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LESSONS FROM TALL WOOD BUILDINGS:
What We Learned from Ten International Examples

Rebecca Holt, M. Urb, LEED AP BD+C, ND, *rebecca.holt@perkinswill.com*
Kathy Wardle, M.E.S, LEED AP BD+C, *kathy.wardle@perkinswill.com*

ABSTRACT
The growing pressure to reduce the carbon footprint of buildings requires designers to balance functionality and cost objectives with environmental impact. With a significantly lower carbon footprint than concrete or steel structures and many other environmental and human health benefits, wood has reemerged as a desirable and viable structural material for taller buildings.

Forestry Innovation Investment and the Binational Softwood Lumber Council commissioned Perkins+Will to undertake an international survey of ten, completed tall wood projects. The goal was to compile experiences from project stakeholders who have designed and built successful tall wood buildings. The survey methodology included a short online questionnaire and individual in-person or telephone interviews. More than 50 individuals participated in the survey and site visits were conducted for nine of the ten project sites during the month of November 2013.

The work aims to learn from individual experiences, solutions and challenges, but also from aggregated information, trends and common lessons. The intent of this article is to distill the research into a concise summary that presents the market context and rationale for using wood in tall building applications, share the most important lessons learned from project stakeholders, and summarize the key design and construction solutions.

KEYWORDS: sustainable design, mass timber, low-carbon material, energy efficiency, quality of space, human health and well-being

1.0 INTRODUCTION

A tree is produced by energy from the sun, it provides valuable functions within ecosystems, it produces oxygen and sequesters carbon during its lifetime and it can be harvested for a durable, beautiful construction material, through responsible forest management. As such, wood offers a compelling opportunity to reduce the environmental impact of materials that are non-renewable, and require more intensive use of resources to extract, manufacture and install. While wood used as structure in taller buildings is not a new concept, century-old examples exist in North America[i], we have largely abandoned wood as a solution for tall structures since the early 20th century in favour of concrete and steel. The negative environmental and social impacts of natural resource extraction and processing of intensive, non-renewable materials present a significant challenge to professionals engaged in sustainable design. The relatively recent advent of engineered, mass timber products now affords the opportunity to consider timber for taller structures significantly lowering the carbon footprint of the built environment, and offering many other environmental and human health benefits.

[i] The Butler Brothers Building, Minneapolis, Minnesota is a nine storey heavy timber building constructed in 1906. http://www.mnpreservation.org/successful-preservation-profiles/. In Vancouver, BC, the Leckie Building is a 7 storey building constructed in 1910, and The Landing is 9 storeys built in 1905. Both are heavy timber clad in brick. http://www.woodfirstbc.ca/sites/default/files/FPI%20study%20on%20Historical%20Tall%20Wood%20Buildings%20in%20Canada_First%20Edition.pdf.

In the context of this work, a tall wood building is defined as a structure consisting primarily of mass timber, with five or more storeys[ii]. An increasing number is emerging around the globe, and 14 completed projects demonstrate mass timber as a successful construction material and method for tall buildings. To advance tall wood building, learning from the experiences of these early adopters in the industry is essential for building capacity, credibility and market acceptance. In 2013, Forestry Innovation Investment (FII) and the Binational Softwood Lumber Council (BSLC) engaged Perkins+Will to conduct a Survey of International Tall Wood Buildings (the Survey), with the goal of collecting lessons and experiences from built projects. The complete publication that outlines the results is publicly available[1]. The aim is to share this information with potential North American project stakeholders to help simplify processes, increase comfort and potentially lower the risk of designing tall wood structures, ultimately broadening the uptake of wood systems used in tall construction. This article is intended to distill the research into a concise summary, highlighting relevant results for design practitioners.

1.1 Market Context

Light frame timber construction is ubiquitous in North American residential construction, a very common building material used in single family and multi-unit housing construction under five storeys and some low-rise commercial buildings. Most building codes prohibit timber construction exceeding five storeys due to fire risk, and the structural limitations of light timber elements. The recent development of what is referred to as heavy timber, mass timber or solid wood products, such as Laminated Veneer Lumber (LVL), Glulams and Cross Laminated Timber (CLT), opens the doors to new structural opportunities for wood. These products are engineered for strength and dimensional stability and are being applied as alternatives to concrete, masonry and steel in many building types including those exceeding five storeys.

Built examples of tall wood projects to date range widely, and only a few exist in North America[iii]. These limited examples have been realized largely through industry leadership, where designers, engineers and timber industry professionals have come together in various ways to put innovation to the test. This momentum has generated support from industry organizations[iv], and a number of important resources have recently been published that have become integral to the discourse on the opportunity to advance mass timber and tall wood projects. These include MGB/Michael Green's The Case for Tall Wood[v], FP Innovations CLT Handbook[vi], which is being used around the world, and SOM's Timber Tower Research Project[vii] proposing that towers at a height of 30 storeys are possible with a timber structure. FP Innovations has also published the Technical Guide for Design and Construction of Tall Wood Buildings in Canada[viii], which presents the unique and technical issues that should be considered when designing and constructing a tall wood building.

While these resources are essential and are certainly advancing education and dialogue about tall wood, they speak to the technical application and theoretical possibilities of constructing tall buildings with mass timber. Missing from this literature is a way to communicate applied experience from completed work, to fill the space between the technical application and the finished product. With 14 completed tall wood buildings around the world, the survey attempts to fill this gap by gathering and aggregating lessons and insights, an exceptionally valuable part of building knowledge and capacity. While many case studies have been published about the projects included in the survey, no other document

[ii] Typically, mass timber buildings are not recognized explicitly by most local building codes, and light frame wood construction is limited to between 4 and 6 storeys depending on the jurisdiction.

[iii] There are three completed examples of tall wood construction in North America including: Fondaction, in Quebec City, http://www.woodworks.org/wp-content/uploads/CS-Fondaction.pdf, the UBC Earth Sciences Building in Vancouver, http://www.cwc.ca/documents/case_studies/Four%20demonstration%20Case%20Study_May_30.pdf and the Wood Innovation Design Centre in Prince George, BC http://mg-architecture.ca/portfolio/widc/.

[iv] Binational Softwood Lumber Council http://www.softwoodlumber.org/, Canadian and American Wood Council http://awc.org/ and http://cwc.ca/, Softwood Lumber Board http://www.softwoodlumberboard.org/, Forestry Innovation Investment http://www.bcfii.ca/, FP Innovations https://fpinnovations.ca/Pages/home.aspx and Wood Works! http://www.woodworks.org/.

[v] The case for tall wood http://wecbc.smallboxcms.com/database/rte/files/Tall%20Wood.pdf.

[vi] FP Innovations CLT Handbook https://fpinnovations.ca/Pages/CltForm.aspx#.UVTCGRm1VVA.

[vii] SOM Timber Tower Research Project http://www.som.com/ideas/research/timber_tower_research_project.

[viii] FP Innovations Technical Guide for the Design and Construction of Tall Wood Buildings in Canada https://fpinnovations.ca/ResearchProgram/advanced-building-systems/Pages/promo-tall-wood-buildings.aspx#.VDM_j_ldWBY.

or project has cross referenced experiences, solutions and challenges to identify trends and common lessons, making this work significant for all jurisdictions around the world.

1.2 Scope and Methodology

The survey was focused on gathering qualitative information from four specific stakeholder groups: owner/developers, design teams, construction teams and authorities having jurisdiction. The emphasis was on discovering the drivers or rationale for pursuing a structural wood solution, lessons about design processes, construction process, approvals, and unique aspects associated with delivering a tall wood project. In addition, it addressed project insurance, financing and building performance.

The data collection was broken down by stakeholder group in order to gather lessons specific to each, thereby addressing the ultimate goal of reducing risk and increasing comfort among key players. Six to eight stakeholders per project were identified that could potentially contribute to the survey, representing one to two people per stakeholder group. Some individuals were able to represent more than one stakeholder group and some projects included several individuals within one group.

The survey methodology was designed to capture a range of information across stakeholder groups, limit redundancies for participants and ensure that not only project specific information was gathered, but that results could be effectively aggregated to identify trends. The approach was a mix of methods that could take best advantage of a short timeline including an online questionnaire followed by in-person or telephone interviews. First, a long list of built projects and associated contacts was created and a formal letter of invitation to participate in the survey was sent by email. Stakeholders who agreed to participate 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. Stakeholders from 13 built projects were invited to join the survey, with the goal of including ten. At least one stakeholder from all 13 agreed to participate.

Site visits were conducted for nine of the ten projects (researchers did not visit Forté in Melbourne, Australia), and in-person interviews were arranged with the majority of project participants. Where stakeholders were unavailable or not within the practical limits of the travel itinerary, researchers conducted interviews by phone. In addition to the project site visits, researchers also visited timber fabricators and fabrication plants, interviewed building owners and developers, architects, structural engineers, construction managers, timber erectors and authorities having jurisdiction. All interviews were conducted by at least two researchers and audio recordings were made to ensure the quality of participant responses. Site visits were conducted during the month of November 2013.

Upon completion of the data collection, the results were analyzed to determine which of the 13 participant projects included the most robust results. The ten participant projects were chosen based on a variety of criteria including building typology, timber structure type, date of completion, willingness and availability of the stakeholders to participate and the extent of information already published. The projects included in the survey are listed in Table 1 below and images follow in Figure 1.

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	Växjö, 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	Residential	10	Panelized	2012
University of British Columbia Earth Sciences Building (ESB)	Vancouver, Canada	Institutional	5	Combination Panels/ Post and Beam	2012
Life Cycle 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	Residential	9	Panelized	2013

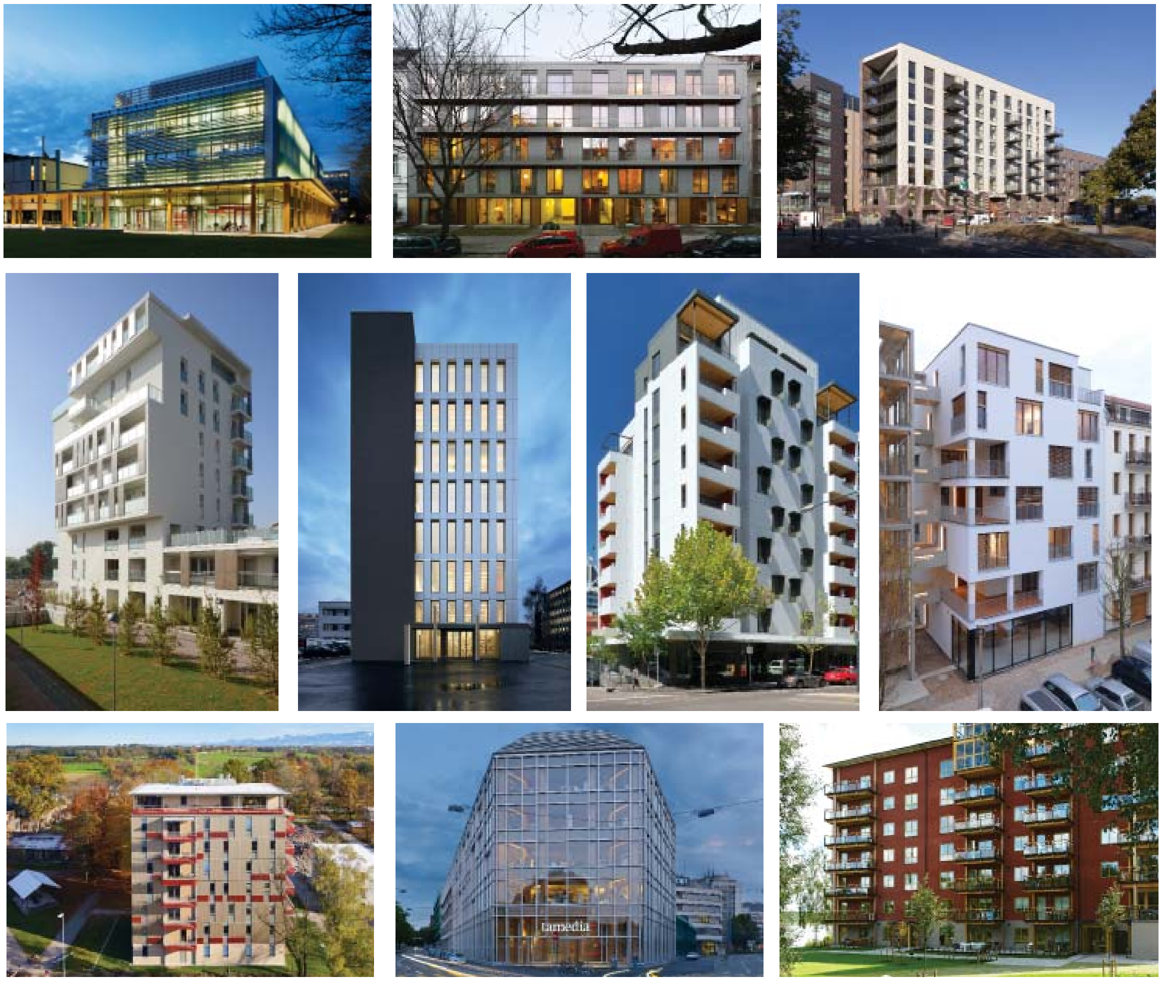

Figure 1: Survey of International Tall Wood Buildings - participant projects
From top, left to right: UBC Earth Sciences Building; 3XGRÜN; Bridport House; Cenni di Cambiamento, LCT ONE; Forté; E3; Holz8; Tamedia; Limnologen.

UBC Earth Sciences Building / Architecture by Perkins+Will (Photo credit: Martin Tessler)
3XGRÜN / Architecture by Atelier PK, Roedig Schop Architekten and Rozynski Sturm (Photo credit: Stefan Mueller)
Bridport House / Architecture by Karakusevic Carson Architects (Photo credit: Wilmott Dixon Group)
Cenni di Cambiamento / Architecture by ROSSIPRODI ASSOCIATI srl. (Photo credit: Riccardo Ronchi)
LifeCycle Tower ONE (LCT ONE) / Architecture by Hermann Kaufmann ZT GmbH (Photo credit: www.creebuildings.com)
Forté / Architecture by Lend Lease (Photo credit: Lend Lease)
E3 / Architecture by Kaden Klingbeil (Photo credit: Bernd Borachrt)
Holz8 (H8) / Architecture by SHANKULA Architekten (Photo credit: Huber&Sohn)
Tamedia / Architecture by Shigeru Ban Architects (Photo credit: Didier Boy de la Tour)
Limnologen / Architecture by Arkitektbolaget Kronoberg (Photo credit: Midroc Property Development)

2.0 LESSONS LEARNED

This section presents the highlights of the lessons learned and strongest trends conveyed by the survey participants relevant to development, design, construction and performance of tall wood buildings.

2.1 Rationale and Motivation

In an attempt to discover the major industry drivers to pursue wood solutions for tall buildings, the survey included a question set for each stakeholder group focused on motivations. The following sections describe the strongest motivators for pursuing a tall wood project emphasized by all stakeholder groups.

Market Leadership and Innovation

The opportunity to lead the market and innovate with techniques, products and ideas was identified as a strong driver for pursuing a tall wood project by all participants. Developers, designers and fabricators recognize the potential of wood to contribute to many goals the industry is trying to address in the built environment, and they have invested their expertise and capital to demonstrate that potential – they are dedicated to leading the market and they see developing expertise in mass timber as an investment in business and innovation for the future.

Environmental Benefit of Wood

All stakeholders identified and emphasized that using wood complements multiple goals as part of the industry's efforts to reduce the impact of carbon emissions from the built environment – both in embodied energy and as a material to support a high performing envelope.

Construction Schedule Savings

Every participant and stakeholder group identified that they were motivated by the potential of construction schedule savings afforded by the opportunity for extensive prefabrication of wood elements.

Cost

Cost was identified as a strong motivator in the sense that owners and developers perceived wood as a cost competitive option to alternatives. It was clear that participants applied a holistic, lifecycle approach to this evaluation accounting for quality, longevity and durability of the building systems over the life of the structure.

Figure 2 presents the online questionnaire results from the owner/developer participants indicating market leadership and carbon footprint as the strongest rationale for pursuing tall wood projects.

In addition to the results below, while not explicit within the questionnaire or interview question sets, the majority of participants emphasized that the motivation and rationale for considering wood in tall building construction was reinforced in almost all cases by a very supportive policy context. This is one of the most important outcomes of the study. It appears that in jurisdictions where governing policies exist in support of low carbon construction, energy efficiency or renewable resources, the market for mass timber construction is developing more rapidly. In such cases the governing framework was key to motivating all stakeholders to innovate with wood solutions, and teams in some cases were able to access incentive funding. A good example is the Limnologen project in Växjö, Sweden (Figure 3). It is sup-

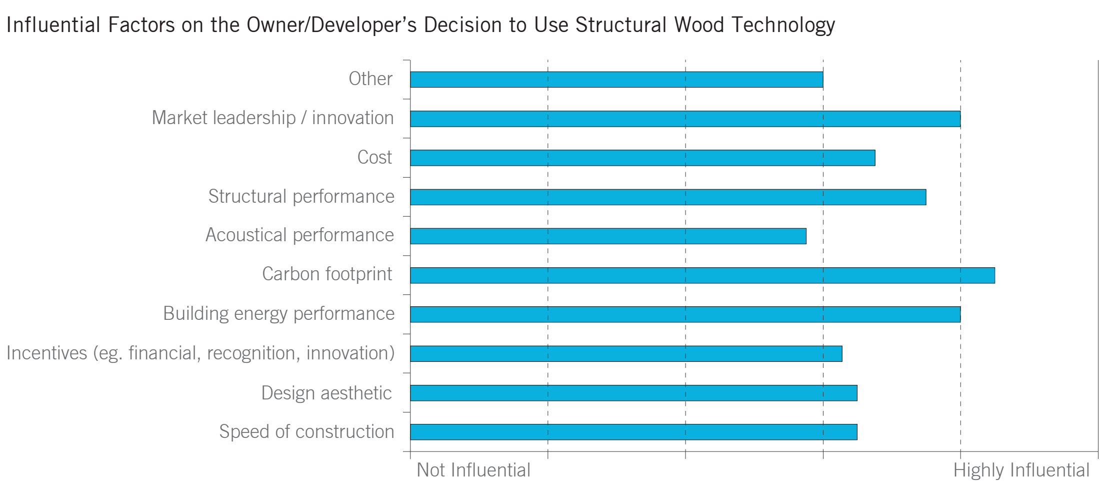

Figure 2: Online questionnaire results for owner/developer participant stakeholders indicating influential factors on the decision to use structural wood technology.

Figure 3: Limnologen (Växjö, Sweden) is supported by local and national programs to expand the timber industry in Sweden. (Photo credit: Midroc Property Development)

ported by local and national programs to expand the timber industry. Also, stringent energy efficiency and carbon regulations make wood an attractive choice to address multiple performance requirements.

2.2 Best Practices - Process

Stakeholders were asked to describe how the project development process, design process or construction process for a tall wood building was different or special from other projects. The following section summarizes the strongest responses.

Commit

Every participant emphasized that the project team must be committed to a wood solution from the start – resolving design, code and market dilemmas require effort and all participants must be committed to moving the project forward with a wood solution.

Conduct Market Research

Most teams identified that understanding the market for the project is imperative. Owners and developers spent additional time to conduct detailed research on how the potential market would react to a timber structure in order to respond accordingly with design decisions, and understand what barriers might need to be overcome. This is the reason many timber buildings do not appear from the exterior to be wood – the perception in the market place is often that a building similar in appearance to a conventional building would be more acceptable by the market.

Create Research Partnerships

Research partnerships were identified as exceptionally important to every project in the survey. Each team collaborated with either an academic research institution or industry organizations in support of advancing timber buildings to help resolve and test design solutions, work on overcoming code issues, market perception issues, and creating long term research projects to monitor performance and publish results to build the body of knowledge.

Collaborate/Integrate

In the field of design, an integrated design process is considered the most successful approach to generate high performance buildings. The survey participants of these tall wood projects described a collaborative process that reached beyond what is typically understood as integrated. Not only did project teams take advantage of research partnerships, but participants stated that contributions from all disciplines at the very earliest stages, especially timber fabricators, was important to success. In the European participant projects, it was clear that a greater blending of professional roles across disciplines and sectors resulted in a strong culture of collaboration – project teams were inclined to access expertise early to help eliminate construction issues with a design solution or collaborate on design drawings. Teams included highly trained fabricators who had a broad range of experience from engineering structure and 3D design modeling software to construction logistics and planning.

Innovate Holistically

Another strong outcome from all projects was the message that tall wood projects should be approached as wholly innovative, rather than with a focus on innovating with wood elements only. This was a very strong message from the Cenni di Cambiamento developer (Figure 4 on following page), who expressed that very

Figure 4: Cenni di Cambiamento, Milan, Italy (Architecture by ROSSIPRODI ARSSOCIATI srl. Photo credit: Ricardo Ronchi).

little about the process reflected a traditional approach, emphasizing that the timber structure opened a new set of opportunities that may never have been considered otherwise.

Pre-plan, Plan, Plan again

The importance of planning was stressed in every conversation and was the answer to almost every participant's response when asked to identify lessons or advice for future project teams. All participants noted planning and pre-planning and then planning some more was key to success and indicated that additional effort early in the project timeline was where the majority of time was spent. This effort was essential to detail design drawings, incorporate construction logistics considerations into drawings, accommodate testing and approvals processes, and ensure experienced subcontractors and trades can be accessed to assemble the building. Online questionnaire results also reflect this, indicating the majority of projects required additional time and resources to support their tall wood projects (Figure 5).

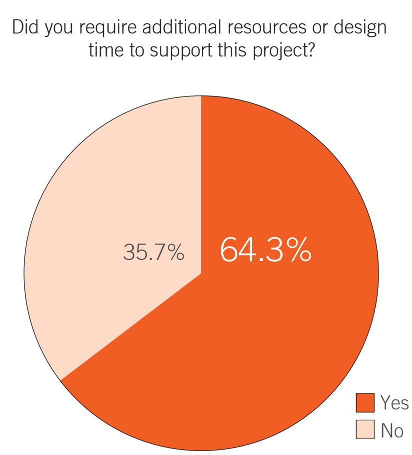

Figure 5: Online questionnaire results for the design team participant stakeholders indicating more than 60% required additional resources or design time to support their tall wood project.

Figure 6: LCT ONE includes the Lifecycle Hub on the main floor of the building, an open education facility dedicated to advancing wood solutions. (Architecture by: Hermann Kaufmann ZT GhmH, Photo credit: www.creebuidlings.com)

Share
Finally, a very important message emphasized by participants was to share experiences, ideas, performance data and research to build the body of knowledge around tall wood construction and advance the industry. This philosophy was clearly practiced by all participant projects demonstrated by their willingness to share their time and thoughts for this survey. In addition, most have published research through various academic partnerships[ix], and are open sourcing performance data and sharing the experience of wood buildings with the public (Figure 6).

2.3 Design Solutions

Participants were asked to describe design and construction solutions across a variety of topics that had been identified as either challenging, were associated with perceived risk, or were thought to have knowledge gaps. These included: structure, lateral stability, fire protection, acoustics and vibration, systems Integration, and moisture protection and durability. The responses in all categories were generally wide ranging, indicating that there is a range of design and construction solutions as well as philosophies about addressing each of these issues. While there were certainly some common solutions, it is clear that no one technique or technology has emerged as the "best" in any category. Highlights of the results are listed below.

Structure
Panels are generally favoured for residential construction, while post and beam is favoured for institutional and commercial space, likely because post/beam offers a more open floor plan that can be reconfigured easily. Panels provide a more compartmentalized layout that are well suited for residential construction.

Fire Protection
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.

Acoustics and Vibration
Acoustic and vibration strategies were generally complex and centered on strategies to separate or decouple floors and ceilings to eliminate noise and vibration transmission throughout spaces. Meeting local building code requirements, which varied widely across participant jurisdictions, was identified by most teams as a major design challenge. Almost all participants indicated that acoustic solutions were researched and tested through research partnerships.

Systems Integration
Design solutions for systems integration were varied across projects. In projects where structural elements are covered or concealed, participants indicated that resolving systems is relatively easy. In cases where

[ix] Serrano, E. Växjö University (2009). Documentation of the Limnologen Project: Overview and Summaries of Sub Projects Results, Retrieved on 10/16/2013 from http://www.cbbt.se/website3/1.0.3.0/31/FULLTEXT01.pdf

Figure 7: Ceiling panels between timber beams conceal systems at LCT ONE (Photo Credit: www.creebuidlings.com).

structure was exposed, integrating systems was identified as more challenging. In commercial applications, raised floors and dropped ceilings accommodated the majority of systems (Figure 7).

Moisture Protection and Durability

In general, moisture protection was not perceived as a major risk by design teams. In all cases, any exposed structural wood elements were either inside the building envelope, protected by an overhang or in the case of cantilevered panels, exposed only on the underside. In two cases, moisture sensors were installed to monitor envelope performance as part of ongoing operational research projects.

2.4 Construction Solutions

Participants were asked to comment on the same issues with respect to construction process. In general, the results were similar to the design solutions, a range of solutions and approaches were identified with a few strong common themes listed below.

Structure

In all cases, projects that used concrete cores emphasized that precast concrete panels accelerates the construction schedule and maintains a dry site. Of the projects that used cast-in-place concrete for the core, almost all of the schedule savings afforded by other prefabricated components were lost due to long curing time. Figure 8 shows the assembly of precast concrete panels for the core at the Holz8 project. The core was assembled first followed by the rest of the building, yielding a very fast construction time of about 16 days for the timber erection.

Figure 8: Holz8 building employed pre-cast concrete for the cores, contributing to a very quick construction time of 16 days (Architecture by: Schankula Architekten, Photo credit: Huber & Sohn).

In addition, every team identified challenges with tolerances at material interfaces (where concrete meets wood, or wood penetrates glass). Construction team participants emphasized that solid planning and detailing are critical to mitigating on-site delays and frustrations with variations in tolerances during construction.

Fire Protection

Participants indicated that accommodating frequent inspections from the fire authority during various stages of construction was key to increasing authority comfort with various fire protection strategies, and in some cases projects were able to eliminate redundant strategies once authorities had visually inspected assemblies and materials.

Weather Protection

Survey results concerning weather protection during construction varied from none at all, to temporary protection, to a fully tented structure. Different opinions on the need for weather protection appear to be related to the type of timber elements being installed and how they are treated before they are moved to the site. The Limnologen project employed a rising tent to cover the structure until enclosed (Figure 9), and all the project stakeholders emphasized the beneficial worksite conditions realized from the tent, as equally important as protecting the structure from weather. It created a clean, dry and warm site for the construction team.

Figure 9: Limnologen's rising tent structure for weather protection during construction (Photo credit: Midroc Property Development).

2.5 Approvals Process

Given that the majority of building codes do not explicitly recognize mass timber systems, obtaining approvals is identified as a significant challenge associated with pursuing tall wood buildings. While every participant project had a different set of experiences with respect to approvals based on existing codes, degree of market acceptance for mass timber as material for taller buildings, and varying regulatory policy, they all emphasized the importance of collaborating early to establish methods of compliance and methods of testing.

Survey participants were careful to emphasize that accounting for the effort to engage the authority having jurisdiction and the effort associated with alternative solutions and innovation is essential. Figure 10 shows results from the online questionnaire indicating that the majority of jurisdictions required additional documentation to satisfy the approvals for the wood solution.

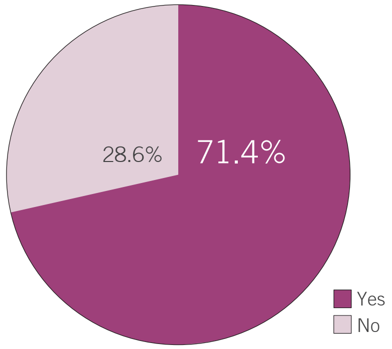

Figure 10: Online questionnaire results for design team participant stakeholders indicating frequency of special or additional documentation required by authorities having jurisdiction due to the use of structural wood technology.

Of the ten participant projects, only one approvals pathway was already established (3XGRÜN), owing to the E3 project completed a few years earlier in the same jurisdiction. All other projects were the first to successfully overcome code barriers and challenges. Participants identified two important strategies:

- "Start educating the authority when you start educating yourself". The Forté developer indicated that they collaborated with the local authority very early, provided them with credible industry resources, and engaged them in research.
- Establish an acceptable method of compliance as early as possible with the authority to allow the team to plan for testing and account for extra time associated with creating a new path to approvals.
- Plan to have the authority conduct regular on-site inspections during construction. Participants reported that where authorities were able to visually inspect assemblies and observe construction process and quality, their level of comfort increased and sense of risk decreased. In some cases, authorities deemed multiple fire protection strategies redundant and allowed a revised, less onerous approach.

2.6 Building Performance

The survey gathered information from project participants about building performance and operations in order to identify any unique issues, benefits or challenges associated with the performance of a tall wood building. In all cases, participants indicated that mass timber was perceived as a beneficial material to support a combination of complementary building performance objectives.

- *Wood supports an efficient envelope*
  As a poor conductor of heat, wood minimizes thermal bridging, improving the effectiveness of the insulation compared to many conventional envelope assemblies.
- *Aligns well with Passive House standard*[x]
  In several instances participants identified the complementary advantage of achieving good air-tightness 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. This aligns very well with the air tightness requirement of Passive House, a European building performance standard applied around the world. The 3XGRÜN project, although not a certified passive house, meets the performance requirements for energy and air tightness. It was able to eliminate many systems and equipment by maximizing the efficiency of the envelope and other passive systems, simplifying operation/maintenance and thereby reducing capital and operational costs.
- *Occupant education is important*
  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, training sessions for tenants and new owners were provided.
  A very strong theme among every project was the benefit associated with occupant well-being and quality of space, listed below.
- *Exposed wood creates warm spaces*
  Almost all participants indicated that the quality of space achieved by exposing wood on building interiors was integral to the rationale for pursing the project.
- *Wood is a healthy material*
  Respondents emphasized that wood is widely understood as a material that contributes to our sense of well-being in spaces and can be a very healthy alternative to other finishes as an exposed surface on the interior.

Finally, every participant agreed that sharing lessons, ideas and performance data about tall wood building examples is key to advancing the industry. Areas of emphasis include moisture monitoring, energy performance and embodied carbon savings accounting, and occupant comfort. Several participant projects are engaged in ongoing performance monitoring in partnership with research and academic institutions.

3.0 CONCLUSION

The value of learning from applied experience cannot be overstated. The survey offers a range of lessons and knowledge from those most deeply involved in all aspects of tall wood buildings, from almost all jurisdictions in which they currently exist. The intent of this survey was to solidify the effort to advance the market for tall wood buildings.

The strongest message from all survey participants was that wood structure for taller buildings is a valid construction method with the potential to contribute substantially in reducing the negative impacts of buildings on the environmental and human condition. Of particular significance for practitioners engaged in sustainable design is the ability of wood to contribute to complementary goals of reducing the impact of carbon associated with buildings (embodied and operational), as well as improving occupants' sense of well-being and high quality indoor environments. Participants also revealed that supportive policy frameworks create an important regulatory grounding for tall wood construction, indicating that advocating for aligned policies at all levels of jurisdiction that serve to move beyond single benefit will be most valuable.

While it is clear from the survey results that the range in design and construction techniques are still evolving to respond to the varied code requirements, market demands and expectations, climates and regulatory conditions, time and innovation will continue to allow refinement and efficiencies are likely to emerge as more examples are realized. To build more momentum and support more built examples in North America and around the world, participants confirmed that more testing data is needed, especially for fire resistance. In order to reduce the perceived risk, the pool of testing data must grow. The survey also indicates that performance monitoring data is essential to demonstrate the benefit of operational efficiencies and human comfort.

[x] Passive House is 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.

Finally, survey respondents confirmed that there is still a gap in the market perception of mass timber construction, particularly regarding fire safety and durability. In general, the market perceives all timber construction equally and is ignorant to the difference between light frame wood construction and mass timber elements. Market research and education to increase familiarity with the qualities of mass timber and the quality of space that can be achieved with wood will be essential to furthering the application of tall wood construction.

While the participants of the survey of International Tall Wood Buildings are considered early adopters and innovators, it is clear from their success that momentum and capacity is growing, making wood a valid structural option for tall buildings with important benefits to consider.

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