dk/wp-content/uploads/2012/07/Via-Cenni.pdf

Rossi Prodi, Fabrizio. (2012) Abitare Sociale. Peasaggio Urbano, 5-6 bis.2012, pg 20-39 http://www.periodicimaggioli.it/promo/2013/paesaggio-urbano/index.htm

LESSONS LEARNED

OWNER/DEVELOPER

- Work with an experienced design team committed to innovation from the start of the project.
- Spend additional time during project planning and design phase to create robust detailed drawings that are well integrated with the construction and logistics plan.
- Apply a holistic approach to innovation, rather than a focusing only on innovating with wood.
- Construction time is very short and requires focused oversight to ensure details are executed as planned.
- Prioritize quality over all other objectives to ensure the project is appreciated and maintained with care by its occupants.

DESIGN TEAM

- Create a project specific design approach that supports innovation within the constraints of the project, rather than applying established practices and procedures.
- Design that facilitates varied and flexible floor plans over fixed layouts is more appealing and durable over time.
- Flexible floor plans must be part of the design strategy from project conception to be successful.
- Planning for systems integration early in design is essential to avoid costly and impractical changes during construction.
- Installation of services in a timber structure is easier, cleaner and more economical than working with concrete.

AUTHORITY HAVING JURISDICTION

- Work closely with the design team early in the project to ensure solutions respond to the unique aspects of the local jurisdiction.

CONSTRUCTION TEAM

- Strong site management and organization are key to ensuring logistics and details are properly executed.

Photo Credit: Riccardo Ronchi

THE OWNER / DEVELOPER
POLARIS REAL ESTATE SGR SpA

The project was built by Polaris Real Estate SGR SpA in collaboration with Social Housing Foundation (FHS). Polaris managed all aspects of the development from design, to construction and property management, leasing and operation.

RATIONALE

- Provide high quality, affordable public housing with all the amenities and qualities of market housing for half the cost.
- Create energy efficient, comfortable and healthy housing that is durable and inexpensive to operate.
- Benefit from improved resource and energy efficiency, and reduction of embodied energy and carbon emissions associated with wood construction.

PROCESS

- The project was funded by Polaris Real Estate SGR SpA.
- A design competition was held to select an architectural team.
- A rigorous due diligence phase focused on the local seismic, fire, energy and acoustics implications of a 9 storey structural timber building.
- A lifecycle cost analysis was applied to ensure long term management and durability was prioritized equally with capital costs.
- The cost of fire protection was one of the most significant capital costs.
- Cost of timber structure was evaluated to be about the same as a similar concrete structure, not including the cost of fire protection.
- Structural design was considered the most significant risk; this was the first instance of timber used for structure in Italy.
- The initial structural design considered concrete stair and elevator cores, but the team opted for a mass timber core based on an evaluation of the difficult interaction between the different structural systems.

Photo Credit: Riccardo Ronchi

CHALLENGES

- Maintaining the project schedule.
- Keeping costs within the budget; specifically the cost of fire protection strategy.
- Keeping the focus on high quality results while working in the context of social housing.

SUCCESSES

- Low income public housing occupants were offered high quality, healthy, beautiful and affordable homes, of which they can be proud.
- Exceptional example of innovation in the context of a social housing development.
- Completed within the expected time frame, with a savings of four months construction time compared to a concrete structure.
- Very efficient and flexible floor plans and building program.

Photo Credit: Riccardo Ronchi

THE DESIGN TEAM

ROSSIPRODI ASSOCIATI srl., BORLINI & ZANINI SA

ROSSIPRODI ASSOCIATI srl. completed the architectural design and Borlini & Zanini SA were the structural engineers.

RATIONALE

- Design a high quality residential project based on the principles of sustainable design.
- A commitment to the principles of sustainable design and realizing the embodied energy and carbon savings associated with mass timber construction.
- Promote ongoing experimentation and innovation in social housing.

DESIGN PROCESS

- Design emphasis was on quality, durability and long term maintenance.
- Obtaining project approvals was challenging given timber construction is not common in Italy and the characteristics of structural timber are not well understood locally.
- Special permission was obtained during the design phase from the authority having jurisdiction to build in timber over three stories.
- Approvals took place during the design process over six months, and this was the first project to earn permission to proceed with a structural timber approach.
- Despite a relatively low earthquake risk in Milan compared to other parts of Italy, the authority placed special emphasis on seismic risk given the new structural timber typology. The most stringent seismic code in Italy (K-1) was required by the authority to ensure the best outcome for this first example of a tall timber building in the region.
- 3D modeling software was used for design.
- Design process was approximately two months longer compared to a conventional structural approach.
- The team considered the LEED rating system, incorporating sustainable design principles, but did not pursue formal certification.
- A platform timber frame structure and a steel structure were considered without detailed calculation and design, before selecting a CLT solution.
- CLT panel prefabrication included window and door openings only, penetrations for system and other finishes were cut on site.

Photo Credit: Riccardo Ronchi

DESIGN SOLUTIONS

STRUCTURE

- Cast-in-place reinforced concrete basement.
- CLT panels for walls and floors from ground level to 9th storey.
- The CLT panels used for the walls decrease in thickness from 200mm on the first floor to 120mm on the 9th floor.
- The CLT walls are interrupted at each level by the floor panels to simplify production, transportation and construction; this creates a greater need for accurately designed and executed connection details.
- Floor element maximum span is 6.7m, using 230mm thick 7-ply CLT panels.

LATERAL STABILITY

- Connections between CLT elements use two strategies to achieve "continuous stitching" to ensure high performance load transfer during a seismic event:
  - Steel plates and screws to connect CLT panels together.
  - High performance self-tapping screws at joints of floor and wall panels.

FIRE PROTECTION

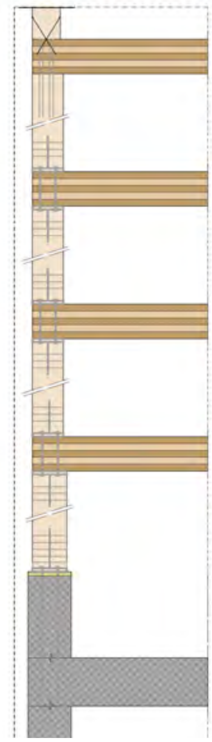
- Fire testing was done by the CLT fabricator.
- Gypsum board encapsulates all exposed timber on the interior with the exception of some ceilings in common areas.
- Doors are specialized fire protection doors.
- Exterior façade is non-combustible stucco cladding.

MOISTURE PROTECTION + DURABILITY

- Vapour barrier installed on the inside of exterior walls.
- All suites have continuous ventilation systems with anti-pollution features and automatic humidity control.
- The building is designed for a service life of at least 70 years with very low maintenance.

SYSTEMS INTEGRATION

- Penetrations for systems were cut on-site after panels were installed.



Schematic of Floor and Wall panels.
Detail Credit: ROSSIPRODI ASSOCIATI srl.

Steel plates
Photo Credit: ROSSIPRODI ASSOCIATI srl.

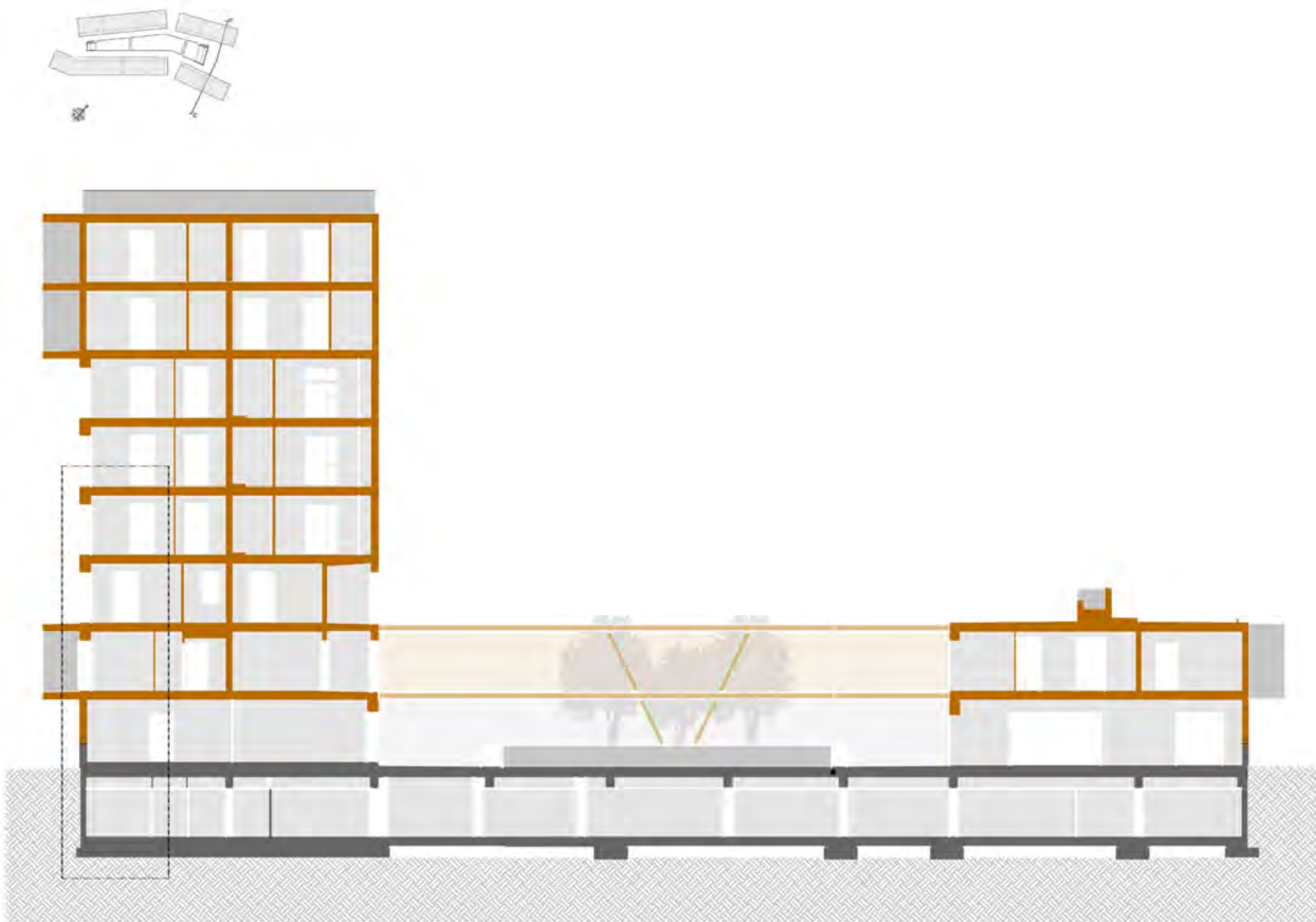
Self-tapping screws
Photo Credit: Riccardo Ronchi

CHALLENGES

- Maintaining a holistic approach to design, in line with the desired architectural language, structural considerations and important social considerations of the project.
- Evaluating options for the façade to ensure the appearance best reflected the goals of the social housing project, required special consideration and effort.
- Resolving structural design to accommodate unique floor plans for each level, while maintaining a flexible and easily customized layout for each suite.
- Developing the structural connection strategies to meet the stringent seismic requirements.
- Although seismic risk is relatively low in Milan compared to other parts of Italy, the Authority's perception of risk was heightened in this first instance of a tall timber structure, necessitating adherence to the most stringent seismic requirements.
- The cost of encapsulating exposed timber with gypsum to meet the fire protection requirements.

SUCCESSES

- Residents reported that they are happy with, and proud of their space.
- Demonstrated that building high quality, healthy, state of the art residential projects was possible within a social housing context.
- Planning and logistics were very well incorporated into design documents.
- All risks were successfully mitigated and approvals obtained, setting the precedent for more mass timber projects in Italy.



Elevation view.
Detail Credit: ROSSIPRODI ASSOCIATI srl.

THE AUTHORITY HAVING JURISDICTION
MINISTRY OF INFRASTRUCTURE AND TRANSPORT

Authority representatives were not available to provide their perspectives, however the information presented here reflects feedback from other project stakeholders on the permissions and approvals process for Cenni di cambiamento.

Prior to Cenni di cambiamento the local building code in Milan did not allow timber buildings above 3 storeys. The design team worked with the Authorities over six months to gain permission to construct with timber up to 9 storeys. This was a significant change to the approvals process in Italy, considering the industry's unfamiliarity with mass timber.

Although seismic risk is relatively low in Milan compared to other parts of Italy, the Authority's perception of risk was heightened in the context of a timber structure. The most stringent seismic code in Italy (K-1) was required by the Authority to ensure the best outcome for this first example of a tall timber building in the region. During design, the Authority evaluated various strategies proposed by the design team over a six month period.

Significant attention was also given to fire testing which was completed by the timber supplier.

Photo Credit: Riccardo Ronchi

THE CONSTRUCTION TEAM

CARRON, SERVICE LEGNO, STORA ENSO, MAKHOLZ

Carron managed construction, Stora Enso were responsible for the fabrication, MakHolz supplied the timber and Service Legno were the timber erectors.

RATIONALE

- Prove a strong, profitable business case for the use of mass timber products in construction.
- Expand expertise and develop industry capacity for mass timber projects.

PROCESS

- Panel delivery logistics followed a continuous delivery schedule according to the assembly plan.
- The delivery schedule kept only two containers of panels on-site at all times, reducing site storage space required and the risk of exposing panels to weather. Panels were delivered to the site in containers.
- The construction team was hand selected, but skilled workers were readily available in the region.
- Scaffolding was used to improve building site safety and to assist with façade installation.
- The timber structure was completed in five months.

Photo Credit: Riccardo Ronchi.

CONSTRUCTION SOLUTIONS

SYSTEMS INTEGRATION

- Making penetrations for systems was relatively easy compared to working with a concrete structure.

MOISTURE PROTECTION + DURABILITY

- All CLT panels were delivered covered with a PVC film, but after the first month of construction, the film was removed to allow the wood to breathe.
- Panel end grains were protected before installation.
- Panels were stored on-site in the delivery containers until installation.
- A nylon cover was used to protect the structure initially, but abandoned to better allow the wood to breathe. Standing water was removed immediately.

CHALLENGES

- Addressing weather protection and standing water and snow removal.
- Achieving innovation and handling the pressure of scrutiny that comes with doing something new.
- Maintaining the project schedule.
- Maintaining construction costs.

SUCCESSES

- Construction process and project planning were well organized.
- Speed of construction was four months faster than a conventional construction process.
- Noise and dust during the construction were reduced as a result of timber materials and prefabricated elements.

Photo Credit: ROSSIPRODI ASSOCIATI srl.

Photo Credit: ROSSIPRODI ASSOCIATI srl.

Photo Credit: ROSSIPRODI ASSOCIATI srl.

APPENDIX B - LIST OF TECHNICAL RESOURCES

3XGRÜN:

Ballhausen, Nils. (2012) Den Holzbau radikalisieren. Bauwelt Issue 21/2012, p36-42: (http://www.roedig-schop.de/presse/3xgruen-bauwelt_2012_21_0036-0043.pdf)

Hoeft, Markus. (2012) Ein Bauherr statt dreizehn. Bauen Mit Holz Issue 5/2012, p48-51: (http://www.roedig-schop.de/presse/3xgruen-bauen-mit-holz-berlin-pankow-2012-05.pdf)

Rozynski, Daniel. (2008) Fertighäuser für die Innenstadt. Sondemeh Urbanes Wohntn Issue 6/ 2008, p19: (http://www.roedig-schop.de/presse/3xgruen_Die_Wohnungswirtschaft_06_2008.pdf)

Roedig, Christoph. (2011) Grüne in Berlin. Bauen Mit Holz Issue 3/2011, p14-18: (http://www.roedig-schop.de/presse/3xgruen_Bauen_mit_Holz_03_2011.pdf)

Bridport House:

Stora Enso project report. (2013) Bridport House, London, UK – Faster, Greener, Neater and More Accurate Building with CLT (http://www.clt.info/wp-content/uploads/2013/05/Bridport_factsheet_EN_light1.pdf)

Willmott Dixon Group. (2011) Bridport House - The Contractors View. (http://www.buildingcentre.co.uk/slideshow/wd_rethinkingclt_presentation_v8.pdf)

Willmott Dixon Group. (2012) Bridport House, Case Study. UK’s largest cross-laminated timber residential scheme. (http://www.willmottdixongroup.co.uk/assets/b/r/bridport-house-case-study.pdf)

Cenni Di Cambiamento:

Bernasconi, Andrea. (2012) Timber construction in the city of Milan - 4 residential buildings with 9 storey. (http://www.traeblog.dk/wp-content/uploads/2012/07/Via-Cenni.pdf)

Rossi Prodi, Fabrizio. (2012) Abitare Sociale. Peasaggio Urbano, 5-6 bis.2012, pg 20-39 (http://www.periodicimaggioli.it/promo/2013/paesaggio-urbano/index.htm)

E3:

ForstBW. Esmarchstraße 3, Berlin (http://forstbw.de/wald-im-land/rohstofflieferant/bauen-mit-holz/urbanes-bauen/kapitel-5-dokumentation/esmarchstrasse-3-berlin.html)

Golden, Elizabeth. (2011) Berlin: Die Offene Stadt / The Open City, Part Two. (http://uwarch-belog.com/index.php/2011/08/berlin-die-offene-stadt-the-open-city-part-two/)

Jaeger, Falk. (2008) e3 - A Timber-Frame Building in “Stone-Built Berlin”. Goethe-Institut e. V., Online-Redaktion (http://www.goethe.de/ges/umw/dos/nac/buw/en3468011.htm)

Mayo, Joe. (2012) Wood Assemblies and Wood Buildings: Kaden Klingbeil. (http://timbercity.wordpress.com/2012/07/21/wood-assemblies-and-wood-buildings-kaden-klingbeil/)

UBC Earth Sciences Building:

Canadian Wood Council. (2012) Innovating with Wood: A Case Study Showcasing Four Demonstration Projects, 3-13 (http://www.cwc.ca/documents/case_studies/Four%20demonstration%20Case%20Study_May_30.pdf)

Karsh, Eric. (2013) Building the Earth Sciences Building at the University of British Columbia. (http://www.kenilworth.com/publications/cc/de/201304/files/8.html)

Naturally Wood. (2012) Mass Timber and Wood Framing, New and Traditional Approaches reduce cost and meet code for mid-rise construction, Case Study 5, 6-9 (http://continuingeducation.construction.com/crs.php?L=324&C=946)

Forté:

Lend Lease. (2013) Forté Creating the World's Tallest Timber Apartment Building. (http://woodworks.org/wp-content/uploads/CLT-PATTERSON.pdf)

Lend Lease. (2013) Forté - Building Australia's First Timber Highrise. (http://woodworks.org/wp-content/uploads/2013-WSF-ATL-Collins.pdf)

Holz8:

Angela, T. & Schäfer, W. (2011), Herausragend Auch Im Detail. Bauen Mi Holz, Issue 12/2011 (http://www.huber-sohn.de/bilder/Allgemein/04_Presse/04_PDFs/Holz8_Bauen-mit-Holz_12-2011.pdf)

Binderholz Bausysteme GmbH. (2013) 8-Storey Timber Building, Bad Aibling. (http://www.binderholz-bausysteme.com/fileadmin/books/en/Case%20study%20Bad%20Aibling%20GB/files/assets/downloads/publication.pdf)

Burk, Maike. (2012) Hoch Hinaus Mit Holz. (http://architektur.mapolismagazin.com/schankula-architekten-holz-8-bad-aibling)

Holzma. (2012) Wooden Town Hits The Heights. (http://www.holzma.com/en-en/references/referencedatabase/weinmann/Pages/Woodentownhitstheheights.aspx)

LCT ONE:

Cree Buildings. (2013) Cree Buildings Information Brochure. (http://www.creebuildings.com/files/CreeBrochure.pdf)

Tahan, Nabih. (2012) LCT ONE: Case Study of an Eight-story Wood Office Building. (http://woodworks.org/wp-content/uploads/C-WSF-2012-NABIH-LCT-1.pdf)

Limnologen:

Serrano, E. (2009). Limnologen – Experiences From an 8- storey Timber Building. (http://www.forum-holzbau.ch/pdf/ihf09_Serrano.pdf)

Serrano, E. Växjö University. (2009). Documentation of the Limnologen Project: Overview and Summaries of Sub Projects Results. (http://www.cbbt.se/website3/1.0.3.0/31/FULLTEXT01.pdf)

Zeng Xiong Yu, Ren Su Xin, Omar Sabri, Växjö University. (2009). Vertical Displacements in a Medium-rise Timber Building - Limnologen in Växjö, Sweden. (http://www.diva-portal.org/smash/get/diva2:226491/FULLTEXT01)

Tamedia:

Lalutea, Ines. (2013) Metalocus. The New Tamedia Building by Shigeru Ban. (www.metalocus.es/content/en/blog/new-tamedia-building-shigeru-ban)

Tamedia AG. (2013). The New Tamedia Building. (www.tamedia.ch/en/company/tamedia/the-new-tamedia-building/)

Shigeru Ban Architects. (2013). Tamedia office building. (http://www.shigerubanarchitects.com/works/2013_tamedia-office-building/index.html)