Forestry Innovation Investment

Research snapshots 2024/25

Research partnerships and knowledge mobilization

The Exchange | Photos: Jason Harding, courtesy naturallywood.com

About this snapshot collection

This collection of research snapshots offers a concise, accessible overview of the work conducted under FII's Wood First 2024/25 research funding. While these summaries were not a required deliverable in the past, they serve an important role in distilling key objectives, methods, findings, and potential applications from each project. The intent is to support broader knowledge sharing across the sector and enable FII to communicate the impact of this research to government, industry, and public audiences. These snapshots also provide a foundation for showcasing how publicly funded research is helping to advance innovation, sustainability, and forest sector value in B.C. and beyond.

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Research Snapshot

RESEARCH PARTNERSHIPS AND KNOWLEDGE MOBILIZATION

FPInnovations

A Database for Design, Modelling, and Analysis of Timber Structures

What you need to know

The first web-based database of its kind was developed to provide crucial information for the design, modelling, and analysis of timber structures, supporting the application and development of timber structures. Its development was the result of a global effort involving experts from around 50 research institutes, consulting firms, manufacturers, software companies, and associations.

What is the research about?

Computer modelling is essential for the design and analysis of mid- and high-rise buildings and long-span structures. Practicing engineers are relatively unfamiliar with modelling timber structures, and researchers often lack resources for advanced modelling of timber systems. This limitation hinders the broader application and development of timber construction, particularly as timber structures are increasingly required to demonstrate performance or equivalence through computer modelling, regardless of whether prescriptive or performance-based design methods are used. In response, FPInnovations initiated an international collaboration in 2020, involving over 100 experts from 13 countries, and published the first-ever Modelling Guide for Timber Structures (Chen, et al., 2022) in 2022.

However, the input data - another critical element for modelling and analysis - was still unavailable, creating a bottleneck in the design and analysis of timber structures. To address this, FPInnovations initiated another global collaboration in 2024, to develop a web-based database to provide easily accessible, accurate, and reliable data, parameters, and information to support the design, modelling, and analysis of large and tall timber structures (Chen, 2025).

What did the researcher do?

A survey was conducted to identify industry needs for design information, modelling input, and analysis information. This survey aimed to collect specific insights from engineers, software developers, and researchers based on their practices and experiences. Based on the survey results, a detailed roadmap was developed to outline the database structure.

A preliminary version of the database was then created through data collection via literature reviews and outreach to researchers, data

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generation via implementation of theoretical models, analysis of experimental and analytical results, and data calibration.

How can you use this research?

A user-friendly webpage, see Figure 1, was created on the FPInnovations website to provide easy access to the database for the public. The database is planned to be published online in 2025. Engineers and researchers can visit the webpage to download information free of charge to support their timber structure projects.

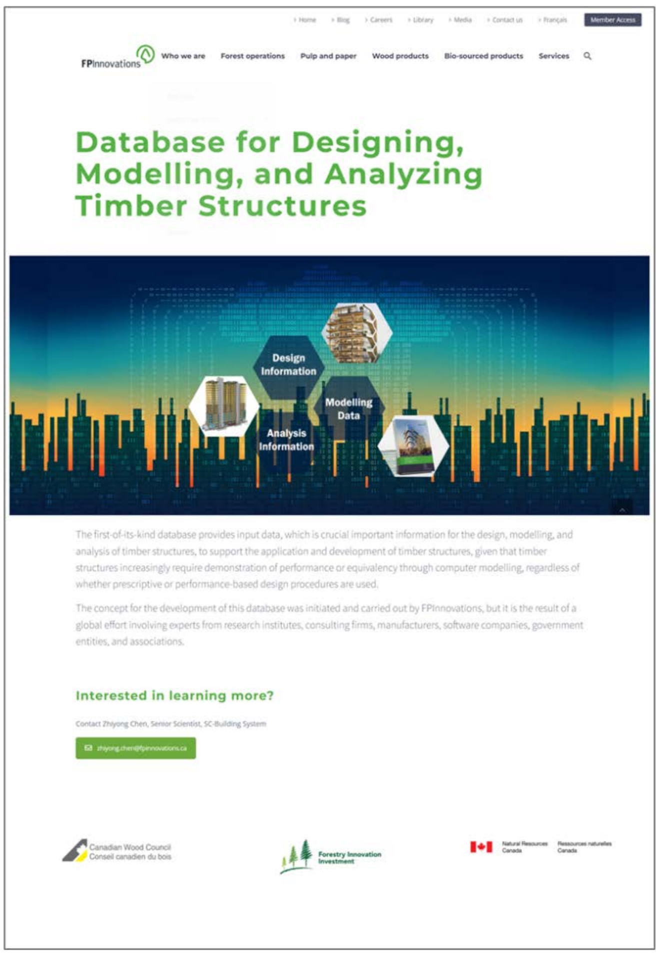

Figure 1. Screenshot of the web-based database

A CSCE Tech Talk Webinar entitled “Numerical Modelling of Timber Structures - Guidelines and Database” was delivered in April 2025 to demonstrate how the modelling guide and the database can be used to support the design, modelling and analysis of timber structures.

About the expert team

Project Lead
Zhiyong Chen, Ph.D., P.Eng.
FPInnovations

The concept for the development of this database was initiated and carried out by FPInnovations, but it is the result of a global effort involving experts from around 50 research institutes, consulting firms, manufacturers, software companies, government entities, and associations, see below.

Keywords

Database; Mass Timber Construction; Design; Modelling; Analysis

Citation

Chen, Z., Tung, D., and Karacabeyli, E. (2022). Modelling Guide for Timber Structures. FPInnovations: https://web.fpinnovations.ca/modelling.

Chen, Z. (2025). A Web-based Database for Supporting the Design, Modelling, and Analysis of Mass Timber Structures (1st Year): FII 2024-25 Project Report.” FPInnovations.

Learn more about this project on the Wood Research Library

Research Snapshot

RESEARCH PARTNERSHIPS AND KNOWLEDGE MOBILIZATION

University of Victoria

Brittle failure of inclined CLT-steel self-tapping screw connections

What you need to know

The failure mode of a CLT-steel self-tapping screw (STS) connection is different from a glulam-steel STS connection due to the cross laminations in a CLT panel. Plug-step shear is the predominant brittle failure mode observed in this research in a CLT-steel STS connection, which has not been included in the STS design provision of CSA O86-24. A mechanics-based equation for plug-step shear was proposed aiming for a more accurate prediction on the failure mechanism and resistance of this type of connection.

What is the research about?

Self-tapping screws (STSs) are popular fasteners in mass timber construction due to their relatively high resistance and ease of installation. A new provision of STS connection has been implemented in the latest Canadian timber design standard, CSA O86-24. However, the brittle failure of inclined STS connections used in a CLT-to-steel connection has not been fully addressed. The current four failure modes (plug shear, step shear, row shear and net tension) in the standard do not reflect the actual failure mechanism of a CLT-steel STS connection. Further research is needed to explore this topic.

What did the researcher do?

A total of 48 steel-to-CLT self-tapping screw (STS) connections were tested at the Structures lab of University of Victoria, which included different insertion angles (45 degrees and 90 degrees), penetration depth (2 layers and 3 layers of CLT panels), lateral load directions (parallel and perpendicular to the major strength direction of CLT panels), and CLT panel width (130 mm as narrow and 390 mm as wide).

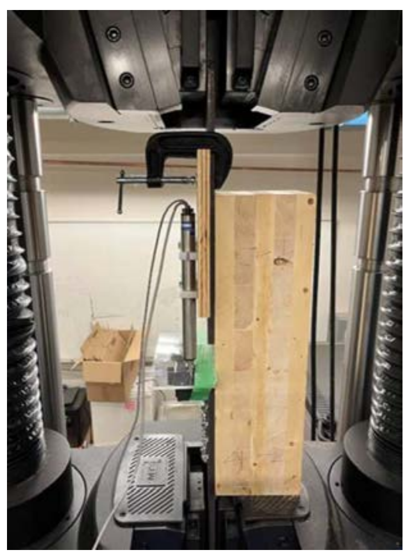

Figure 1: Test set-up of CLT-steel STS connections

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What did the researcher find?

- Plug-step shear was identified as the primary brittle failure mode for a CLT-steel connection using inclined self-tapping screws. There was no pure plug shear observed in this type of connection.

- A mechanics-based equation for plug-step shear was proposed following the same theory for the other brittle failure modes in CSA O86-24. It was noticed that failure planes may not reach their peak resistance at the same time. A reduction factor was introduced to account for this sequential failure mechanism.

Figure 2: Plug-step shear failure (plug shear in parallel to major strength layers and step shear in perpendicular to major strength layers)

How can you use this research?

This research provides a test database for improving the brittle failure prediction of CLT-steel self-tapping screw connections in the Canadian timber design standard, CSA O86-24.

Future research will explore the effect of CLT panel width on the brittle failure mode of self-tapping screw connections. More evidence is needed to determine the reduction factor to account for the sequential failure mechanism in different CLT layers and failure planes.

About the researchers

Dr. Lina Zhou, Associate Professor, Department of Civil Engineering, University of Victoria, funding recipient and principal investigator

Dr. Ying-Hei Chui, Professor, Department of Civil and Environmental Engineering, University of Alberta, project collaborator

Huiqi Wang, master's student, Department of Civil Engineering, University of Victoria

Keywords

CLT-steel connection; Inclined self-tapping screw; Brittle failure; Plug-step shear failure

Citation

Wang, H., Zhou, L. and Chui, Y.H. (2025). "Experimental study on brittle failure of laterally loaded steel-to-CLT connections with inclined self-tapping screws." Proc., 14th World Conf. on Timber Engineering, Brisbane, Australia.

Learn more about this project on the Wood Research Library

Research Snapshot

RESEARCH PARTNERSHIPS AND KNOWLEDGE MOBILIZATION

Developing self-bonded bark cladding products

What you need to know

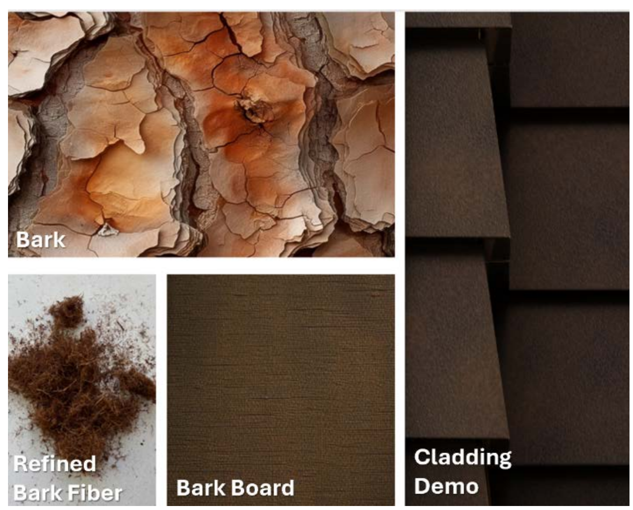
Researchers have developed and begun field-testing a binderless bark board cladding panel made entirely from forest residues. These self-bonded panels, pressed without synthetic adhesives, have promising properties and are now being evaluated on demonstration buildings across Canada for durability and performance.

What is the research about?

To help address wood industry viability there is a need for more sustainable forestry practices such as recycling rather than burning logging residues. This research explored the potential of converting softwood bark into natural, self-bonding exterior building cladding. Phases 1 and 2 of the project focused on furnish modification, optimum pressing schedules, and the mat behaviour under hot pressing. Phase 3 is fabricating larger panels to evaluate their installation and performance as exterior cladding on a demonstration building in the Lower Mainland of British Columbia. Commercialization of the products and local manufacturing is anticipated.

What did the researcher do?

Douglas fir bark in both particle and refined fibre form was hot pressed into panels with a target density of 1050 kg/m^3. The effects of hot press schedule, particle size, and furnish pretreatment on mechanical and physical properties were evaluated. FTIR and TGA analyses were used to study bonding mechanisms. Twelve 24” x 24” binderless bark board panels have also been fabricated for outdoor exposure tests at BCIT. One-factor ANOVA with a 95% confidence level and Tukey’s HSD test were used for statistical analysis.



Bark board development: bark (top left), refined bark fibre (bottom left), pressed bark board (centre), and installed demonstration cladding (right). Image credit: Urban Arts Architecture and Maddie Shen.

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What did the researcher find?

- Bark fibre refining and board density are crucial for consolidation and bonding.
- Pre-treatment with alkali has little effect on panel properties but increases moisture susceptibility.
- Top and bottom caul mesh must be used during hot pressing to avoid blistering.
- Hot press temperature has the greatest effect on board properties, followed by press time. 7 mm thick boards must be pressed at a temperature higher than 200°C, 2.76 MPa for at least 10 min.
- Optimized pressing schedule gives panels with excellent properties: IB = 1.53 MPa, TS = 5.29%, WA = 9.52%, and MOR = 17.14 MPa.
- Interaction between condensation reactions for self-bonding and thermal degradation during hot pressing underscores the need to balance temperature and press time to maximize mechanical strength and dimensional stability of the cladding boards.
- Boards demonstrated strong structural integrity and scalability, with successful pressing of larger panels for demonstration cladding.

How can you use this research?

This bark board project demonstrates potential viable production of high-performance, adhesive-free exterior cladding from forestry waste. Possible adopters of the technology include BC First Nations forestry enterprises which collectively generate large volumes of bark waste. Future work will focus on refining the process to further reduce time and energy consumption, and monitoring the performance of prototype bark cladding products in service.

About the researchers

The research is led by Maddie Shen (MSc student), supervised by Professor Chunping Dai, with support from Dr. Kate Semple (Research Associate), at the UBC Department of Wood Science.



Maddie Shen Kate Semple Chunping Dai

Preliminary tests and site evaluations are supported by Urban Arts Architecture and FII.

Urban Arts Architecture Inc

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international timberframes

Project collaborators include Jordan Edmonds and Marius Hexan from Urban Arts Architecture, Sigi Liebmann of International Timberframes Inc., with financial support from Forestry Innovation Investment (FII).

Keywords

Lignocellulosic Materials; Bark Composites; Building Cladding; Binderless fibreboard; Self-bonding; Mechanical Properties

Citations

Manuscript in progress; citation to be added upon publication.

Learn more about this project on the Wood Research Library

Research Snapshot

RESEARCH PARTNERSHIPS AND KNOWLEDGE MOBILIZATION

UNBC

Dynamic properties of mass timber buildings by vibration testing

What you need to know

Seismic and wind performance assessment of buildings requires an in-depth understanding of their dynamic properties. However, limited knowledge of the dynamic behaviour of mass timber buildings remains an open challenge for researchers and designers [1]. This study aims to characterize the dynamic properties of mass timber buildings through experimental testing.

What is the research about?

Despite the recent development in dynamic characteristics identification of structures, lack of knowledge in the dynamic properties of tall timber buildings is still an open issue for researchers. There are ongoing efforts to develop a database for predicting the vibration performance of timber structures for serviceability and seismic design [2].

This report presents vibration tests conducted on three mass timber buildings and a 2-story balloon-type cross-laminated timber (CLT) shear wall mock-up.

What did the researcher do?

In the spring and summer of 2024, ambient vibration tests (AVTs) were conducted on two 12-story and one 5-story hybrid mass timber buildings located in Canada. The collected data were analyzed by two Stochastic Subspace Identification (SSI) and Frequency Domain Decomposition (FDD) algorithms, and the extracted dynamic properties were compared with the recommended values provided in the 2020 National Building Code of Canada (NBCC) [3] and the 2019 Canadian CLT Handbook [4].

In the winter of 2025, a shaker test was performed on 2-story CLT balloon-type mock-ups with different connection configurations, and their dynamic properties were extracted.

Figure 1. Overall view of, a) 2-story; b)12-story; c) 5-story; d) 12-story tested mass hybrid buildings

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What did the researcher find?

The key findings of this study are summarized as follows:

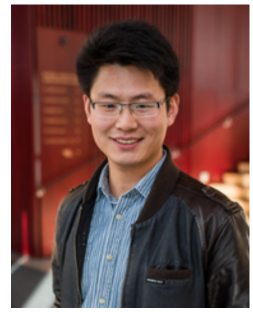
- The fundamental periods calculated using the 2020 NBCC and the 2019 Canadian CLT Handbook differ from the experimental values by up to 33% and 11%, respectively.
- The measured frequencies by SSI and FDD are close, with a difference of less than 3%; however, greater discrepancies are observed in the damping ratios, which show higher uncertainty of damping ratio parameter.
- Up to eight modes were identified for the buildings. These findings provide a more comprehensive understanding of the buildings' dynamic behaviour, including the higher mode effects, and can be used to improve numerical structural analysis in the future.
- The measured damping ratios of the three tested buildings range from 1% to 3%. For the 2-story CLT shear wall mock-up, the damping ratio is less than 10%.
- Test results on the 2-story mock-up indicate that the presence of spline joints between CLT shear walls increases the fundamental frequency by 41%.

How can you use this research?

This research will contribute to a growing database aimed at developing fundamental period empirical formulas specific to mass timber buildings. In addition, the results of this study will serve as a reference for developing finite element models and analytical beam-like models for frequency prediction of mass timber structures. Future research should focus on the seismic analysis of the developed numerical and analytical models.

About the researchers

This research is part of the PhD thesis of Samira Mohammadyzadeh, conducted under the supervision of Dr. Jianhui Zhou. The test on the two-story CLT shear wall was carried out in collaboration with Dr. Thomas Tannert's team.



The financial support from BC Forest Innovation Invest -Wood First program and the Natural Sciences and Engineering Research Council of Canada (NSERC) is greatly acknowledged.

Keywords

Mass timber buildings; Ambient vibration Test; Dynamic properties

Citation

[1] S. Mohammadyzadeh, J. Zhou, L. Hu, Fei Tong, System identification of tall mass timber structures employing ambient vibration test and FE modelling, in: Norway, 2023.
[2] L. Hu, S. Cuerrier Auclair, Advanced Wood-based Solutions for Mid-rise and High-rise Construction: In-Situ Testing of the Arbora Building for Vibration and Acoustic Performances, FPInnovations, 2018.
[3] National Building Code of Canada (NBCC), Canadian Commission on Building and Fire Codes National Research Council of Canada, 2020.
[4] E. Karacabeyli, S. Gagnon, Canadian CLT handbook, 2019th ed., FPInnovations, 2019.

Learn more about this project on the Wood Research Library

Research Snapshot

RESEARCH PARTNERSHIPS AND KNOWLEDGE MOBILIZATION

Embodied carbon reductions using recycled wood through building deconstruction

What you need to know

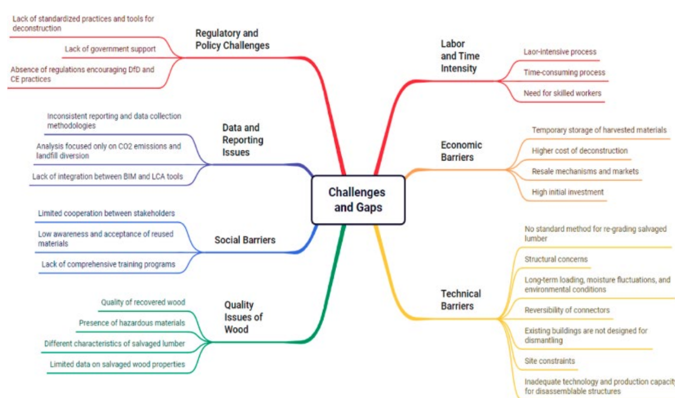
Over 30% of global solid waste comes from construction and demolition, with wood waste largely landfilled or incinerated. This project demonstrates that deconstruction—an alternative to conventional demolition—enables wood reuse, reduces embodied carbon emissions, and supports circular, low-carbon building end-of-life strategies.

What is the research about?

Although wood is highly recyclable and reusable, most of it ends up in landfills or incinerators, contributing to greenhouse gas emissions and resource loss. This research explores deconstruction as a sustainable strategy to recover wood materials, reduce embodied carbon, and support circular construction. Through literature review and case study, it evaluates environmental benefits to inform industry practices and policy development.

What did the researcher do?

The researcher conducted a comprehensive literature review of 41 studies to assess the environmental, economic, and social impacts of wood waste reuse through deconstruction. A comparative life cycle assessment (LCA) was performed using real-world data from a Vancouver case study to evaluate 14 end-of-life scenarios. Field collaboration with a local deconstruction company enabled on-site data collection, validating the environmental performance of reclaimed wood reuse strategies.



Images: Identified challenges and gaps for wood waste circulation through deconstruction.

What did the researcher find?

The researcher found that deconstruction provides clear environmental advantages over conventional demolition, particularly in managing building wood waste. Key findings include:

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- **Literature Review Results:** The literature review of 41 studies revealed that reusing or recycling wood through deconstruction can reduce GHG emissions by more than 50% compared to landfilling or incineration.
- **Case Study Results:** A comparative life cycle assessment of 14 end-of-life scenarios for a 1910 wood-framed house in Vancouver BC showed that optimized deconstruction and wood reuse pathways can reduce embodied carbon by up to 8.36 tonnes CO_2-equivalent per building compared with demolition.
- **Material Recovery:** Fieldwork conducted in partnership with a local deconstruction company confirmed that a substantial portion of structural wood can be recovered in reusable condition, supporting circular material flows.
- **Key Barriers:** Despite its benefits, adoption of deconstruction is limited by regulatory gaps, a lack of standardized methods for material quality assessment, and underdeveloped markets for reclaimed wood.
- **Practical Implications:** The findings are informing the development of industry guidelines and policy recommendations to support wider implementation of deconstruction practices and stimulate demand for reclaimed materials.

How can you use this research?

This research provides valuable insights for policymakers, construction professionals, and sustainability advocates looking to reduce carbon emissions in the building sector. Future research should focus on optimizing deconstruction techniques, improving material recovery processes, and developing standardized quality assessments for reclaimed wood. Key questions remain regarding market incentives and scaling deconstruction practices.

About the researchers

Haibo Feng

Assistant Professor

Wood Science, UBC

Shiyao Zhu

PhD Candidate

Wood Science, UBC

Involved Organizations and Members

Erick Serpas Ventura

VEMA Deconstruction

Stephanie Dalo

CLF British Columbia

Keywords

Life-Cycle Assessment; Deconstruction; Wood Waste; Circular Economy

Citation

Zhu, Shiyao, and Haibo Feng. "Enhancing circularity of wood waste through deconstruction in building sector." *Journal of Cleaner Production* (2024): 144382.

Learn more about this project on the Wood Research Library

Research Snapshot

RESEARCH PARTNERSHIPS AND KNOWLEDGE MOBILIZATION

FPInnovations

Force Modification Factors for Concentrically Braced Timber Frames

What you need to know

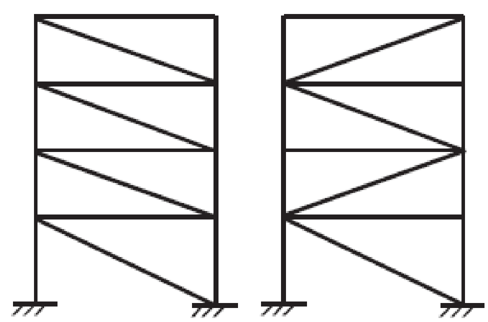
The main objective of the project was to evaluate the ductility-related force modification factors (R_d-factors) for concentrically braced timber frames (CBTFs) with bolted connections with and without self tapping screws (STS) reinforcement. Results showed which connection configurations can be used for moderately ductile (R_d=2.0) and limited ductility (R_d=1.5) categories of frames currently present in the National Building Code (NBC).

What is the research about?

Although braced timber frames (BTFs) are implemented as a seismic force-resisting system (SFRS) in the NBC, no design guidelines for this system currently exist in CSA O86. Results from the study provided valuable information on the performance of CBTFs with various bolted connection configurations under different earthquake ground motions. Results from this study were used to develop the design guidelines for CBTFs in CSA O86.

What did the researcher do?

Hundreds of archetype buildings that use CBTFs as SFRS with different key parameters were designed. The archetypes were located in Montreal, Vancouver, and Victoria to capture the seismicity of Eastern and Western Canada. Non-linear models of the designed archetypes were developed in OpenSees. Models included the connection hysteretic behavior obtained from testing. Evaluation of the R_d-factors for the archetypes was performed by conducting a series of non-linear incremental dynamic analyses (IDAs) according to CCMC guidelines.



CBTF configurations studied: single diagonal braced frame (left), and zigzag braced frame (right)

What did the researchers find?

Results from the IDAs have shown that:

- The R_d-factors for the analysed models were often governed by the shortest (2-storey) archetypes in all locations;

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- Frames with a tier aspect ratio of 3:2 (narrow frames) were more flexible and their pronounced bending behavior during the analysis made the braces less efficient compared to frames with an aspect ratio of 1:1 or 2:3. For these reasons, frames with a tier aspect ratio of 3:2 will not be recommended as an option in the upcoming CSA O86 design provisions. CBTFs with tier aspect ratios between 1:1 and 2:3 led to efficient designs;
- Reinforcing the bolted connections in Douglas Fir with STS provided significant improvement to the frame performance. All frames with reinforced connections were able to satisfy the required performance criteria when designed with an R_d = 2.0 (moderately ductile);
- A factor of 67% (2/3) needed to be applied to the factored design resistance of the unreinforced bolted connections in Douglas Fir and Spruce Pine for them to satisfy the required performance criteria when designed with an R_d = 1.5 (limited ductility);
- CBTFs with bolted connection configurations used in this study could only be allowed in the first three seismic categories SC1 to SC3 in Canada according to NBC at this point.

How can you use this research?

Research findings were helpful in developing the draft design guidelines for CBTFs for CSA O86. Also, they will be helpful to designers looking to use CBTFs as an SFRS as they will no longer need to follow the more strenuous alternative designs path in CSA O86. Further research involving different connection designs is needed for CBTFs to be allowed in high seismic zones (SC4) in Canada. In addition, research is needed to determine the R_d-factors for CBTFs with different connections such as dowels with inserted steel plates, STS, and others.

About the researchers

FPInnovations' research team included:

Marjan Popovski, Ph.D., P.Eng., Principal Scientist, Building Systems, Project Lead

Zhiyong Chen, Ph.D., P.Eng., Senior Scientist, Building Systems

Brandon Rossi, M.A.Sc., Scientist, Building Systems

This research was conducted with funding from BC FII, NRCan, and the FRII initiative.

Mr. Moein Ahmadipour from Altair developed the modules for design of CBTF archetypes.

Ali Mikael and Sarah Stevenson from CWC designed a significant portion of the CBTF archetypes.

Western Archrib donated the glulam for testing the braces with bolted connections.

Keywords

Braced Timber Frames, Seismic Performance, R_d-factors, Mass Timber Construction; Bolted Connections

Citation

Popovski, M., Chen, Z., Rossi, B., Tung, D. (2025). Evaluation of force modification factors for braced timber frames. FPInnovations report on project number 301016331.

Learn more about this project on the Wood Research Library

Research Snapshot

RESEARCH PARTNERSHIPS AND KNOWLEDGE MOBILIZATION

UNBC

Impact of Beam Hanger-Induced Moments on Glulam Column Design

What you need to know

Glulam post-and-beam frames are widely used for gravity load resisting systems. Deep beam connections can introduce large bending to columns which are designed for axial loads only. Design guidance is needed to address these combined loading conditions and ensure the safety and reliability of timber structures.

What is the research about?

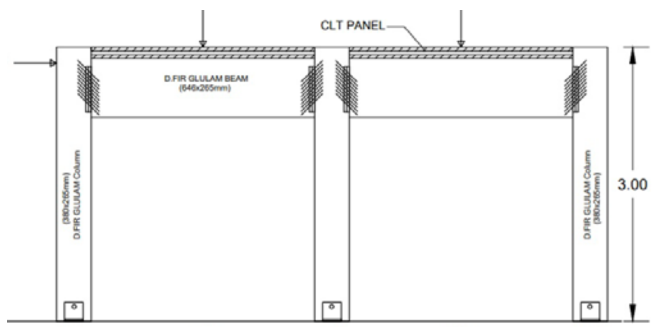
This research aimed to evaluate the impact of the deep beam-induced moment demands on column resistance when the entire post-and-beam frame undergoes lateral drifts along with the lateral-force-resisting system.

Commonly used beam-hanger connectors were adopted for typical frame configurations, which maximize the applicability of the research findings.

What did the researcher do?

Finite element models were developed to represent a single-storey, two-bay glulam frame. Parametric nonlinear static analyses were performed to investigate the frame's lateral behavior, with a focus on column resistance under combined moment and axial loadings.

Full-scale experimental tests were carried out at UNBC's Wood Innovation and Research Lab to validate the numerical findings, using displacement-controlled loading protocols in quasi-static reversed cyclic tests.



Full-scale experimental test on a glulam frame. (Credit: UNBC Wood Innovation Research Lab)

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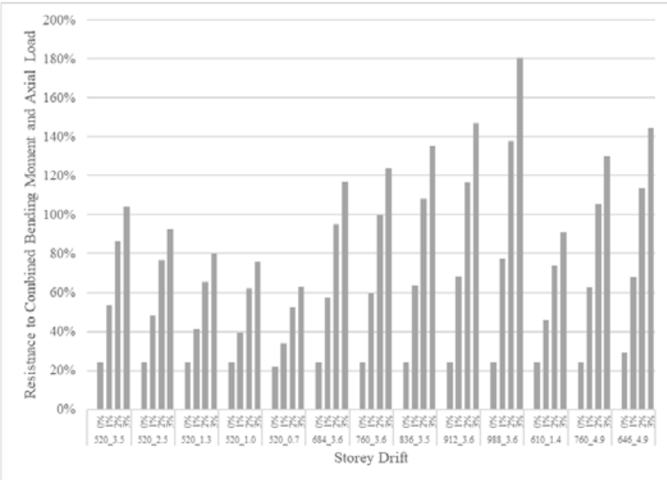
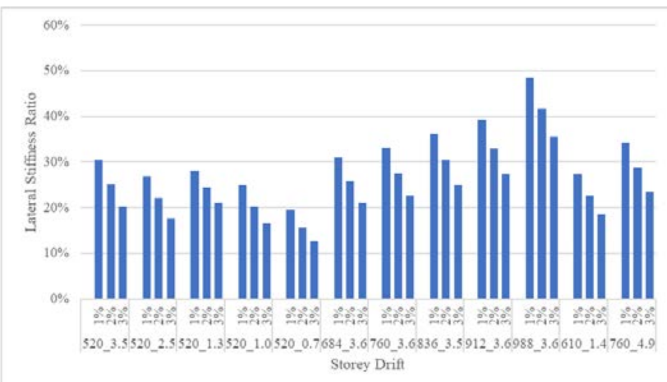


Combined bending moment and axial load design check for the interior column(Credit: Laura Walters)



Lateral stiffness of a beam hanger-connected frame relative to moment-resisting frame.
(Credit: Laura Walters)

What did the researcher find?

Comprehensive numerical and experimental investigations led to several key conclusions:

- Beam hangers used as deep beam-to-post connections induce significant bending moments, causing the combined design demand to exceed code-prescribed resistance by more than 75% at a 2% drift.
- Both beam depth and the beam-to-column stiffness ratio influence the magnitude of the induced bending moments, with beam depth being the primary driving factor.
- The semi-rigid behavior of beam-hanger connections enables gravity load-bearing frames to contribute substantial lateral stiffness to the overall structure and should therefore be considered in lateral design.

How can you use this research?

Findings in this research provide a strong basis for future investigations, including:

- Extended numerical analyses for multi-story frames with columns erected following platform- and balloon-framed construction.
- Empirical formulae to be developed to quantify the rotational stiffness of beam-hanger connections for possible inclusion in the 2029 version of CSA O86 Engineering Wood Design.

About the researchers

The PI, Dr. Fei Tong, P.Eng. is an Assistant Professor with the School of Engineering at UNBC.

The Co-PI, Dr. Thomas Tannert, P.Eng., holds a Canada Research Chair and a BC Leadership Chair in Tall Wood and Hybrid Structures Engineering at UNBC.

Laura Walters was an MASc student who worked on this project and won the Catherine Lalonde Memorial Scholarship due to her research contribution.

Hamid Reza Nasiri is an MASc student who worked on the experimental tests of this project.

The support received from MTC Solutions Inc., Aspect Structural Engineers and the UNBC lab lead Maik Gehloff and technicians James Andal, Nathan Downie and Ryan Stern is appreciated.

Keywords

Glulam, post-and-beam frames, beam hangers, semi-rigid joints, column resistance, lateral design

Citations

Walters, L., Tong, F., Tannert, T., & Wiebe, L. (2025). Moments in timber columns induced by deep beam connections under lateral deformations. In *Proceedings of CSCE 2025 Annual Conference*, Winnipeg, Canada, May 28 - 30.

Walters, L., Nasiri, H., Tong, F., Wiebe, L., & Tannert, T. (2025). Impacts of semi-rigid beam hangers on column resistance and lateral design of post-and-beam frames. In *Proceeding of WCTE*, Brisbane, Australia, June 22 - 26.

Learn more about this project on the Wood Research Library

Research Snapshot

RESEARCH PARTNERSHIPS AND KNOWLEDGE MOBILIZATION

University of Victoria

Moisture content effect on self-tapping screw connections

What you need to know

Due to the hygroscopic characteristics of wood, the dimension of wood element changes when moisture content (MC) changes, which will result in extra stress in both wood and STSs in a steel-to-wood connection. There are no design guidelines to predict this wetting-induced stress in STSs in CSA O86-24. Numerical and analytical models were developed in this research to predict the STS stress caused by MC changes and installation torque.

What is the research about?

Self-tapping screws (STSs) are widely used in mass timber construction due to their high strength and ease of installation. A new provision of STS connection has been implemented in the latest Canadian timber design standard, CSA O86-24. However, the effect of moisture content is not covered in the current version due to a lack of research data. Extra stress in screws in a mass timber connection caused by wetting may be significant and cannot be ignored in design. Failure of STSs has been reported by structural engineers and contractors in several mass timber projects during construction.

What did the researcher do?

A numerical model was developed via ABAQUS utilizing a cohesive zone model to simulate the wood-screw interaction. The model was verified with test data provided by FPInnovations. Two screw diameters (8 mm and 13 mm), four penetration depths (10d, 15d, 20d and 25d), three MC variations (12-16%, 12-21%, 12-30%), and with and without installation torque (0 and 100%) were considered in the parametric analysis. Analytical solutions were proposed for estimation of STS stress development and withdrawal failure.

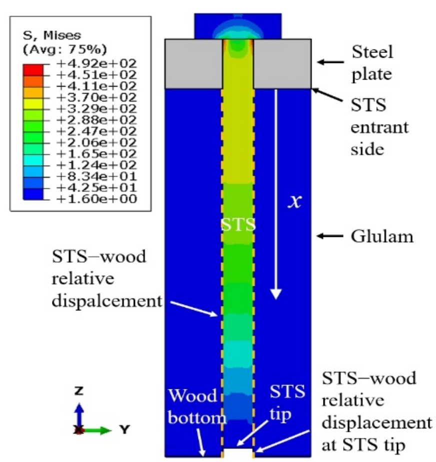


Figure 1: Wetting-induced stress in STS and STS–wood relative deformation

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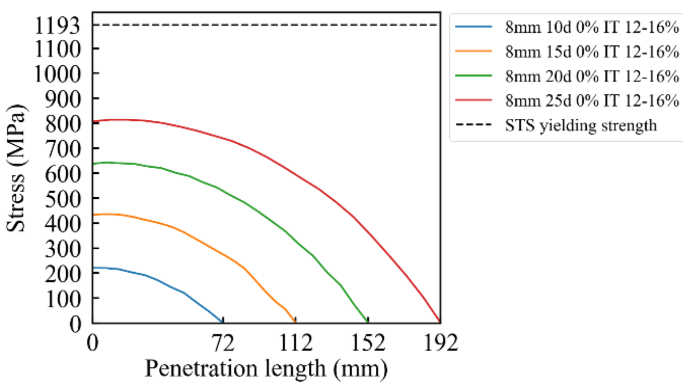
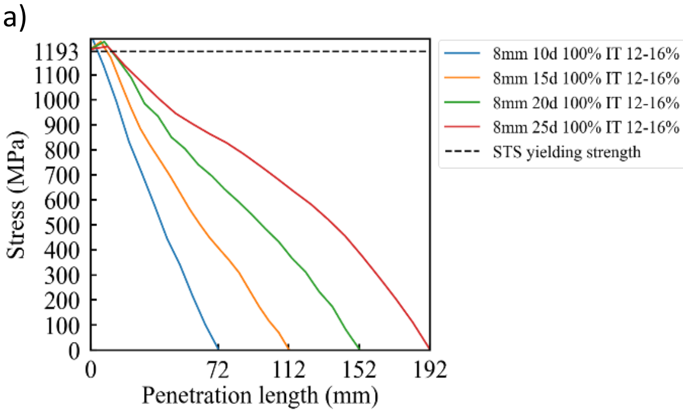
What did the researcher find?

- After wetting exposure, STSs may yield at the entrant point due to combined stress from wetting and installation torque or localized STS withdrawal at the STS tips in a steel-to-wood connection.

- Installation torque significantly increases the risk of STS yielding near STS head, even under minor wetting. However it has minimal effect on the withdrawal failure at STS tips, which is primarily driven by wetting-induced STS-wood relative displacement.



a)



b)

Figure 2: Stress distribution of 8 mm diameter STSs: a) without installation torque (IT); b) with 100% installation torque suggested by STS supplier

How can you use this research?

This research provides a numerical modeling database to consider the effect of moisture content and installation torque on the stress development of STSs.

An excel spreadsheet based on the analytical model developed in this study was created for design engineers to predict the STS stress and withdrawal failure under wetting.

About the researchers

Dr. Lina Zhou, Associate Professor, Department of Civil Engineering, University of Victoria, funding recipient and principal investigator

Dr. Chun Ni, Lead Scientist, Building system, FPInnovations, project collaborator

Jintao Zhang, PhD student, Department of Civil Engineering, University of Victoria

Keywords

Stee-to-wood connection; Self-tapping screw; fully threaded, Moisture content effect; numerical and analytical modes

Citation

Zhang, J., Zhou, L. and Ni, C. (2025). "The effect of specimen size on wetting-induced stress in self-tapping screws in steel-to-wood connections." Proc., 14th World Conf. on Timber Engineering, Brisbane, Australia.

Learn more about this project on the Wood Research Library

Research Snapshot

RESEARCH PARTNERSHIPS AND KNOWLEDGE MOBILIZATION

UNBC

Performance of balloon-framed CLT structures

What you need to know

Cross-laminated timber (CLT) two-storey balloon-framed shear wall structures were tested at the UNBC Wood Innovation and Research Laboratory in Prince George, investigating the impact of:

1) Hold-down screw configuration;
2) Stiffness of vertical joints; and
3) Horizontally spliced panels.

What is the research about?

The 2024 provisions in the Canadian Standard for Engineering Design in Wood CSA-O86 for CLT shear walls are limited to platform-type construction, where one storey's ceiling forms the platform for the next storey's walls.

In contrast, in balloon-type construction, the bearing perpendicular to the wood grain between floors and cumulative shrinkage of the floors over the building height are eliminated, and fewer panels are required to create slender segments.

The objective of this project was to evaluate the performance of balloon-framed CLT structures.

What did the researcher do?

The structures were 1.5 m x 2.0 m in plan and 6 m tall, composed of two coupled balloon-framed CLT panels. The hold-downs were attached with self-tapping screws in two configurations: i) all screws acting in shear; and ii) mixed angle installation. Shear brackets decoupled the uplift from the sliding resistance. Surface-mounted D-Fir splines were used as panel-to-panel connections.

Balloon-framed CLT structure; ©Thomas Tannert

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What did the researcher find?

The main findings can be summarized as follows:

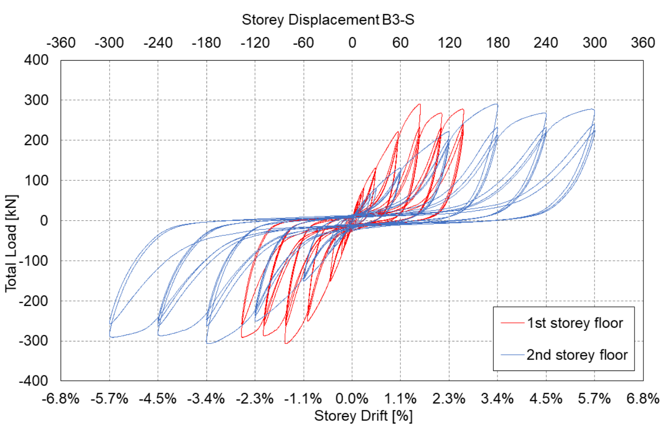
1) The balloon-framed structures exhibited significantly higher strength and stiffness than previously tested platform-type structures.

2) Structures with all hold-down screws acting in shear exhibited higher peak lateral resistance.

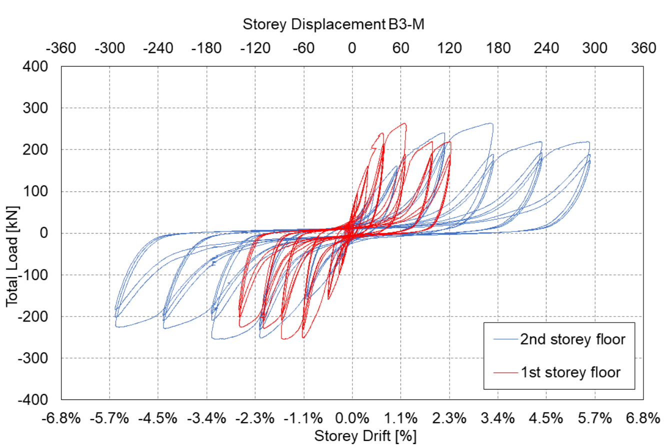
3) Structures with mixed-angle screws in the hold-downs exhibited larger initial stiffness.

4) Stiffer vertical joints increased the initial stiffness and load resistance of the structure.

5) Panels horizontally spliced with tension straps maintained the balloon framing configuration.



Load-displacement behaviour of structure with hold-down screws acting in shear



Load-displacement behaviour of structure with mixed-angle hold-down screws

How can you use this research?

The results will allow engineers and designers to more reliably and efficiently design balloon-framed CLT shear walls. More experimental evidence and numerical studies are needed to develop standardized design guidance. Ongoing research at several Canadian Universities addresses this issue.

About the researchers

The PI, Thomas Tannert, holds a Canada Research Chair and a BC Leadership Chair in Tall Wood and Hybrid Structures Engineering at the University of Northern British Columbia. Abdul Basit is a MASc student at the UNBC School of Engineering.

The support received from Kalesnikoff Lumber Co. Ltd. and MTC Solutions Inc. (in-kind contribution in form of CLT panels and STS supplied at discounted prices), Aspect Structural Eng. and FPInnovations (supporting the application), as well as the UNBC lab lead Maik Gehloff and technicians James Andal, Nathan Downie and Ryan Stern is appreciated.

Keywords

Mass Timber Construction, Lateral Load Resisting System, Shear Walls, Reversed Cyclic Testing

Citation

Abdul Basit & Thomas Tannert (2025) UNBC test report: “Seismic performance of balloon-framed CLT shear walls”.

Learn more about this project on the Wood Research Library

Research Snapshot

RESEARCH PARTNERSHIPS AND KNOWLEDGE MOBILIZATION

UNBC

Structure-borne sound in mass timber buildings

What you need to know

How mass timber floors vibrate and make noise depends heavily on the type of impact (like real footsteps vs. standard tests) [1]. Annoying low-frequency 'thuds' from footfall or jumping are a key challenge in timber buildings [2], requiring specific treatments for different frequency ranges and further research to improve building acoustic comfort [3, 4].

What is the research about?

Mass timber buildings, which frequently utilize Cross-Laminated Timber (CLT) for floor structures, are becoming increasingly popular due to their sustainable advantages. However, these buildings can present acoustic challenges, often suffering from annoying impact sounds such as footsteps traveling between units [2]. This transmitted noise, especially the low-frequency 'thudding' sounds below 100 Hz, is particularly difficult to mitigate with conventional methods and significantly affects resident comfort and perception of quality [4, 5]. Growing concerns exist that standard laboratory impact tests, typically employing tapping machines, may not fully capture the characteristics or annoyance potential of real-life noise events in these lighter-weight structures [1]. Therefore, this research undertakes a detailed investigation specifically comparing how different types of impacts—including realistic human footfalls, the standardized tapping machine, and heavy rubber ball drops simulating activities like jumping or walking [6]—generate structure-borne sound and vibrations within CLT floor systems, aiming to better understand the resulting vibroacoustic behavior under more varied and representative loading conditions.

What did the researcher do?

The researchers meticulously tested CLT floor panels under several important configurations relevant to common construction practices. This included examining the baseline performance of bare CLT panels, the improvements offered by adding a common ceiling system (comprising elements like resilient channels, insulation, and gypsum board), and potentially exploring the effects of different floor topping materials, though details aren't fully provided here. Crucially, these distinct floor assemblies were subjected to a range of impact scenarios designed to simulate both real-world events (like human footfall) and standardized test conditions (using tapping machines and rubber balls). Utilizing advanced measurement equipment,

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including accelerometers, microphones, and data acquisition systems, they thoroughly assessed the impact sound insulation performance, considering both compliance with technical standards and potential links to human perception. Concurrently, they measured the resulting floor vibrations across multiple points and conducted operational modal analysis to understand how the floor structure dynamically responds to impacts. A significant aspect of their methodology was the employment of a velocity-based Integral Transmission Method (ITM) [8], which involves directly measuring the vibration velocity across the floor surface to precisely calculate the sound power radiated by the structure itself, independent of room acoustics. This objective physical characterization of the vibration field is essential for fundamentally understanding the source of structure-borne sounds that ultimately travel through the building and affect occupant perception and acoustic comfort in mass timber environments [2, 3].

Figure 1. Different structure-borne excitations such as footfall, rubber ball, and standard tapping machines

What did the researcher find?

The study revealed several key insights into how floors respond to impacts:

- **Impact Type Affects Perception:** How floor was impacted drastically altered its physical vibration and sound characteristics. Standard tapping machine results were distinct from the broader, lower-frequency responses generated by footfall or the rubber ball. This objective difference strongly suggests occupants would perceive these sounds very differently, influencing annoyance levels and highlighting why standard tests alone may not predict real-world acoustic comfort.
- **Low vs. High Frequencies:** Footfall and rubber ball impacts tended to excite the whole floor more, especially at lower frequencies (the 'thudding' sounds often associated with annoyance). The tapping machine produced more localized vibrations with higher frequency content.
- **Ceiling Performance Varies with Frequency:** Adding a ceiling significantly reduced vibrations and potential noise at mid-to-high frequencies. However, its effectiveness was limited at low frequencies (around 63 Hz), where it could even amplify vibrations due to resonance, demonstrating that acoustic treatments work differently across the frequency spectrum.
- **Measurement Matters:** Measuring directly on the floor surface (using the ITM) indicated higher potential sound levels than sound measured in the room, particularly at low frequencies. This shows that not all floor vibrations translate directly into audible or equally annoying sounds within a space.

How can you use this research?

This research helps designers make more informed choices when selecting floor treatments and ceiling systems, specifically highlighting the persistent challenge of mitigating low-frequency noise. It clearly demonstrates that standard tests, like those using a tapping machine, cannot capture the full picture needed for assessing floor impact sound comfort under realistic conditions. Relying solely on these standard metrics might lead to designs that underperform when subjected to actual footfall impacts. Key questions remain on how these measured physical differences precisely correlate with occupant annoyance levels. Future research must bridge this gap by integrating psychoacoustic studies and critically investigate flanking noise pathways, as sound transmission through walls and junctions often dictates the final acoustic outcome, in order to create genuinely quieter mass timber buildings.

About the researchers

This research originates from work at the University of Northern British Columbia (UNBC), supervised by Dr. Jianhui Zhou. The objective floor performance data supports related studies by PhD student Mohammad Hossein Asadi Jafari, focusing on sound transmission mechanisms (including flanking), and MSc student Jintong Xu, who investigates human perception and annoyance associated with these sounds.



Keywords

Examples: Structural-borne sound, Human Perception, Impact sound

References

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Research Snapshot

RESEARCH PARTNERSHIPS AND KNOWLEDGE MOBILIZATION

Affine CLIMATE SOLUTIONS

Total Cost of Ownership Analysis for Mass Timber Affordable Housing

What you need to know

Mass timber can reduce construction time and carbon impact, but higher insurance, financing, and upfront costs may limit adoption.

This study helps building owners – especially in affordable housing – in evaluating total cost of ownership, including both tangible and intangible factors, to make informed decisions about using mass timber.

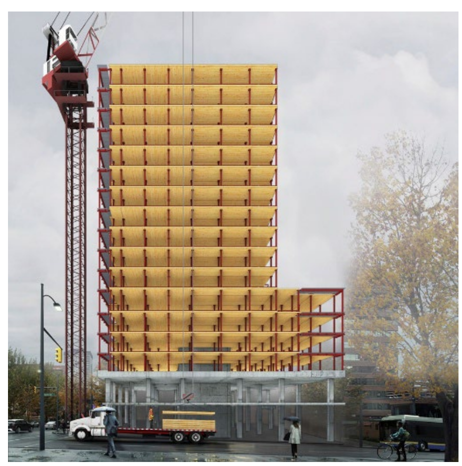
What is the research about?

Mass timber offers a promising solution to housing challenges while advancing climate goals and economic growth. It is gaining momentum in B.C., supported by recent code changes and championing by government, industry, Indigenous groups, and post-secondary institutions. However, challenges around financing, insurance, and construction costs are reducing scalability.

This study uses a hybrid mass timber affordable housing project to evaluate the Total Cost of Ownership (TCO) along 9 key factors that influence construction method decisions. The report serves as a resource for affordable housing providers and other building owners assessing the long-term value of building with mass timber.

What did the researcher do?

To assess upfront and long-term costs and benefits, we applied actual case study project data to a modeled pro-forma of a comparable conventional new construction project built with concrete and steel with similar building performance. This approach allowed us to evaluate the relative strengths and trade-offs associated with each construction method including cost, occupant benefits, and environmental impacts over the building's lifecycle.



Hybrid construction featuring a site-cast concrete podium, concrete core, encapsulated cross-laminated timber (CLT) floor plate, steel columns, and steel-framed balcony. Photo credit: ZGF

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What did the researcher find?

- **Insurance**: Mass timber is often perceived as higher risk, resulting in elevated insurance costs. Course of construction insurance was estimated to be 42% to 180% higher for the hybrid mass timber case study. Project teams must provide detailed information to brokers to manage these costs.
- **Financing**: Mass timber projects have higher upfront equity requirements. Banks may perceive them as higher risk. Public sector financiers may not accommodate different fund advancement schedules.
- **Upfront costs**: The case study's hybrid mass timber structure had a 15% cost premium compared to a conventional concrete tower. However, this was influenced by code constraints and market conditions at the time, which may improve in future projects.
- **Construction time**: A two-month construction time savings was realized compared to a conventional tower.
- **Lifecycle energy costs**: Both building types are expected to perform similarly on energy consumption and costs, assuming equivalent energy performance targets.
- **Replacement and lifespan:** Mass timber structures can match traditional lifespans. Modular elements, like exterior wall panels, allow for easier maintenance and replacement.
- **Occupant benefits**: Mass timber provides strong fire resistance but requires integrated acoustic design.
- **Embodied carbon**: The CLT floor in the case study reduced embodied carbon by approximately 11%.
- **End-of-life**: Mass timber is generally reusable or biodegradable, with reclamation potential influenced by adhesives, fasteners, and design choices.

Key recommendations: Start insurance and financing conversations early, selecting experienced mass timber teams to optimize design and delivery. Prioritize timber in early design and consider alternatives to traditional design-bid-build contracting. Plan for longer procurement timelines and leverage government incentives. Advocate for supportive policies that promote standardization, helping lower costs and accelerating broader adoption over time.

How can you use this research?

The TCO study serves as a practical resource and decision-making tool for building owners – particularly those in the affordable housing sector – who are considering mass timber for their next project. It is especially relevant for owners planning to retain their buildings over the long term.

About the researchers

Lead researcher: Michaela Neuberger, Executive Director, Affine Climate Solutions.

Organizations consulted include:

Community Land Trust, Kindred Construction, ZGF Architects, Canadian Wood Council, Marsh, Hub International, BFL Canada, Flynn Group of Companies, BCNPHA, CMHC, Vancity Credit Union, Vancity Community Foundation, BMO, and Scotiabank.

Keywords

Total Cost of Ownership; Affordable Housing; Co-Benefits; High-rise Buildings; Lifecycle Assessment; Mass Timber Construction

Citation

Affine Climate Solutions. (2025). Total Cost of Ownership Analysis for Mass Timber Affordable Housing: A Guide for Owners and Developers.

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