Modeling of Cross-Laminated Timber (CLT) panels loaded with combined out-of-plane bending and compression

https://research.thinkwood.com/en/permalink/catalogue2842

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Organization: Southeast University
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Publisher: Elsevier

Year of Publication: 2022

Country of Publication: China
Canada

Format: Journal Article

Material: CLT (Cross-Laminated Timber)

Application: Columns
Walls

Topic: Mechanical Properties

Keywords: Rolling Shear
Beam-and-Column
Analytical Model
Load-Carrying Capacity

Language: English

Research Status: Complete

Series: Engineering Structures
Summary:
Rolling shear is one of the major concerns that significantly impact the performance of CLT walls if they are subjected to combined out-of-plane bending and compression loads. Because the effects of rolling shear and out-of-plane bending are coupled to each other, prediction of the load-carrying capacity of CLT wall is always a challenge for the design of CLT structures. Current design codes employ an Ayrton-Perry type interaction equation as the failure criterion to check the safety of a CLT panel loaded with combined bending and compression. Nevertheless, there is no model available to predict their load-carrying capacity. The presented work aims at developing an analytical model to predict the load-carrying capacity of CLT wall loaded with combined out-of-plane bending and compression. In total 12 five-layer CLT panels loaded with different initial load eccentricities were tested to investigate the failure modes. Observed during the test were two ultimate failure modes, i.e., compression crush on the concave side and tension rupture in convex side. Based on these failure modes and deeming the test member as a beam-column, an analytical model which takes rolling shear effects into account to predict the load-carry capacity of CLT compression-bending members was developed. An explicit formula based on compression failure mode was proposed. The model is capable of determining the distribution of rolling shear stress along longitudinal direction, rolling shear-induced axial force and moments in CLT beam-columns. By calculating the load-carrying capacities of the specimens tested in this study as well as the additional three- and seven-layer specimens tested by another studies, it was found that the compression failure mode-based formula can provide good agreements with the test results.

Online Access: Free

Resource Link
https://doi.org/10.1016/j.engstruct.2021.113335

What Is the Impact of Mass Timber Utilization on Climate and Forests?

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As the need to address climate change grows more urgent, policymakers, businesses, and others are seeking innovative approaches to remove carbon dioxide emissions from the atmosphere and decarbonize hard-to-abate sectors. Forests can play a role in reducing atmospheric carbon. However, there is disagreement over whether forests are most effective in reducing carbon emissions when left alone versus managed for sustainable harvesting and wood product production. Cross-laminated timber is at the forefront of the mass timber movement, which is enabling designers, engineers, and other stakeholders to build taller wood buildings. Several recent studies have shown that substituting mass timber for steel and concrete in mid-rise buildings can reduce the emissions associated with manufacturing, transporting, and installing building materials by 13%-26.5%. However, the prospect of increased utilization of wood products as a climate solution also raises questions about the impact of increased demand for wood on forest carbon stocks, on forest condition, and on the provision of the many other critical social and environmental benefits that healthy forests can provide. A holistic assessment of the total climate impact of forest product demand across product substitution, carbon storage in materials, current and future forest carbon stock, and forest area and condition is challenging, but it is important to understand the impact of increased mass timber utilization on forests and climate, and therefore also on which safeguards might be necessary to ensure positive outcomes. To thus assess the potential impacts, both positive and negative, of greater mass timber utilization on forests ecosystems and emissions associated with the built environment, The Nature Conservancy (TNC) initiated a global mass timber impact assessment (GMTIA), a five-part, highly collaborative research program focused on understanding the potential benefits and risks of increased demand for mass timber products on forests and identifying appropriate safeguards to ensure positive outcomes.

Online Access: Free
Deconstructable Hybrid Connections for the Next Generation of Prefabricated Mass Timber Buildings

https://research.thinkwood.com/en/permalink/catalogue2809

Author: Shulman, Samuel
Loss, Cristiano

Organization: University of British Columbia

Year of Publication: 2021

Country of Publication: Canada

Format: Report

Material: CLT (Cross-Laminated Timber)

Application: Floors
Hybrid Building Systems
Shear Walls

Topic: Connections

Keywords: Steel Rods
Epoxy
Push-Out-Shear Tests
Prefabrication
Disassembly
Reuse

Language: English

Research Status: Complete
Summary:
Timber has been used for building construction for centuries, until the industrial revolution, when it was often replaced by steel and concrete or confined to low-rise housings. In the last thirty years however, thanks to the development of mass timber products and new global interest in sustainability, timber has begun to make a resurgence in the building industry. As building codes and public perception continues to change, the demand for taller and higher-performance timber buildings will only grow. Thus, a need exists for new construction technology appropriate for taller mass timber construction, as well as for fabrication and deconstruction practices that respect wood’s inherent sustainable nature. With this in mind, this research program aims to develop a new hybrid shear connection for mass timber buildings that allows for easy construction, deconstruction, and reuse of the structural elements.

This report includes results of Phase 1, which focused on connections consisting of partially threaded 20M and 24M steel rods bonded into pockets formed in CLT and surrounded by thick crowns of high-strength three-component epoxy-based grout. A total of 168 specimens were designed and fabricated, and push-out shear tests carried out with a displacement-controlled monotonic loading protocol. Strength and stiffness values were assessed and effective failure modes in specimens identified. These latter, along with the recorded load-deformation curves, indicate that it is possible to develop mechanics-based design models and design formulas akin to those already used for typical dowel-type fastener timber connections. Additionally, the specimens were easily fabricated in the lab and quickly fastened to the test jig by means of nuts and washers, suggested such connections have a strong potential for prefabrication, disassembly, and reuse.

Online Access: Free

Resource Link

Enhancing Thermal and Mechanical Performance of Engineered Wood Product Adhesives using Novel Fire Retardant Nanoclays
https://research.thinkwood.com/en/permalink/catalogue2810

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Organization: University of British Columbia
Year of Publication: 2021
Country of Publication: Canada
Format: Report
Material: CLT (Cross-Laminated Timber)
Application: Wood Building Systems
Topic: Mechanical Properties
Fire
Summary:

One component PUR adhesive is widely used in engineered wood products applications, such as cross-laminated timber (CLT). However, the dramatic deterioration of PUR adhesive bond strength at elevated temperature can out tremendously threat for tall wood building, especially under fire. In this project, we are aiming to improving the bond strength of the PUR adhesive at high temperature by incorporating chemically modified halloysite to improve the poor interface between inorganic fillers and the polymer matrices. To improve the interaction with PUR (Loctite UR20 by Henkel®), the halloysite was chemically grafted with polymeric diphenylmethane diisocyanate (pMDI) (pMDI-H). The effect of adding pMDI modified halloysite to the PUR adhesives was investigated in terms of nanofiller dispersibility, thermal and mechanical properties of the pMDI-halloysite-PUR composite film, and the bonding shear strength of the glued Douglas fir and Spruce-Pine-Fir (SPF) shear blocks under different temperature.

Significant improvement of the bond shear strength can be observed with the addition of 5 and 10% of pMDI-modified PUR adhesive, and the key research findings are summarized as below,

a. pMDI can be successfully grafted onto hydroxylated halloysites to improve its dispersibility in one-component PUR adhesive;
b. Addition of pMDI-H into PUR adhesive can lead to improved glass transition temperature and storage modulus. In contrast, no significant enhancement was observed in h-H added PUR films due to the poor dispersibility;
c. Addition of up to 10% h-H and pMDI-H did not show significant change of the shear strength at 20 °C for both Douglas Fir and SPF;
d. Significant enhancement of shear strength at elevated temperature (60-100 °C) can be observed for 5% and 10% pMDI-H modified PUR adhesive, showing 17% improvement for Douglas Fir and 27-37% for SPF.

Resource Link

Expanding wood use towards 2025: development of mass timber midply wall systems, year 1

https://research.thinkwood.com/en/permalink/catalogue2907

Author: Chen, Zhiyong
Ni, Chun
Dagenais, Christian
Hu, Lin

Organization: FPInnovations

Year of Publication: 2021
Country of Publication: Canada
Format: Report

Material: CLT (Cross-Laminated Timber)

Application: Walls
Shear Walls

Topic: Seismic

Keywords: Performance
Building Construction
Building Materials
Standard

Language: English

Research Status: Complete

Summary:

Mass timber (MT) building systems are gaining momentum around the world, especially in Canada where Federal and Provincial governments encourage the greater use of wood in construction projects through various promotion programs such as GCWood Program. In the meanwhile, seismic design provisions in the 2020 National Building Code of Canada have been revised, resulting in significantly higher seismic loads for structures in many locations. Consequently, there is a need to develop new lateral load resisting systems that allow mass timber structures to better compete against their counterparts in steel, concrete and masonry. Building on the success of midply shear walls for wood-frame construction, a multi-year research project was initiated at FPInnovations to develop MT version of midply shear wall systems that have greater structural capacities, fire, and acoustical performance.

In the first year of this project, literature reviews were conducted to identify the code requirements on MT components and to survey the available LLRSs used in the MT structures. Conceptual MT midply wall systems meeting structural, fire, and acoustical performance requirements were proposed. An advisory group meeting was held to evaluate the practicability of the proposed MT midply systems. In the next fiscal year, the proposed MT Midply will be optimised further according to the comments and suggestions from the advisory group. Analytical evaluation of the proposed MT Midply wall systems along with necessary tests will be conducted. Based on the evaluation, a go / no-go decision will be made as to whether the study should be continued for the proposed MT Midply.

Online Access: Free

Resource Link

https://library.fpinnovations.ca/en/permalink/fpipub8111
Cross-laminated timber (CLT) is a large prefabricated solid engineering plank made of multiple layers of planks glued together and it is primarily used in structures such as the floors, walls, and roofs of buildings. ANSI/APA PRG 320 is the world recognized CLT lumber production standard, and the main raw material of CLT has always been softwood rather than hardwood. However, the bending strength, compressive strength, and shear strength of hardwood CLT lumber are stronger than softwood CLT lumber. The large and underutilized hardwood resources in central and southern Ontario provide a huge resource advantage for the hardwood CLT project. This article uses the Cost-Benefit Assessments model to assess the feasibility of investing in hardwood CLT plants in central and southern Ontario. The results show that the payback period of the hardwood CLT factory is 5 years, and the rate of return on investment of 10 years, 15 years, and 20 years are all-around 11%. This study could strengthen investor confidence and it also identifies the direction for the development of hardwood CLT plants in central and southern Ontario.
In-situ performance testing of a four storey CLT building in Vancouver. Building vibration and sound insulation

https://research.thinkwood.com/en/permalink/catalogue2909

Author: Sadegh-Mazloomi, Mohammad
Organization: FPInnovations
Year of Publication: 2021
Country of Publication: Canada
Format: Report
Material: CLT (Cross-Laminated Timber)
Application: Floors
Topic: Acoustics and Vibration
Keywords: Ambient Vibration Testing, Acoustic Testing, Insulation
Language: English
Research Status: Complete

Summary:

FPInnovations has been conducting a series of field testing on wood mid-rise and tall wood buildings, including this 4-story mass timber building in Vancouver, to measure their dynamic performance. The general objectives of the field measurements of the building wind-induced vibrations and sound insulation performance are to develop improved knowledge and assemble a database of wind-induced vibration and sound insulation performance of mid-rise and tall-wood buildings. Ambient vibration and ASTM acoustic testing were performed to measure the dynamic performance of the building including the building natural frequencies, damping ratios and mode shapes. It was found that the measured first natural frequency and damping ratio of this building are overall similar to those measured from other 4-storey buildings that have exhibited good wind-induced vibration performance. The measured apparent impact insulation performance (AIIC) of 58 is considered as a satisfactory sound insulation performance indicator according to FPInnovations’ field experience about occupant satisfaction. It is believed that the test results will help the designers to obtain insight into the construction details of the building and the correlations between the details and the final performances in terms of building dynamic and sound insulation performance. Furthermore, the test results provided reliable data on the vibration and the sound insulation performance of the selected floor assemblies. The measured AIIC, building natural frequencies, and damping ratios can provide technical reference to architects and engineers to verify their designs and the design tools used.

Online Access: Free

Resource Link

https://library.fpinnovations.ca/en/permalink/fpipub8428
Mass timber seismic force resisting systems in the Canadian codes and standards

Author: Chen, Zhiyong
Popovski, Marjan
Organization: FPInnovations
Year of Publication: 2021
Country of Publication: Canada
Format: Report
Material: CLT (Cross-Laminated Timber)
Application: Frames, Shear Walls
Topic: Seismic
Keywords: Performance, Building Code, Standard, Building Materials
Language: English
Research Status: Complete
Series: InfoNote
Summary:

Mass timber (MT) products, such as Glued Laminated Timber (GLT), Cross Laminated Timber (CLT), Laminated Veneer Lumber (LVL), Nail Laminated Timber (NLT), Dowel Laminated Timber (DLT), Laminated Strand Lumber (LSL), Parallel Strand Lumber (PSL), Mass Plywood Panels (MPP) and others, provide options for developing efficient structural systems to resist gravity and lateral loads. Such systems can be competitive alternatives to their steel and concrete counterparts. This InfoNote briefly introduces the MT Seismic Force Resisting Systems (SFRSs) that will be implemented in the 2020 National Building Code (NBC) of Canada, their height limits, and the main design requirements according to Canadian Standard for Engineering Design in Wood CSA O86-19. Differences among height limits for MT gravity and lateral load resisting systems are also discussed.

Online Access: Free

Resource Link

https://library.fpinnovations.ca/en/permalink/fpipub8478
Modelling of mass timber seismic force resisting systems

https://research.thinkwood.com/en/permalink/catalogue2905

Author: Chen, Zhiyong
Popovski, Marjan

Organization: FPInnovations

Year of Publication: 2021
Country of Publication: Canada

Format: Report
Material: CLT (Cross-Laminated Timber)
Application: Shear Walls, Frames

Topic: Seismic
Keywords: Platform-type Shear Walls, Ballon-Type Shear Walls, Post-tensioned Shear Walls, Braced Frames

Language: English
Research Status: Complete
Series: InfoNote

Summary:
This InfoNote briefly introduces the promising mass timber seismic force resisting systems, and the corresponding analytical and finite element models to support their adoptions in structural design offices.

Online Access: Free

Resource Link

https://library.fpinnovations.ca/en/permalink/fpipub8031

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https://research.thinkwood.com/en/permalink/catalogue2804

Author: DeVall, Ron
Popovski, Marjan
McFadden, Jasmine

Organization: National Research Council Canada, Canadian Construction Materials Centre

Publisher: National Research Council Canada
Year of Publication: 2021
Country of Publication: Canada
The objective of this guideline is to provide a simple, systematic, and sufficient procedure for evaluating the performance of Seismic Force Resisting Systems (SFRSs) and to determine the appropriate ductility-related (Rd) and over-strength related (Ro) force modification factors for implementation in the National Building Code of Canada (NBC). The procedure relies on the application of non-linear dynamic analysis for quantification of the seismic performance of the SFRS. Note that the procedure is also suitable for assessing force modification factors (RdRo values) of systems already implemented in the NBC.

The audience for this guideline are those (called the “project study team” in this document) who submit proposals for new SFRSs with defined RdRo values to the NBC for inclusion in Subsection 4.1.8., Earthquake Loads and Effects, of Division B of the NBC. This guideline can also be used by a team performing an alternative design solution for a specific project and seeking acceptance from authority having jurisdiction. In such cases, not all aspects of this guideline (e.g., having different archetypes) will be needed.
Two-step analysis procedure for seismic design of timber structures on reinforced concrete podium

https://research.thinkwood.com/en/permalink/catalogue2915

Author: Chen, Zhiyong
Ni, Chun

Organization: FPInnovations

Year of Publication: 2021

Country of Publication: Canada

Format: Report

Material: CLT (Cross-Laminated Timber)

Application: Shear Walls

Topic: Seismic

Keywords: Standards
Seismic Design
Concrete Podium
Design Criterion
Nonlinear Time-history Dynamic Analysis

Language: English

Research Status: Complete

Series: InfoNote

Summary:
In the National Building Code of Canada (NBCC) and American Society of Civil Engineering (ASCE) standard (ASCE7), different criteria for a two-step analysis procedure to design podium buildings are provided. However, nonlinear time-history dynamic analysis results show that such designed buildings may not meet the intended seismic performance. A new criterion has been developed at FPInnovations (Chen & Ni, 2017 & 2020). Analysis results show that when the normalized stiffness ratio is at least 10 times greater than the normalized mass ratio, the buildings designed by the two-step analysis procedure can meet the performance requirement. This InfoNote briefly reviews the two-step analysis procedure, demonstrates the shortcoming of the NBCC and ASCE criteria, and introduces the developed criterion.

Online Access: Free

Resource Link

https://library.fpinnovations.ca/en/permalink/fpipub8384
From Canada to the World: FPInnovations' Three-Generation Floor Vibration Research and Code Implementation

https://research.thinkwood.com/en/permalink/catalogue2826

Author: Hu, Lin
Cuerrier-Auclair, Samuel
Qian, Cheng
Dale, Angela

Organization: FPInnovations

Year of Publication: 2021

Country of Publication: Canada

Format: Report

Material: CLT (Cross-Laminated Timber)
Light Frame (Lumber+Panels)

Application: Floors

Topic: Acoustics and Vibration

Keywords: Lumber Joists
Engineered Wood Joists
Mass Timber
Floor Vibration-controlled Design Method
CSA 086
National Building Code of Canada

Language: English

Research Status: Complete

Series: InfoNote

Summary:
FPInnovations’ involvement in various codes and standards technical committees aims to monitor, contribute or propose changes for improvement as well as to create new standards to include new wood products and systems based on knowledge developed from FPInnovations’ research activities. Involvement also allows FPInnovations to be aware of any potential changes to codes and standards and to recognize and address threats and opportunities for wood use. Codes and standards exist to protect consumers but are written to reflect the current practices and knowledge based on a consensus agreement by committee members. FPInnovations’ involvement in codes and standards committees helps to align the coming changes with new wood products. This InfoNote reports on FPInnovations’ contribution to the floor vibration-control design methods on codes and standards implementation and research.

Online Access: Free

Resource Link

https://library.fpinnovations.ca/en/permalink/fpipub7936
Pinching Effect on Seismic Performance of a SDOF Lightframe Timber Structure

https://research.thinkwood.com/en/permalink/catalogue2542

Author: Eini, Ariya
Zhou, Lina
Ni, Chun

Year of Publication: 2021
Country of Publication: Canada

Format: Conference Paper
Material: CLT (Cross-Laminated Timber)
Light Frame (Lumber+Panels)

Application: Shear Walls
Topic: Seismic

Keywords: Pinching Behavior
Energy Dissipation
Hysteresis Loop
Light-frame wood
IDA Analysis
SDOF System

Language: English
Conference: World Conference on Timber Engineering
Research Status: Complete

Summary:

Although energy dissipation is one of the key factors in resisting seismic force, current design codes only take into account the ductility of the backbone properties of hysteresis curves, and the energy dissipation is usually not accounted for. This paper focuses on understanding and assessing the influence of energy dissipation due to different pinching levels on the seismic performance of a light-frame wood shear wall system. Timber structures with identical backbone curves but different pinching levels were analyzed. Incremental dynamic analyses were run on a single-degree-of-freedom system with varying pinching stiffness and residual strength. The seismic evaluation is presented by the spectral accelerations causing failure of the structure and the hysteresis energy dissipation under a suite of 22 ground motions (2 components per motion) over a wide range of fundamental periods of typical timber structures. Results show that the effect of pinching on the seismic performance of timber structures is period-dependent. Short period structures are more sensitive to the pinching of hysteresis loops compared to long period structures. The residual strength of pinching loops has a greater influence on the seismic performance than the stiffness of the pinching loops. Hysteretic energy dissipation derived from standard reversed-cyclic tests can provide a better understanding on the seismic resistance of timber structures. However, the hysteretic energy under a seismic event at near-collapse stage neither agrees with quasistatic cyclic test’s energy dissipation nor is well correlated to the maximum seismic capacity of the structure.

Online Access: Free
Experimental Investigation on Axial Compression of Resilient Nail-Cross-Laminated Timber Panels

https://research.thinkwood.com/en/permalink/catalogue2832

Author: Nehdi, Moncef
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Organization: Western University
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Editor: Billah, Muntasir

Publisher: MDPI

Year of Publication: 2021

Country of Publication: Canada
China

Format: Journal Article

Material: CLT (Cross-Laminated Timber)

Application: Floors
Walls

Topic: Mechanical Properties

Keywords: Nails
Axial Compression
Nail-Cross-Laminated Timber
Slenderness Ratio

Language: English

Research Status: Complete

Summary:

Conventional cross-laminated timber is an engineered wood product consisting of solid sawn lumber panels glued together. In this study, the structural behavior of solid wood panels of Nail-Cross-Laminated Timber (NCLT) panels connected with nails instead of glue was studied. The failure mode and nail deformation of the novel NCLT panels under axial compression load using eight full-scale NCLT panels was investigated. The effects of four key design parameters, namely, the nail type, number of nails, nail orientation angle, and nail slenderness ratio on axial compression performance of NCLT panels were also analyzed. In addition, a formula for predicting the axial compression bearing capacity of NCLT panels was developed. For calculation of the slenderness ratio, the moment of inertia of the full section or the effective section was determined based on the nail type, number of nails, angle of nail orientation and number of layers of the plate. Results showed that specimens connected by tapping screws had best compressive performance.

Online Access: Free

Resource Link

https://doi.org/10.3390/su132011257
Multi-storey buildings require mitigation of consequences of unexpected or accidental events, to prevent disproportionate collapse after an initial damage. Cross-laminated timber (CLT) in platform-type construction is increasingly used for multi-storey buildings, however, the collapse behaviour and alternative load paths (ALPs) are not fully understood. A 3D non-linear component-based finite element model was developed for a platform-type CLT floor system to study the ALPs after an internal wall loss, in a pushdown analysis. The model, which accounted for connection failure, timber crushing and large displacements, was calibrated to experimental results and then adapted for boundary conditions corresponding to typical residential and office buildings. Subsequently, five parameters (floor span, connection type, vertical location of the floor, tying level, horizontal wall stiffness) were varied, to study their effects on the ALPs in 80 models. The results showed that three ALPs occurred, of which catenary action was the most dominant. Collapse resistance was mainly affected by the floor span, followed by the axial strength, stiffness and ductility of the floor-to-floor connection, the weight of the level above and the floor panel thickness. This study provides an approach to model ALPs in a platform-type CLT floor system to design disproportionate collapse resistant multi-storey CLT buildings.

Online Access: Free

Resource Link

https://doi.org/10.1016/j.engstruct.2021.112362
Circular Economy & the Built Environment Sector in Canada

https://research.thinkwood.com/en/permalink/catalogue2805

Organization: Delphi Group
SCIUS Advisory

Year of Publication: 2021

Country of Publication: Canada

Format: Report

Material: CLT (Cross-Laminated Timber)
Glulam (Glue-Laminated Timber)
NLT (Nail-Laminated Timber)
Other Materials

Application: Wood Building Systems
Hybrid Building Systems

Topic: Environmental Impact
Design and Systems

Keywords: Circular Economy
Greenhouse gas emissions
Waste
Demolition
Design for Disassembly and Adaptability
Design for Durability
Deconstruction
Material Recovery
Reverse Logistics

Language: English

Research Status: Complete

Summary:
This study on Circular Economy & the Built Environment Sector in Canada was carried out by The Delphi Group in collaboration with Scius Advisory and completed in March 2021 on behalf of Forestry Innovation Investment Ltd. (FII) in British Columbia and Natural Resources Canada (NRCan) as the co-sponsors for the research. The work identifies a broad range of current efforts across Canada and undertakes a deeper dive on design for disassembly and adaptability (DfD/A) best practices, including an analysis of the ISO Standard 20887:2020 (i.e., design for disassembly and adaptability) in line with current Canadian industry practice and market readiness.

Online Access: Free

Resource Link


The acceptable solutions in Division B of the anticipated 2020 NBCC limit the height of Groups C and D buildings of sprinklered encapsulated mass timber construction (EMTC) to 12 storeys in building height, and a measured building height of 42m. The recently published 2021 IBC contains provisions to permit buildings of mass timber construction under the IBC Type IV construction, surpassing the NBCC provisions by maximum building height, building area, occupancy groups, and interior exposed timber. The IBC mass timber buildings are permitted to have a building height of maximum 18 storeys, depending on the occupancy group. Within Type IV construction, four subdivisions are described to have varying maximum permissible building height, area, fire resistance rating (FRR), and interior exposed timber.

Through a comparison of mass timber provisions of both Codes, relevant research reports, test reports, industry standards, this report documents the consequential and inconsequential differences and developed conclusions on whether the NBCC can adopt the IBC provisions, and with what modifications so that the new provisions may fit the NBCC context.
Summary:
The development of this primer commenced shortly after the 2018 launch of the Mass Timber Institute (MTI) centered at the University of Toronto. Funding for this publication was generously provided by the Ontario Ministry of Natural Resources and Forestry. Although numerous jurisdictions have established design guides for tall mass timber buildings, architects and engineers often do not have access to the specialized building science knowledge required to deliver well performing mass timber buildings. MTI worked collaboratively with industry, design professionals, academia, researchers and code experts to develop the scope and content of this mass timber building science primer. Although provincially funded, the broader Canadian context underlying this publication was viewed as the most appropriate means of advancing Ontario’s nascent mass timber building industry. This publication also extends beyond Canada and is based on universally applicable principles of building science and how these principles may be used anywhere in all aspects of mass timber building technology. Specifically, these guidelines were developed to guide stakeholders in selecting and implementing appropriate building science practices and protocols to ensure the acceptable life cycle performance of mass timber buildings. It is essential that each representative stakeholder, developer/owner, architect/engineer, supplier, constructor, wood erector, building official, insurer, and facility manager, understand these principles and how to apply them during the design, procurement, construction and in-service phases before embarking on a mass timber building project.

When mass timber building technology has enjoyed the same degree of penetration as steel and concrete, this primer will be long outdated and its constituent concepts will have been baked into the training and education of design professionals and all those who fabricate, construct, maintain and manage mass timber buildings.

One of the most important reasons this publication was developed was to identify gaps in building science knowledge related to mass timber buildings and hopefully to address these gaps with appropriate research, development and demonstration programs. The mass timber building industry in Canada is still a collection of seedlings that continue to grow and as such they deserve the stewardship of the best available building science knowledge to sustain them until such time as they become a forest that can fend for itself.

Online Access:  Free

Resource Link
https://academic.daniels.utoronto.ca/masstimberinstitute/building-science-primer/
This project proposes a timber-based composite floor that can span 12 m and be used in the construction of 40+ story office buildings. This floor system integrates timber panels and timber beams to form a continuous box girder structure. The timber panels function as the flanges and the timber beams as the web. The beams are spaced and connected to the flange panels so that sufficient bending stiffness of a 12 m span can be achieved via the development of composite action.

The current phase of this project studied the performance of the connections between timber elements in the proposed composite member. Six types of connections using different flange material and connection techniques were tested: Cross Laminated Timber (CLT), Laminated Strand Lumber (LSL), Laminated Veneer Lumber (LVL), and Post Laminated Veneer Lumber (PLVL). Glulam was used as the web. The majority of the connections used self-tapping wood screws except one had notches. The load-carrying capacity, stiffness, and ductility of the connections were measured. The stiffness of CLT, LSL, and PLVL connections was in the same range, 19-20 kN/mm per screw. Amongst the three, LSL had the highest peak load and PLVL had the highest proportional limit. The stiffness of the two LVL screw connections was around 13 kN/mm. The notched LVL connection had significantly higher stiffness than the rest, and its peak load was in the same range as LSL, but the failure was brittle.

LVL was used to manufacture the full scale timber composite floor element. With a spacing of 400 mm, the overall stiffness reached 33689 N mm²×10⁹, which was 2.5 times the combined stiffness of two Glulam beams. The predicted overall stiffness based on Gamma method was within 5% of the tested value, and the estimated degree of composite action was 68%. From both the test results and analytical modeling, the number of screws may be further reduced to 50% or less of the current amount, while maintaining a high level of stiffness.

Future work includes testing the composite floor under different screw spacings, investigating the effect of concrete topping, and the connections between floor members and other structural elements.

Resource Link

Nonlinear Static Seismic Response of a Building Equipped with Hybrid Cross-Laminated Timber Floor Diaphragms and Concentric X-Braced Steel Frames

https://research.thinkwood.com/en/permalink/catalogue2761

Author: Roncari, Andrea
Gobbi, Filippo
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Organization: University of British Columbia
University of Trento

Publisher: MDPI

Year of Publication: 2021

Country of Publication: Canada
Italy

Format: Journal Article

Material: CLT (Cross-Laminated Timber)
Steel-Timber Composite

Application: Floors

Topic: Seismic

Keywords: Seismic Design
Hybrid Structures
Lateral Resistance
Semi-rigid Diaphragms
Load Distribution
Seismic Performance
Pushover Analysis
Nonlinear Static Analysis
Finite Element Model

Language: English

Research Status: Complete

Series: Buildings
Summary:
Simplified seismic design procedures mostly recommend the adoption of rigid floor diaphragms when forming a building’s lateral force-resisting structural system. While rigid behavior is compatible with many reinforced concrete or composite steel-concrete floor systems, the intrinsic stiffness properties of wood and ductile timber connections of timber floor slabs typically make reaching a such comparable in-plane response difficult. Codes or standards in North America widely cover wood-frame construction, with provisions given for both rigid and flexible floor diaphragms designs. Instead, research is ongoing for emerging cross-laminated-timber (CLT) and hybrid CLT-based technologies, with seismic design codification still currently limited. This paper deals with a steel-CLT-based hybrid structure built by assembling braced steel frames with CLT-steel composite floors. Preliminary investigation on the performance of a 3-story building under seismic loads is presented, with particular attention to the influence of in-plane timber diaphragms flexibility on the force distribution and lateral deformation at each story. The building complies with the Italian Building Code damage limit state and ultimate limit state design requirements by considering a moderate seismic hazard scenario. Nonlinear static analyses are performed adopting a finite-element model calibrated based on experimental data. The CLT-steel composite floor in-plane deformability shows mitigated effects on the load distribution into the bracing systems compared to the ideal rigid behavior. On the other hand, the lateral deformation always rises at least 17% and 21% on average, independently of the story and load distribution along the building’s height.

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