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NSERC Alliance Grant 'Next-generation Wood Construction'

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An Initiative By:

CANADIAN WOOD CONSTRUCTION RESEARCH NETWORK

INSIDE THIS ISSUE

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A Note from the NSERC Project Coordinator

Dear Wood Construction Community,

As we approach the completion of our successful second year under the NSERC -Alliance Grant Project "Next-Generation Wood Construction," I am deeply grateful to all who have contributed to our ongoing journey. This five-year research project, supported by an NSERC Alliance Grant and funds from partners totalling $6.7 million, continues to support advancements in mass timber construction.

We are pleased to announce that additional funding received from Natural Resources Canada has allowed us to support 6 new projects, and add three junior faculty members to our interdisciplinary team. Together, we are dedicated to addressing challenges in structural safety, fire safety, energy efficiency, durability, and sustainability in wood buildings.

Central to our mission is the advancement of tall wood buildings through collaborative partnerships with industry, government, and the construction sector. With 39 highly skilled HQP trainees actively involved, we are collectively driving innovation and progress in wood construction practices along with creating highly skilled engineers for the society. To further support our HQP trainees, we are introducing a new feature in our newsletter: the HQP Spotlight. Each edition will highlight one of our HQPs, giving them the recognition they deserve and helping them gain visibility within our network and beyond.

As we mark this milestone at the end of the second year, we remain committed to our overarching goals: influencing design standards and building codes, promoting sustainable construction technologies, and quantifying the socio-economic and environmental benefits of wood buildings. Additionally, we are committed to supporting capacity building within the wood industry, nurturing new talent and fostering innovations.

I extend my heartfelt appreciation to each member of our community for your unwavering support and invite you to stay updated on our website and our LinkedIn page.

Warm regards.

Dr. Ying Hei Chui

The Inaugural NextGen Wood Conference 2024

In May 2024, we hosted the inaugural NextGen Wood Conference at Fantasyland Hotel, Edmonton, on May 13-14, welcoming over 110 attendees from various sectors. This event was a pivotal platform for sharing our research and fostering collaboration among designers, manufacturers, builders, regulators, researchers, and students.

Day 1 Highlights: Structural Performance and Fire Safety

The conference kicked off with breakfast and registration, followed by sessions on Structural Performance and Fire Safety. Theme Leaders chaired their respective sessions and the HQPs presented research on seismic performance, structural integrity, and fire safety in wood construction. The day concluded with a formal dinner and a keynote speech **by Mr. Paul Fast**, Founder of Fast+Epp, who provided insightful perspectives on the future of mass timber.

Day 2 Highlights: Building Envelope, Sustainable Technologies, and Expert Panel

Day 2 continued with sessions on Building Envelope and Energy Performance, showcasing advancements in building technologies for sustainability. Dr. Chui introduced Theme-4 and presenters explored eco-friendly construction practices and the role of BIM in prefabricated timber buildings.

An expert panel session convened industry leaders to examine current trends and future directionsin wood construction, enriching attendees' perspectives on industry dynamics.

The NextGen Wood Conference 2024 successfully showcased the latest research and innovations, fostering collaboration and knowledge exchange among participants. We extend our heartfelt thanks to all contributors, participants and volunteer team who made this event a success. Please find links to all the presentations here.

Equity, Diversity, & Inclusion

In our ongoing dedication to equity, diversity, inclusion, and decolonization (EDID), we held a voluntary EDID information survey among our HQPs. We are delighted to share our progress in cultivating a more balanced and inclusive research community. With 39 HQPs now onboard, we're actively advancing gender diversity, evidenced by our team's composition of 75% male and 25% female representation.

Embracing cultural diversity, our team boasts a diverse array of backgrounds, with 30% identifying as visible minorities, 5% choosing not to disclose, and 65% not identifying as visible minorities. Our commitment to inclusivity extends to disability, with 95% reporting no disability and 5% choosing not to respond. Additionally, 5% of our team members identify as Aboriginal, while 95% do not. This diversity data was gathered through voluntary responses from over 50% of our HQPs, underlining our pledge to transparency and inclusivity.

We remain steadfast in our efforts to nurture an environment where every voice is valued and heard, ensuring that our research community is not only diverse but also inclusive and supportive of all its members.

HQP Spotlight: Mr. Javad Tashakori Sourkouhi

Position:

Ph.D. Candidate, Department of Civil Engineering, Lakehead University, ON, Canada

Role and Contributions:

Javad is at the forefront of enhancing CLT-concrete composite floors through his Ph.D. research. Under the expert guidance of Prof. Sam Salem, he has developed and experimentally tested a novel configuration of individual notch shear connections, aimed at improving efficiency and performance under standard fire exposure.

Personal Insights:

Hailing from Guilan University in Iran, Javad graduated with a Master's degree in Structural Engineering, where he delved into the development of advanced design criteria for steel structures. He focused on utilizing the cumulative plastic strain concept for structural steel components. Currently, he is pursuing higher education as a Ph.D. Candidate in Civil Engineering at Lakehead University, where his research centers around investigating the fire behavior of mass timber components in fire conditions, with a keen focus on several fire endurance tests on CLT-concrete composite slabs under standard fire exposure. A diligent researcher dedicated to engineering solutions for structural challenges, I have demonstrated this capability by identifying design gaps in steel structures during my master's thesis. This expertise is further evidenced in my current Ph.D. research on notch shear connection design gaps in TCC floors.

Awards and Scholarships:

Javad has been awarded the Entrance Scholarship for Doctoral International Students from the Faculty of Engineering and the Faculty of Graduate Studies at Lakehead University (2021–2025).

Research Highlights:

To address the pressing need for efficiency in CLT-concrete composite floors, a novel individual notch shear connection configuration, with an insulation interlayer between the components of the composite section, has been introduced for long-span floor systems. This innovative design significantly increased the flexural strength and stiffness, surpassing design limits achievable with other rigid shear connections for Timber-Concrete Composite (TCC) slab-type floors. To date, several full-size TCC slabs have been experimentally examined in the Fire Testing and Research Laboratory at Lakehead University (LUFTRL). The new design of individual notch shear connections enhanced the fire resistance of the investigated TCC floor slabs to surpass the 2-hour fire resistance rating required by applicable building codes for tall mass timber buildings.

Future Plans:

The design of this novel individual notch shear connection examined in full-size CLT-concrete composite floor slabs under standard fire exposure can be further refined through comprehensive finite element (FE) modelling. The development of the FE models will allow for the precise determination of lower and upper-bound composite flexural stiffness design limits for those TCC sections. Subsequently, analytical models can be developed based on the experimental results obtained from the fire endurance tests conducted at LUFTRL and the predictions of the FE models.

Research Updates

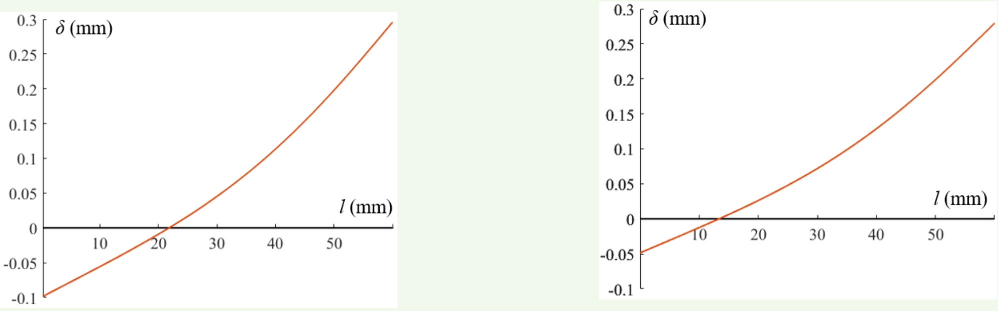
T1-1-F: Stiffness of timber connections

HQP: *Tao Gui, University of Alberta*
Supervisors: *Dr. Ying Hei Chui, University of Alberta, and Dr. Alex Salenikovich, Laval University*

Background and Motivation: In structural design, understanding the stiffness of timber connections is crucial for both ultimate and serviceability limit states designs. Serviceability performance such as vibration and deflection heavily depends on connection stiffness. Current empirical models in design standards often yield conservative estimates due to their limited scope and reliance on simplistic assumptions. Thus, developing generalized mechanics-based models is essential to accurately predict timber connection stiffness, especially for dowel-type fasteners inserted at various angles relative to the shear plane.

Progress Summary: Early models for dowel-type timber connection stiffness have traditionally utilized the Winkler foundation theory, which assumes point-wise load distribution and neglects shear strain effects. To address these limitations, a model based on semi-infinite elastic foundation theory has been derived. An example calculation under specified conditions verified this model, yielding foundation stiffness values of 65.6 N/mm² parallel and 20.9 N/mm² perpendicular to the grain, with a modulus of elasticity for the screw at 210,000 N/mm². Comparing this new approach with the Winkler foundation model, the semi-infinite elastic foundation model predicts a slightly lower displacement (0.27 mm vs. 0.29 mm) and higher stiffness (3642 N/mm vs. 3451 N/mm), showing a 5.55% improvement.

Outcomes: The comparison between Winkler and semi-infinite elastic foundation models, depicted in Figure [1], illustrates the improved accuracy of the latter in predicting displacement and stiffness for timber connections. This outcome underscores the potential for more precise structural analyses and design optimizations in timber construction.



(a) Winkler foundation (b) Semi-infinite elastic foundation

Figure 1:Displacement

Next Steps: The next phase of research will work on further expanding the semi-infinite elastic foundation model to target connections consisting of self-tapping screws (STS) and steel dowels. Additionally, an extensive experimental program will be conducted. This program aims to investigate the impact of various parameters such as fastener type (steel dowel and STS), insertion angle, number of fasteners, fastener diameter, timber product variations, and pre-drilling on connection stiffness and strength. These experiments will serve to validate and refine the developed connection stiffness models, enhancing their applicability and reliability in structural design practice.

Research Updates

T-1-2-C: Resilient Timber Buildings Structural Performance

HQP: *Biniam Tekle Teweldebrhan, University of Waterloo*
Supervisor: *Dr. Solomon Tesfamariam, University of Waterloo*

Background and Motivation: Current seismic design practices for timber buildings often rely on prescriptive approaches, which may not sufficiently address resilience factors crucial for minimizing economic losses and prolonged building downtime post-seismic events. This research aims to pioneer a resilience-based design methodology tailored for tall timber structures, aiming to enhance their performance and recovery capabilities.

Progress Summary:

Task 1: Developing CLT Shear-wall and Glulam Moment Resisting Frame (CLTW-GMRF) System

The research successfully designed and developed baseline CLTW-GMRF mass timber buildings using established seismic guidelines. Key features include CLT balloon shear-walls, glulam moment-resisting frames, replaceable steel dampers in beam-column joints, buckling-restrained brace hold-downs, and conventional column-base joints. Archetype CLTW-GMRF buildings were modeled in OpenSees, investigating their performance under static and dynamic conditions with ground motions aligned to the NBC 2020 seismic hazard model.

Task 2: Performing Seismic Loss and Resilience Assessment of the System

A resilience framework was developed to assess functional recovery following seismic events. Nonlinear time history analyses conducted in Task 1 informed simulations of various damage scenarios via Monte Carlo Simulation (MCS). Using PELICUN, seismic losses—including repair costs and times—were quantified for each system component based on FEMA P-58 (2018) consequence functions and data from experimental works. Current efforts include refining downtime calculations to incorporate factors delaying repair initiation, utilizing advanced repair time and scheduling frameworks.

Outcomes:

- Task 1: Examination of the feasibility and effectiveness of the CLTW-GMRF system in high-rise hybrid construction, exploring variations in wall-to-frame moment ratios and seismic modification factors.
- Task 2: Quantification of structural and non-structural damages to evaluate seismic losses and resilience. Ongoing development of building-specific recovery trajectories to outline expected timelines and processes for re-occupancy, functional recovery, and full functionality restoration post-seismic events.

Next Steps:

Future research will focus on refining the damage fragilities and resilience assessment of the developed system through available experimental studies and field applications. The study will identify and enhance components that contribute to prolonged system downtime, thereby improving the overall seismic resilience of tall timber buildings. Beyond evaluating seismic loss and resilience of the code-compliant baseline system, the ultimate goal is to propose an innovative resilience-based seismic design framework for tall timber buildings. This framework aims to minimize economic losses and achieve targeted building downtime post-seismic events.

T2-1-C: Design Fires and Charring Rates for Mass Timber Analysis

HQP: *Ethan Philion, York University*

Supervisor: *Dr. John Gales, York University*

Background and Motivation: The "Design Fires and Charring Rates for Mass Timber Analysis" project, now in its second year, seeks to address critical gaps in understanding the fire performance of mass timber structures. Current practices often rely on empirical data, highlighting the need for advanced charring rate modeling and experimental validation to enhance safety and performance in timber construction.

Progress Summary :

Year One Achievements: Initial efforts focused on conducting baseline experimental tests on engineered wood and solid lumber. Additionally, a comprehensive literature review on charring modeling (Theme 1i) provided insights into predictive capabilities for charring at larger scales across different wood type

Current Year Developments: PhD candidate Ethan Philion conducted new small-scale experimental tests (Theme 1ii) to investigate underlying mechanisms and improve modeling tool performance. Collaborating with HQP Katie Chin, validation using LS-DYNA (Theme 2iv) successfully replicated charring trends and identified areas for further exploration, such as moisture dynamics and temperature measurement reliability. Their research paper, "Fire Performance of Canadian Hardwood and Softwood," has been accepted for publication in Structural Engineering International (May 2024).Ethan is progressing towards completing his graduate coursework and defending his doctoral proposal this year. Comprehensive exams in Fire Testing, Fire Modeling, and Timber Structures were overseen by Dr. Panos Kotsovinos, enhancing Ethan's expertise. Additionally, a collaborative conference proceeding with Anne Davidson explored BIM's role in enhancing collaboration for timber fire dynamics at the SFPE Performance-Based Design Conference.

Outcomes: To assess parameter effectiveness, correlation charts based on nearly 40 tests have been prepared, illustrating factors influencing charring characteristics. Plans for publication include submission to an appropriate journal special issue.

Next Steps: Significant quantities of CLT panels from Element 5 have been acquired and stored at York University and the University of Waterloo for large-scale tests (Theme 1iii), focusing on optimal instrumentation and technology for precise charring measurement. A proof-of-concept test using narrow spectrum illumination technologies on a large solid wood sample demonstrated real-time degradation and approximate charring layer thickness estimation. Results from this test will be presented at the Structures in Fire conference in June, titled "Towards Alternative Fire Design Solutions for Canadian Wood-to-Wood Connections.“

Follow-up tests on two glulam beam samples are scheduled, with detailed char measurement procedures documented for presentation at CONFAB in London, titled “Advancements in the Characterization of Structural Material High-Temperature Deformation.”

Co-PI Daniel Lacroix has recruited Adrian Lau for a MASc program starting in September 2024 and is in discussions with Element 5 to procure glulam samples to complement CLT studies. Continuing efforts include gathering cutting-edge research articles to inform and enhance experimental designs following the WCTE 2023 conference in Oslo.

This structured approach ensures comprehensive exploration of fire performance in mass timber, advancing theoretical understanding and practical applications in timber construction safety and resilience.

Research Updates

T3-2-C: Improved Resiliency against damage caused by indoor water leakage

HQP: *Bisrat Tariku, University of Victoria*

Supervisor: *Dr. Phalguni Mukhopadhyaya, University of Victoria*

Background and Motivation: This study evaluates the impact of indoor water leakage on mass timber buildings, particularly focusing on plumbing issues in CLT (Cross-Laminated Timber) buildings. Both laboratory experiments and hygrothermal simulations using WUFI (Wärme Und Feuchte Instationär) Hygrothermal Simulation software will be employed to assess the responses of individual CLT floor panels under different assemblies and water leakage scenarios. The primary objective is to assess the resiliency and durability of mass timber buildings when exposed to incidental water leakage.

Progress Summary: For each test scenario, three specimens are used. The apparatus includes drying desiccants silica gel, devices for measuring room air flow rate, relative humidity (RH), and temperature, point moisture measurement sensors, and a weight scale. The procedure involves cutting and polishing the CLT samples, installing moisture sensors from the bottom surface to measure moisture at different layers, sealing all surfaces except for the exposed ones, and subjecting them to a free water pooling for four weeks in an environmental chamber that is set to replicate indoor condition. After the exposure period, the samples are swept to remove any remaining water and left in the chamber for further observation. Subsequently, hygrothermal simulations will be conducted to estimate the long-term performance and potential mold growth on the structure. By varying certain parameters while keeping others constant, we can identify which factors have the most significant impact on the results.

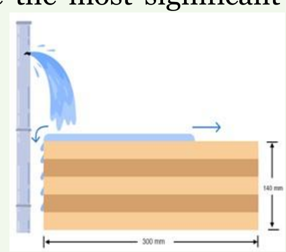


Fig. 1: A Diagram of Water Fountain

Specific test scenarios include:

- Top surface exposed.
- Top surface exposed with single surface spline connection.
- One End grain surface exposed.
- Top surface exposed with checks and cracks.
- One end grain surface exposed with concrete topping.
- One end grain surface exposed with concrete topping; top surface cracked.
- One end grain surface exposed with concrete topping and a water-resistive membrane underneath.

Outcomes: The laboratory experiments and simulations aim to identify which factors most significantly impact the resiliency and durability of CLT panels under water leakage scenarios. This will involve analyzing the moisture distribution within the panels, the impact of different assembly configurations, and the effectiveness of water-resistive measures

Next Steps: The next steps include:

- Conduct the planned laboratory experiments to observe the behavior of CLT panels under various water exposure conditions.
- Perform hygrothermal simulations to estimate long-term performance and potential mold growth.
- Analyze the data from the experiments and simulations to identify key factors affecting the resiliency of CLT panels.
- Document the findings and prepare for dissemination through reports or potential publications.

This approach aims to provide a better understanding of the impact of indoor water leakage on mass timber buildings, which can inform future research and practices in the field.

Research Updates

T4-2-B: LCA of material and utility flows from forest to wood buildings in Canada

HQP: *Bidhan Bhuson Roy, University of British Columbia*

Supervisor: *Dr. Qingshi Tu, University of British Columbia*

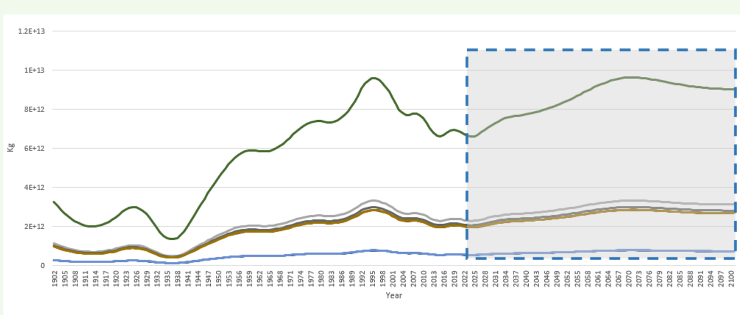
Background and Motivation: In pursuing sustainable practices and environmental conservation, the role of wood as a carbon storage medium has garnered increasing attention. Recognizing the need to unlock its full potential, our project, titled "LCA of Material and Utility Flows from Forest to Wood Buildings in Canada," delves into the intricate dynamics of wood's journey, emphasizing the crucial importance of systematic end-of-life management for wood wastes. Wood's inherent advantage lies in its renewability and capacity to sequester carbon, making it a valuable asset in the fight against climate change.Wood waste management is at the forefront of our endeavor, driven by the belief that the sustainable use of wood requires a comprehensive approach. The project recognizes that recycling options must be thoroughly exhausted before pursuing energy recovery to preserve the intrinsic value of wood.

Progress Summary:

Objective 1: Quantifying Prospective Demand for Wood Products This objective addresses the need to estimate the demand for wood, particularly in carbon-intensive sectors like construction, power, and transportation. By applying socio-economic scenarios, we aim to provide insights into wood consumption patterns and advocate for its use as a viable alternative to traditional carbon-positive materials.

Objective 2: Optimizing End-of-Life Pathways for Wood Wastes This objective focuses on optimizing end-of-life pathways for wood wastes to enhance wood circularity. By prioritizing recycling options over energy recovery, we aim to improve carbon retention and environmental conservation.

Outcomes: Our project aims to position wood as a key player in the transition to a carbon-neutral future by addressing modelling gaps, quantifying demand, and optimizing end-of-life pathways. Through comprehensive research and scenario analysis, we expect to provide valuable insights into the sustainable use of wood, enhancing its role in various sectors while promoting environmental conservation and carbon sequestration.



Projected demand for wood and other materials from our preliminary model

Next Steps: We will develop socio-economic scenarios to predict wood consumption patterns, enhance end-of-life management strategies by prioritizing recycling over energy recovery, and publish our findings while engaging with stakeholders to promote sustainable wood use. This structured approach ensures a comprehensive understanding of wood's potential in combating climate change, informing better practices, and contributing to a sustainable and circular economy.

Outreach Activities

Monthly HQP Seminars

We have been actively organizing monthly HQP (Highly Qualified Personnel) seminars. These seminars are an excellent platform for disseminating knowledge, promoting collaboration, and showcasing the latest advancements within our network. Below is a recap of recent seminar highlights:

- **Seminar 1 (September 2023):** Dr. John Gales initiated the series with a presentation on "Important Factors in Growing Canadian Wood Engineering Education.“
- **Seminar 2 (October 2023):** Dr. Robyn Braun taught the HQPs strategies for mastering "Technical Writing: Audience, Clarity, and Feedback.“
- **Seminar 3 (November 2023):** Dr. Lina Zhou followed with a discussion of her insights into "Seismic Performance of Light Wood Frame Shear Walls.“
- **Seminar 4 (December 2023):** Dr. Thomas Tannert highlighted his latest work on "Seismic Performance of Cross-Laminated-Timber Shear Walls and Recent Research on Hold-Downs.“
- **Seminar 5 (January 2024):** Dr. Mickey Richards shared her thoughts on "Promoting Equity, Diversity, and Inclusion in Engineering: A Holistic Perspective.“
- **Seminar 6 (February 2024):** Dr. Yuxiang Chen provided a comprehensive overview of "Design, Construction, and Actual Performance of Prefabricated Wooden Houses.“
- **Seminar 7 (March 2024):** Dr. Hua Ge delivered an engaging seminar on "High Performance Building Envelope for Climate Resilient and Carbon Neutral Buildings.“
- **Seminar 8 (April 2024):** Diego Flores gave a seminar on "Mastering Structural Design: A Quick Overview of Shear Walls, Sizer, and Connections Software.“
- **Seminar 9 (May 2024):** Dr. Cristiano Loss presented a seminar on "Composite and Hybrid Mass Timber-Steel Floors: Engineering by Connections Design and Detailing."

These seminars not only facilitate the exchange of ideas but also fortify the research community by fostering active participation and networking among members. We take pride in witnessing such diverse and impactful research being shared and anticipate more insightful sessions in the months ahead.

Our sincere thanks to all presenters and participants for their valuable contributions, fostering knowledge exchange and elevating the professional development of our academic community. Please find links to all the presentations here.

Theme-Specific Workshops

In February 2024, we hosted a series of workshops, starting with the **Theme 1 workshop** on Structural and Serviceability Performance on February 6th. This event saw 52 attendees and featured 11 presentations that explored various aspects of structural integrity and serviceability in wood constructions, providing attendees with a wealth of knowledge.

Theme 2 workshop, held on February 14th, focused on Fire Safety. This critical session attracted 46 participants and included 7 presentations covering essential fire prevention and safety measures in wood construction. The engaging discussions highlighted the importance of fire safety and shared valuable strategies and innovations.

On February 20th, the **Theme 3 workshop** on Building Envelope and Energy Performance drew 46 attendees and featured 9 presentations. This workshop showcased the latest advancements in building envelope technologies and energy performance, fostering discussions on enhancing building efficiency and sustainability.

Concluding the month, the **Theme 4 workshop** on Sustainable Construction Technologies and Practices took place on February 27th. With 34 attendees and 4 presentations, this session emphasized innovative and eco-friendly construction practices, contributing to our collective efforts toward sustainable construction. These workshops significantly enhanced knowledge dissemination and collaboration within our network, setting a strong foundation for future events.