SESSION 1
Monday 23rd June 2025
11am to 1pm

Session No.	Session Topic	Abstract Topic	Submission Title	Summary	First Name	Last Name	Company
1A	TESP - Engineering - Eurocode 5 - recent developments	Session Chair: PROFESSOR ERIK SERRANO / LUND UNIVERSITY					
1A	TESP - Engineering - Eurocode 5 - recent developments	Timber Engineering & Structural Performance - Engineering Focus	DESIGN OF HOLES IN BEAMS – A NEW SECTION FOR EUROCODE 5	Architectural reasons or user-specific requirements often require that pipes for water, ventilation, heating etc. are arranged in the plane of the load-bearing structure. As a result, holes are required in the beams which significantly influence the load-bearing behaviour. The current edition of Eurocode 5 (EC 5) does not contain standardized rules for the design of holes in beams. Hence such design rules had to be included as non contradictory complementary information (NCCI) in National Annexes (NA) to EC 5. However, the design rules currently contained in specific NAs feature considerable restrictions with regard to the size, position and distance of holes in beams. In order to close the obvious gap in Eurocode 5, the design of holes in beams was prioritised for the revision of Eurocode 5. This paper will report on the new and extended rules for the design of holes in beams in Eurocode 5. Compared to current national rules, these rules extend the possibilities to holes with larger diameters, holes with eccentric arrangement and holes arranged in groups. The standard text illustrated in this contribution is complemented by extensive background information and literature.	Philipp	Dietsch	Karlsruhe Institute of Technology - Timber Structures and Building Construction
1A	TESP - Engineering - Eurocode 5 - recent developments	Timber Engineering & Structural Performance - Engineering Focus	THE SECOND GENERATION OF EUROCODE 5 – FIRE DESIGN	The European Commission has a strong interest on the further development of the Eurocodes to achieve a further harmonization of design rules in Europe and the revision process of all Eurocodes has started 2015. The second generation of the Eurocodes is expected to be published starting from 2025. The main objectives of the revision are the improvement of the Ease-of-Use of the Eurocodes for practical users, the reduction of National Determined Parameters and the further harmonization and inclusion of state-of-the-art. After an intensive discussion within CEN/TC250 it was defined that the Eurocodes are addressed to competent civil, structural and geotechnical engineers, typically qualified professionals able to work independently in relevant fields. This paper provides an overview to the second generation of the European design standard EN 1995-1-2 entitled Eurocode 5: Design of timber structures — Part 1-2: Structural fire design	Alar	Just	TalTech
1A	TESP - Engineering - Eurocode 5 - recent developments	Timber Engineering & Structural Performance - Engineering Focus	THE TIMBER CHAPTER OF THE NEW EUROCODE 8 – PART 1-2: NEW FEATURES AND FUTURE IMPROVEMENTS	The revision of the new Timber Chapter (i.e. Chapter 13 and Annex L) of Eurocode 8 (prEN1998-1-2) started almost 10 years ago, and significant changes have been introduced with respect to the current version bringing this chapter to almost 50 pages in total with respect to the 4 pages of the current version (i.e. Chapter 8 of EN1998-1). These changes which have been extensively described in at least five papers published in the last six years, will include new engineered wood products, provisions for dissipative zones, new and existing structural systems, all of them including extensive and detailed rules for capacity-based design (at the local/connection, wall and building level), together with the values of the overstrength factors and a new table with the default values of the behaviour factors for medium dissipative (ductility class 2) and highly dissipative (ductility class 3) structures which was recently updated. Also a new Annex have been included (Annex L) with the provisions for non-linear static analyses on timber buidings, and lately some improvements including the introduction of provisions for bonded-in rods. However still some improvements are needed, which will probably follow after the publication of the new standard in future updates after a period of application of the code, in order to possibly slightly reduce the values of the overstrength factors which currently limit the design of tall timber buildings in high seismicity areas and to further enrich the seismic detailing rules and simplication of some design formula for the application of capacity design.	Massimo Martina	Fragiacomo Sciomenta	University of L'Aquila
1A	TESP - Engineering - Eurocode 5 - recent developments	Timber Engineering & Structural Performance - Engineering Focus	OVERVIEW OF THE WORK WITHIN CEN TC 250/ SC5/ WG12 ASSESMENT AND RETROFITTING OF THE TIMBER EXISTING STRUCTURES	CEN/TC250 had taken the initiative to prepare a document to evaluate the purpose and justification for new European technical rules and related standards for evaluation and retrofitting of existing structures. The corresponding document was produced by the advisory committee of the former president. The ongoing discussions in CEN/TC250 confirmed the need to form first a CEN working group WG2 and after that CEN TC 250 SC10 WG4 for the further development of the subject. A preliminary discussions within CEN/TC250/SC5 resulted in a forming AHG Timber existing structures which was transformed in WG12 Assesment and retrofitting of the existing timber structures. This article will show a basis for the future work program	Vlatka	Rajčić	University of Zagreb Faculty of Civil Engineering
1A	TESP - Engineering - Eurocode 5 - recent developments	Material Performance & Durability - Engineering Focus, Timber Engineering & Structural Performance - Engineering Focus, Education, Innovation & Challengers - Engineering Focus	EUROCODE 5: FROM MANDATE TO SECOND GENERATION – REVIEW, INSIGHT AND OUTLOOK	The second generation of European timber design standards, known as Eurocode 5, is scheduled for publication in August 2025. This paper provides comprehensive insights into the final state of this new generation including background documents and training material. Additionally, this document dedicates a chapter on lessons learned to review the standardization process and the challenges encountered. Furthermore, the paper offers an outlook on upcoming documents, potential developments and the next generation of design standards. Finally, it discusses the interaction with the ongoing revision of the European Construction Products Regulation (CPR), focusing on its future implications for a harmonized European building market.	Stefan	Winter	Technical University Of Munich
1A	TESP - Engineering - Eurocode 5 - recent developments	Timber Engineering & Structural Performance - Engineering Focus	THE 2ND GENERATION OF THE EUROCODE FOR TIMBER BRIDGES	The design of timber bridges is regulated by Eurocode 5 part 2 (EN 1995-2), which has been extensively updated to fullfill the requirement of 100 years service life. The paper will show the structure and content, highlighting the improvements especially for durability and sustainability. Furthermore, it will present the new content regarding timber-concrete composite and integral bridges, laminated timber decks, bracings, bearings and foundations as well as the topics of serviceability limit states (deflections, vibration and damping) and fatigue.	Antje	Simon	University Of Applied Sciences Erfurt
1A	TESP - Engineering - Eurocode 5 - recent developments	Timber Engineering & Structural Performance - Engineering Focus	The new chapter on timber structures in the second generation of EN 1998-3	This presenttion explores the newly introduced chapter on timber structures in the second generation of European Standard EN 1998-3, "Eurocode 8 — Design of Structures for Earthquake Resistance - Part 3: Assessment and Retrofitting of Buildings and Bridges," which is anticipated to be published by 2026/2027. Following a brief introduction to the rationale behind the development of Chapter 10, the presentation delves into the main aspects in detail, providing contextual background on the motivations for these key components. To clarify the framework from which the new provisions originated and to aid their application in specific scenarios beyond those covered in the standard, extensive references to pertinent literature are also included.	Ivan	Giongo	University of Trento
1B	TESP - Architectural	Session Chair: PROFESSOR EMERITUS JEFF MORRELL / OREGON STATE UNIVERSITY					

Session No.	Session Topic	Abstract Topic	Submission Title	Summary	First Name	Last Name	Company
1B	TESP - Architectural	Sustainability and Timber in a Circular Economy - Architectural Focus, Timber Engineering & Structural Performance - Architectural Focus	OPTIMIZING MASS TIMBER STRUCTURAL GRID FOR FUNCTIONAL ADAPTABILITY	The paper discusses extending the lifespan of mass timber (MT) buildings to enhance carbon sequestration, emphasizing adaptability in achieving this goal. Building adaptability involves designing structures that can accommodate future modifications, which is critical because more than half of buildings are demolished prematurely, before reaching their physical end-of-life. This premature demolition generates waste and results in the use of additional energy and resources for new constructions. The research introduces a novel industry-informed workflow to optimize three-dimensional structural grids, a key aspect of enhancing building adaptability. This workflow emphasizes multidisciplinary collaboration among architects, structural designers, and building service engineers, incorporating material constraints and capabilities from manufacturers and fabricators. The system's ability to generate optimized structural configurations for gravity load-bearing systems is demonstrated through a case study featuring glulam post-and-beam structures with CLT floor panels, utilizing databases of standard market products. The study finds that the multi-objective optimization workflow can extend grid spans and increase ceiling-to-floor clearance while meeting structural performance criteria. The parametric design approach facilitates the exploration of various design possibilities across different structural systems and fitness functions, suggesting that this methodology can be replicated and extended. The paper concludes by recommending the adoption of this optimization methodology in early-stage design processes for MT buildings, suggesting that further validation through real-world case studies could refine and validate the system's practical applications. This convergent design strategy has the potential to create adaptable buildings with longer lifespans, thereby contributing to sustainable construction practices.	Mariapaola	Riggio	Oregon State University
1B	TESP - Architectural	Sustainability and Timber in a Circular Economy - Architectural Focus, Timber Engineering & Structural Performance - Architectural Focus	DESIGN AND FABRICATION OF A WOODEN PAVILION USING UNDERUTILIZED LUMBER AND PROPOSAL FOR CONVERSION	The aging of planted forest resources and the decline in the population of forest managers have resulted in a lack of access to these resources, and trees are dying and wood that could be used for building materials is being turned into chips and fuel. Through collaboration between universities, towns, and companies, it was possible to safely create pavilions and furniture using unused trees, off-specification sizes, and species, thereby promoting the utilization of forest resources. The method of conducting parametric studies using the Young's modulus of the analytical model as a variable was also proposed to enable the use of wood with a Young's modulus that would otherwise go unused.	Ayano	Kodera	Toyo University
1B	TESP - Architectural	Timber Engineering & Structural Performance - Engineering Focus, Timber Engineering & Structural Performance - Architectural Focus	EXPERIMENTAL AND ANALYTICAL STUDY ON THE SEISMIC PERFORMANCE OF LOAD-BEARING WALLS WITH DIAGONAL WOODEN LATHS AND PLASTER FINISH	This paper reports the results of experimental and analytical investigations into the structural performance of bearing walls with diagonal wooden lath boards and plaster finish, which were frequently used in early modern Japanese wooden buildings. Full-scale tests were conducted on lathboard walls with a width of 50 mm, a clearance of 6 mm and attached to the wall body by nailing, confirming a high bearing capacity of about 6 times the wall magnification equivalent in Japan. Elemental tests on a single lath board were carried out and the results were used to estimate the structural performance of the full-scale wall. An analytical calculation model that takes into account the shear performance and deformation of the nails at the joints was used to estimate the initial stiffness and bearing capacity with good accuracy. It was also quantitatively shown that the plaster finish contributes to the stiffness and bearing capacity increase in the early stages of deformation.	Naoyuki	Matsumoto	Tohoku University
1B	TESP - Architectural	Timber Engineering & Structural Performance - Engineering Focus, Timber Engineering & Structural Performance - Architectural Focus	STATIC LOADING TESTS OF THE SINGLE-STORY CLT ROCKING SHEAR WALL STRUCTURE	We propose a structural system utilizing cost-effective residential hardware instead of the expensive, high-performance hardware typically employed in contemporary CLT panel construction methods. This system is designed to ensure no damage under moderate seismic events while relying on restoring forces to resist collapse during massive seismic events. This study aims to obtain fundamental insights into the lateral resisting mechanism, collapse limits. To this end, a single-story full-scale CLT building equipped with existing residential hardware was subjected to deformation exceeding 1/3 rad. The experimental results confirmed the addition of lateral resistance by hardware, a consistent negative slope of elastic restoring forces, and collapse limit displacement of over 910mm. Furthermore, it was observed that rocking behavior caused the weight concentration on the CLT walls. These findings were verified by numerical analysis.	So	Momose	Kyoto University
1B	TESP - Architectural	Timber Engineering & Structural Performance - Architectural Focus	Study on effective of controlled wooden houses based on energy balance	In this study analyzes a typical wooden house with added hystertic dampers as lumped mass system and discusses the effectiveness and design methods of vibration control devices using cumulative plastic deformation, ductility and equivalent loading coefficient. The analysis models are a typical 1-3 story ZHE wooden house. The parameters are include the number of storys, seismic elements, damper yield displacement and ratio for the structure, as well as the input earthquake and number of repeated earthquakes.The input waves are the 6 earthqukake. The n significantly decrease when the number of repeated earthquakes from 1 to 2, however no significant decrease was observed from 2 to 3. The n of epicental earthquake KobeNS, has a tendency to small.	Mai	Kunikyo	Sugiyama Jogakuen University
1B	TESP - Architectural	Timber Engineering & Structural Performance - Architectural Focus	Concept to Construction: Co-Design and Integrative Development Processes for the IntCDC Multi-Story Timber Building System	In the context of the climate crisis and increasing urbanization, there is an urgent necessity to expand the typological possibilities in timber construction. Wide-span, point-supported timber systems for multi-story buildings offer the potential to substitute CO_2-intensive construction materials such as concrete and steel, utilize buildings as carbon sinks, and provide additional qualitative living and working spaces in urban areas. The development and incremental refinement of bespoke systems from initial conceptualization to technical feasibility and regulatory approval require the integration and coordination of comprehensive expert knowledge. A highly integrative approach and interdisciplinary exchange of expert knowledge within the research team, as well as iterative and reciprocal expert knowledge exchange with innovative stakeholders from the construction industry, are imperative. This paper presents the development of a co-design framework for the IntCDC Multi-Story Timber Building System (MSTBS), which facilitates reciprocal and iterative knowledge exchange within the interdisciplinary core research team, as well as between researchers and stakeholders from the construction industry. The research demonstrates how an organizational co-design framework fosters the methodical collaboration between research and industry partners and enables the development of a novel timber building system, contributing to the transition towards more sustainable building practices.	Simon Lorenz	Treml Riedel	University of Stuttgart; Institute for Computational Design and Construction
1B	TESP - Architectural	Timber Engineering & Structural Performance - Architectural Focus	MUSASHINO UNIVERSITY SCHOOL GYMNASIUM: DESIGN AND TESTING OF A TIMBER-STEEL HYBRID BEAM STRING STRUCTURE	This paper discusses the design and construction of the gymnasium at Musashino University's Musashino Campus in Tokyo, Japan. The project integrates a hybrid section combining steel and European redwood, addressing the need to blend the building harmoniously with the campus's lush greenery. A key design challenge was to incorporate wood as a significant structural element while adhering to Japan's stringent fire regulations. The solution involved a T-shaped steel section with a timber sandwich, preventing steel web buckling and achieving superior structural performance. Approximately 50 cubic meters of timber were used, enhancing both the aesthetic appeal and the environmental sustainability of the project. The hybrid approach allowed the beam string structure to meet design load requirements effectively. Full-scale testing confirmed the structural integrity and load-bearing capacity of the hybrid section, matching those of a full steel section.	Nicolas	Giron	Nikken Sekkei Ltd

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1B	TESP - Architectural	Timber Engineering & Structural Performance - Architectural Focus, Education, Innovation & Challengers - Engineering Focus, Education, Innovation & Challengers - Architectural Focus	HygroShell – Material Programming for in-situ self-shaping timber construction	While curved, surface active shell structures are well known for their structural performance and material efficiency, construction is typically from amorphous materials such as concrete and steel that can be shaped onto elaborate onsite curved formworks. The HygroShell demonstrates an alternative approach, generating curved surface geometry through the natural hydromorphic, anisotropic shrinking and swelling of wood. Flat pack, cross ply, bilayer components are manufactured with programed arrangements of boards based on wood moisture content and fiber orientations with the weather proofing and shingle cladding applied in the flat configuration. With the shape encoded into the flat components they are wrapped and transported to the site. Once positioned and opened, the wings of the components slowly unfurl autonomously through air drying. The components interlock forming a rigid shell structure spanning 10 meters with a structural thickness of just 28 mm. By deploying self-shaping in the construction of the shell, extensive formwork is avoided while simultaneously reducing the amount of kiln	Dylan	Wood	University of Oregon
1C	TESP/TABD - Engineering - Shearwalls & Panels / Structrual Behaviour	Session Chair: DR LISA OTTENHAUS / THE UNIVERSITY OF QUEENSLAND					
1C	TESP/TABD - Engineering - Shearwalls & Panels / Structrual Behaviour	Timber Engineering & Structural Performance - Engineering Focus	Dynamic and long-term performance of friction-based connectors with wooden dowels	Shear walls in wood construction typically exhibit pinched hysteresis loop resulting in limited energy absorption, which is important for seismic performance. Thus, in order to develop a connection with high energy absorption using wood friction, shake table tests of a shear wall with friction-base connectors were conducted. To evaluate a long-term performance of the wood clamping force that generates the frictional force in an analytical model, coefficients related to pure creep and mechano-sorptive creep, which are required in the model, were obtained. Using these coefficients, the loss of wood clamping force under temperature and humidity fluctuations was evaluated by the analytical model. This paper presents the results of these tests and analyses.	Yoshiaki	Wakashima	Toyama Prefectural Agricultural, Forestry and Fisheries Research Center
1C	TESP/TABD - Engineering - Shearwalls & Panels / Structrual Behaviour	Timber Engineering & Structural Performance - Engineering Focus	INVESTIGATING THE MECHANICAL BEHAVIOUR OF MULTI-PANEL BALLON-TYPE CLT SHEARWALLS THROUGH FULL-SCALE TESTS	Balloon-type Cross-Laminated Timber (CLT) shearwall systems are widely used in construction due to its ability to overcome issues associated with perpendicular-to-grain compression failure and vertical shrinkage typically encountered in platform-type shearwall construction. Despite its widespread use and ease of assembly, research on this system is limited, and current timber codes lack specific design provisions. This paper presents an experimental study of the mechanical behavior of multi-panel balloon-type CLT shearwalls, where effects of variables such as panel aspect ratios, connection stiffness, and number of panels are investigated.	Ghasan	Doudak	The University of Ottawa
1C	TESP/TABD - Engineering - Shearwalls & Panels / Structrual Behaviour	Timber Engineering & Structural Performance - Engineering Focus	Optimized lumber arrangement in NLT subject to in-plane shear force	Nail-Laminated Timber (NLT) is a wooden panel utilizing lumbers fastened with nails, traditionally used in Canada and the United States. Despite its widespread use, the effects of lumber grade, length, placement, and nail stiffness on structural performance during in-plane deformation is not well understood. This study employs numerical analysis to investigate the effect of member arrangement on the structural performance of NLT panels, particularly for a continuous wall. The analysis focused on optimized lumber arrangement to improve shear stiffness while reducing material usage. The results show that some arrangements provide shear stiffness more efficiently than full-volume walls. Additionally, the lumber arrangement evolves into a diamond shape as the volume decreases, with each side functioning like a brace. This study provides insights into more economical and structurally efficient NLT panel designs.	Yuki	Takahashi	Tokyo University of Science
1C	TESP/TABD - Engineering - Shearwalls & Panels / Structrual Behaviour	Timber Engineering & Structural Performance - Engineering Focus	DEVELOPMENT OF OVERSTRENGHT FACTORS FOR MULTI-PANEL CLT SHEARWALLS BASED ON PANEL-TO-PANEL CONNECTIONS	This study presents the results of a study with the aim to develop overstrength factors for multi-panel CLT shearwalls. A new hierarchy of failure has been introduced in the new edition of the Canadian Engineering Design in Wood (CSA O86) standard, in which dissipative and non-dissipative components are required to be designed based on the strength variation of the panel-to-panel vertical joint connections. Experimental results from three monotonic and ten cyclic tests on spline-joint for various connections typically used as vertical joints and stemming from different manufacturers will be presented. A framework for the development of overstrength factors based on the experimental results will be discussed in the full-length paper.	Antoine	Bérubé	University of Ottawa
1C	TESP/TABD - Engineering - Shearwalls & Panels / Structrual Behaviour	Timber Engineering & Structural Performance - Engineering Focus	MECHANICAL PROPERTIES AND FAILURE CRITERIA OF WOOD UNDER COMBINED NORMAL-SHEAR LOADING	In this study, combined normal-shear behaviors of six type of specimens were conducted. An auxiliary device was designed and equipped to testing machine to help achieving combined normal-shear loading. Failure modes, and shear stress-strain curves under different normal stresses were obtained. The applicability of several commonly used orthotropic strength criteria including Hill, Tsai-Hill, Tsai-Wu, Hoffman, et al. to predict the combined tension/compression and longitudinal shear failure were systematically assessed according to test data from the experiment as well as existing literature. Results indicated that normal stress greatly affects the shear failure mode and performance. The best applicable normal stress ranges of the examined failure criteria were confirmed.	LI-PENG	ZHANG	Xi'an University of Architecture and Technology
1C	TESP/TABD - Engineering - Shearwalls & Panels / Structrual Behaviour	Timber Engineering & Structural Performance - Engineering Focus	Development of GIR system Improved on-site workability	In this study, moment resistance experiments on joints of four-story rigid-frame building as the new GIR joint system are carried out. This specimen showed yield behavior at a rotation angle of 1/50 radian and did not break even at a rotation angle of 1/15 radian. These results indicate that the toughness connectors did not rupture and exhibited high structural performance even use the cast iron cubes. The experiments on other types of joints, such as column-foundation joints, cross-shaped joints, and L-shaped joints will be carried out.	YUTA	MORI	Oita Univ.
1C	TESP/TABD - Engineering - Shearwalls & Panels / Structrual Behaviour	Material Performance & Durability - Engineering Focus, Timber Engineering & Structural Performance - Engineering Focus, Timber Architecture & Biophilic Design - Engineering Focus	Validation of Empirical Models and Simplified Testing Approach for Predicting Pull-out Strength of Glued-in Rods in Japanese Larch Timber	This paper investigates the validity of existing regression equations for predicting the pull-out strength of Glued-in Rods (GiR) in Japanese larch timber and explores a simplified testing approach based on the GIROD model. Key points of the research: 1. Tested various rod diameters (16mm, 19mm, and 24mm) and anchorage lengths (200mm, 300mm, and 400mm) for GiR specimens. 2. Aims to verify if existing regression models are applicable to Japanese larch GiR 3. Conducted small glued wood block shear tests to determine bond layer properties for the GIROD model and assess whether simplified shear tests can accurately predict GiR strength . The paper mentions several existing empirical models for predicting GiR strength, including those by Riberholt, Gerold, and Rossignon. The GIROD model, based on Gustafsson's "Generalized Volkersen theory," is also introduced as an analytical approach. The study used Japanese larch glued-laminate timber with threaded rods bonded using two-component epoxy adhesive. Pull-out tests were conducted at a loading rate of 2 mm/min. Small glued wood block shear tests were performed according to the KS F 2209 test method to calculate shear strength and fracture energy of the bond layer for the GIROD model.	Gwang-Ryul	Lee	Seoul National University

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1C	TESP/TABD - Engineering - Shearwalls & Panels / Structrual Behaviour	Timber Architecture & Biophilic Design - Engineering Focus, Timber Architecture & Biophilic Design - Architectural Focus, Exemplars & Construction Case Studies - Architectural Focus	Think in concrete but build in wood - Modern Living with Sustainability and TS3 technology	The example of the Zelgstrasse Uster development shows that even after the contract for the construction of a residential building in concrete has been awarded, it is possible to "plan in concrete but build in wood" by using TS3 technology and involving all parties. The TS3 technology shows how it is possible to switch from concrete to timber, thus making an important contribution to climate change. It shows the organisation, logistics and quality assurance on a large construction site and the positive impact on the CO2 balance compared to building in wood instead of concrete. This project is an impressive example of how sustainability and innovative construction technologies can go hand in hand.	Stefan	Zoellig	Timbatec Timber Engineers International AG
1D	TESP / MPD / STCE - Engineering - Seismic	Session Chair: CARMEN SANDHAAS / KARLSRUHE INSTITUTE OF TECHNOLOGY					
1D	TESP / MPD / STCE - Engineering - Seismic	Material Performance & Durability - Engineering Focus, Timber Engineering & Structural Performance - Engineering Focus	Experimental Study and Finite Element Analysis of Racking Resistance subjected to varied mortise-tenon joints and wedge configurations	This study is about invetiagating racking resistance of column-Nuki joints in tradtional timber structure with varied types of mortise-tenon joint and wedge configuration, cross-shaped specimens were assembled for lateral reciprocating static tests. In order to develop a systematic evalution method on aseismic performance of varied column-Nuki joints, 3-D nonlinear finite element model of each specimen was established respectively to verify the applicability of finite element analysis, and realized accurate prediction on racking resistance by quantitatively comparing simulations with corresponding experimental results such as initial stiffness and bearing capacity.	CHEN	Jiuzhang	0
1D	TESP / MPD / STCE - Engineering - Seismic	Material Performance & Durability - Engineering Focus, Timber Engineering & Structural Performance - Engineering Focus	COMPARISON OF CYCLIC LOADING PROTOCOLS AND CYCLIC BENDING PERFORMANCES OF SELF-TAPPING SCREWS	Load-displacement behavior of joints against cyclic loading is important especially for seismic area. There are several kinds of standards for fastener bending test and joint shear test, but the relationship between them is unclear. In this study, we investigated the relationship between joint testing methods and repeated bending testing methods. Cyclic shear test with full thread screw and cyclic bending test of the screw under the same loading protocols were conducted. Failure lifetime of the screw was estimated using cyclic bending parameters obtained form cyclic bending test. Estimated failure lifetime showed good agreement with the hysteresis bending test and joint test results.	Kenji	Kobayashi	The University of Tokyo
1D	TESP / MPD / STCE - Engineering - Seismic	Sustainability and Timber in a Circular Economy - Engineering Focus	COMPARISON OF A SEISMIC DESIGN OF A 10-STORY ALL TIMBER BUILDING AND OF A 10-STOREY HYBRID STEEL-FRAME CLT FLOORS BUILDING USING RESILIENT TECHNOLOGY	Environmental awareness is a major challenge for our generations, especially in the construction sector which is notorious for its polluting impact. This awareness is stimulating the development of new construction techniques in which the optimization of materials is a priority. Concrete stands out for its excellent resistance to compression, water, and heat, while steel offers advantageous properties in compression and tension. At the same time, timber, and its derivatives, such as CLT, are emerging as credible alternatives to concrete in certain situations. By combining these materials, we can exploit advantages of each, developing composite structure. However, a major challenge in construction is the safety of occupants and their surroundings, especially in the face of hazards such as earthquakes The aim of this document is to demonstrate the differences in outcomes when constructing a multi-story building either constructed entirely of timber or combining steel and CLT, and both using resilient seismic technology in earthquake-prone zones in Europe. To achieve that, a case study prototype building was conducted using resilient braces as the lateral load resisting members. The seismic analysis consisted in performing a lateral forces analysis, a pushover and a nonlinear time history analysis following European standards. This paper shows the design outcomes, particularly the amount of timber and steel used, the amount of carbon emissions and the overall structural performance for	Pierre	Quenneville	The University of Auckland
1D	TESP / MPD / STCE - Engineering - Seismic	Timber Engineering & Structural Performance - Engineering Focus	Applicability of mid-rise timber structures in the metropolitan area	To advance the goal of a zero-carbon society, promoting the use of wood in building construction is increasingly recognized as a viable solution. Current efforts are directed towards enabling medium to high-rise and large-scale timber buildings. This study aims to evaluate the applicability of steel and timber rigid frame, which offer greater spatial flexibility, in terms of their structural performance and environmental sustainability in urban areas. In this paper, the seismic performance of steel and timber structures is presented and compared by eigenvalue analysis, static incremental analysis, and time history analysis. At the same time, the two models are also used to compare carbon dioxide emissions.	Chia-Lung	Yeh	Kyushu University
1D	TESP / MPD / STCE - Engineering - Seismic	Timber Engineering & Structural Performance - Engineering Focus	Investigation of undesirable brittle failure observed in high-capacity shear walls	The building height limit for light wood-frame construction has been increased from four to six stories in 2015 National Building Code of Canada. In addition, the seismic design spectra in the 2020 NBCC has increased substantially for all site classes. These increases in building height and seismic loads have raised the demand for a stronger shear wall system for construction of midrise wood-frame buildings, especially for those located in high seismic zones. To respond to the demand for higher strength shear wall systems, a new high-capacity shear wall system with multiple rows of nails along sheathing edges has been jointly developed by FPInnovations and the University of Victoria. Shear walls with two and three rows of nails along sheathing edges were designed and tested in 2020, 2021 and 2022. In this paper, test results of high-capacity shear walls conducted in previous years were summarized. Brittle failure modes observed in previous test programs were investigated and causes for these brittle failure modes were discussed. New construction details for high-capacity shear walls to prevent these undesirable brittle failures were recommended	Ruite	Qiang	University of Victoria
1D	TESP / MPD / STCE - Engineering - Seismic	Timber Engineering & Structural Performance - Engineering Focus	CASE STUDY: SEISMIC AND GRAVITATIONAL DESIGN OF 15-STORY OFFICE AND RESIDENTIAL BUILDING ARCHETYPES WITH A SEMI-RIGID CLT DIAPHRAGM AND REINFORCED CONCRETE SHEAR WALLS IN CHILE	This study is part of the "Ciudad Madera" technological consortium, which seeks to promote widespread wood construction in Chile, whose seismic code provides no guidance for cross-laminated-timber (CLT) seismic diaphragms. Currently, this lack of a design methodology for Hybrid Mass-Timber–Reinforced-Concrete (HMT-RC) buildings, has pushed a tendency for structural designers to solely rely on the concrete topping as the seismic horizontal diaphragm element. This study validates HMT – RC and develops a seismic-design method for buildings up to 15 stories high, with CLT floor system performing as the seismic diaphragm. Twenty monotonic/cyclic connector tests and six full-scale 4 m × 4 m Radiata-pine CLT diaphragm tests will calibrate nonlinear models of office and residential building archetypes, analyzed in a 72-case parametric matrix (height, seismic zone, soil class, design philosophy). Findings show: (i) RC-core and coupling-beam detailing governs drift, (ii) flooring size is controlled by a vibration criterion, and (iii) commercial timber column-to-column splices meet seismic inter-story rotation demands	Jairo Alonso	Montaño Castañeda	Centro Nacional de Excelencia para la Industria de la Madera (CENAMAD-CIM UC)

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1D	TESP / MPD / STCE - Engineering - Seismic	Timber Engineering & Structural Performance - Engineering Focus	A STUDY ON THE COLLAPSE LIMIT OF CLT PANEL CONSTRUCTION BASED ON STATIC LATERAL LOADING TESTS	There is no example of seismic collapsing behaviour of CLT panel constructions in past earthquakes and shake table tests even in Japan as a high seismic area, leading true collapse limit still unknown. It causes the seismic design standard in Japan probably too conservative. In-plane stiffness and strength of CLT walls are generally larger than the other wooden walls, and the gravitational restoring force from wall rocking is also larger. Therefore, the collapse limit deformation of CLT constructions is expected large. In this paper, based on static lateral loading tests of 2-story models, the lateral load carrying capacity under large deformation, and its causal factors are examined. As results, it is confirmed that the ultimate story drift angle of the test models is 1/4.0-1/3.3rad, indicating the probability of escaping collapse against sever seismic motion. And the restoring force in the region of large deformation mainly depends on tensile resistance of orthogonal walls and moment resistance of lintel-wall connections. These knowledges are useful for optimization of the seismic design standard of CLT panel constructions in the future.	Tatsuya	Miyake	Nihon System Sekkei Architects & Engineers
1E	TESP Engineering Fire Engineering	Session Chair: A/PROF DAVID LANGE / THE UNIVERSITY OF QUEENSLAND					
1E	TESP Engineering Fire Engineering	Timber Engineering & Structural Performance - Engineering Focus	SIMPLIFIED ENGINEERING METHOD TO ESTABLISH STRUCTAL ADEQUACY OF MASS TIMBER COLUMNS FOR FULL FIRE DURATION	Data from mass timber research has shown that thermal penetration continues into a load-bearing member well after peak temperatures from fire exposure are reached. Using results from the CodeRed series of experiments, the authors have developed an engineering methodology to assess the impact of thermal penetration on structural adequacy during fire growth and decay, for an exposed mass timber column. The methodology specifically addresses the thermal degradation of strength and stiffness that occurs in-depth behind the char layer. Columns are particularly vulnerable given the potential of four-sided exposure and compressive strength parallel to the grain reducing substantially and irreversibly at temperatures over 140ºC, a relatively low temperature in the context of fire exposure. The results show that where the thermally impacted timber is included in the assessment of structural adequacy, the load-bearing resistance of a column is much reduced when compared with the calculated resistance of a column using just char depth and a zero-strength layer. This is of concern for current engineering design of high-rise mass timber buildings and when an assessment of structural adequacy is based on char depth at the time of cessation of flaming.	David	Barber	Arup
1E	TESP Engineering Fire Engineering	Timber Engineering & Structural Performance - Engineering Focus	SOLID TEMPERATURE PREDICTION FOR CLT WALLS IN FIRE USING SUPERVISED MACHINE LEARNING	Machine learning (ML) tools have proven valuable in predicting the fire behaviour of structural elements, including timber elements, under standard fire conditions, but limited ML analysis is available for structural timber elements under non-standard fire exposure. The study explored the viability of using ML models to predict in-solid temperatures over time and depth in structural timber elements, specifically axially loaded cross-laminated timber (CLT) walls. The study compared two supervised ML approaches: time-series forecasting and symbolic regression. The dataset used in the study was comprehensive, including 7 variables for each test. These variables covered a range of factors, including time, adhesive type, number of layers, heat flux, thickness, thermocouple depth, and temperature. Symbolic regression emerged as the superior method, offering a promising future for using simpler models in predicting in-solid temperatures of timber in fire.	Arwa	Abougharib	Department of Wood Science, Faculty of Forestry, University of British Columbia
1E	TESP Engineering Fire Engineering	Material Performance & Durability - Engineering Focus, Timber Engineering & Structural Performance - Engineering Focus	Temperature dependent bending mechanical properties of densified wood	Thermo-hydro-mechanical (THM) densified wood is rarely used in construction, although its mechanical properties are excellent in many cases [1]. The reason behind its rare use is not only due to its set-recovery, which reduces the degree of densification over time thereby the mechanical properties deteriorate, but also our knowledge of the fire-performance of densified timber is insufficient. For wood products, the inherent combustibility is always the main challenge which restrict its role in construction applications [2]. Therefore, the implementation of engineering modification processes to improve wood with regards to durability or other properties should not overlook how these processes influence the fire safety. In terms of fire safety classifications in wooden constructions, "reaction to fire" (EN13501-1) and "fire resistance" (EN 13501-2) are the two main test standards used in the European Union [3]. When subjected to elevated temperatures, wood surface will be thermally degraded into zero-strength charred layer and the mechanical properties of beneath unburned pyrolysis zone also monotonously decrease with the increase in temperature. Therefore, the reduced cross-section method is normally adopted in the fire design of timber structural elements to estimate the residue load-bearing capacity and fire resistance [3]. It should be kept in mind that wood starts to lose its strength and stiffness at temperature as low as 65°C. According to Eurocode 5, when the temperature of the wood rose from 50°C to 100 °C, its tension, shear and compression strength parallel to grain will only be about 65%, 40%, and 25% of its original value respectively. The continued penetration of the heat inside the timber construction elements may result in additional hazard in the cooling phase of a fire due to such mechanical properties loss.Knowledge of the temperature-dependent reduction behavior of strength and stiffness properties is an important precondition for determination of the resistance of wood construction in-fire and post-fire. The unexplored potential high mechanical properties of densified wood at elevated temperature could provide extra residue load-	Lei	Han	InnoRenew CoE
1E	TESP Engineering Fire Engineering	Timber Engineering & Structural Performance - Engineering Focus	Structural Design of Timber Columns in Realistic Fires	This paper describes numerical modelling to predict the strength of glued laminated (glulam) timber columns during and after fire exposure. This modelling is necessary because of the thermal wave propagation beyond the charred depth in the decay phase of the fire. The elevated temperatures inside a column will reduce the strength and stiffness, potentially causing the column to buckle under compression loads even after the fire has been extinguished. The literature contains results of experimental testing and numerical modelling of various timber columns, and the research highlights the importance and suitability of numerical models such as SAFIR for simulating the changes in heat transfer and residual structural capacity. This paper focuses on the simulated fire performance of non-encapsulated free-standing glulam timber columns using the SAFIR software, with a sensitivity analysis on design variables relating to the growth and decay phases of a parametric fire. This paper describes the analysis and design process for a typical mass timber building. Such a process is a possible path for compliance with Clause B1 of the New Zealand Building Code, to obtain a Building Consent from the local authority, following guidance in the New Zealand Commentary to the FSUW Global Design Guide.	Cameron	Douglas	PTL | Structural & Fire

Session No.	Session Topic	Abstract Topic	Submission Title	Summary	First Name	Last Name	Company
1E	TESP Engineering Fire Engineering	Timber Engineering & Structural Performance - Engineering Focus	New Encapsulation Technique for Strengthening and Enhanced Fire Resistance of Mass Timber Structural Elements	The rising use of mass timber in tall wood construction necessitates effective fire safety measures and strategies. This study introduces a new encapsulation technique for mass timber sections using a fabric-reinforced cementitious matrix (FRCM) composite system with enhanced thermal insulation and fire resistance. Mortar mixes incorporating Portland cement, aerated Portland cement, Portland-slag blended cement, and aerated Portland-slag blended cement are thoroughly investigated for this new FRCM system. Compressive strength tests have been conducted on the different mixes to evaluate their mechanical properties. Preliminary results indicate the potential of selected mixes to meet the target strength criteria of 24 MPa at 28 days of moist curing as per ACI guidelines (AC 434). Thermal conductivity analysis and high-temperature compressive strength testing are conducted to identify a low thermal conductivity mix (targeting < 0.3 W/m·K) with high strength retention at elevated temperatures. Upon exposing FRCM-encapsulated glulam columns to standard fire, the encapsulation and fire-resistance ratings are evaluated. The experimental results demonstrate that the FRCM systems, particularly those using aerated Portland cement, Portland-slag blended cement, and aerated Portland-slag blended cement, significantly delay the ignition of the glulam columns. This delay provides superior fire resistance and structural integrity for a longer duration. The potential of the proposed FRCM systems in enhancing mass timber elements' fire safety and structural resilience is significant, potentially enabling their broader adoption in high-rise building construction.	Sam	Salem	Lakehead University
1E	TESP Engineering Fire Engineering	Timber Engineering & Structural Performance - Engineering Focus	Fire Endurance Tests on Optimized CLT-Concrete Composite Floor Slabs with Individual Notch Shear Connections	Although CLT-concrete composite floors with shear connections demonstrate enhanced flexural performance in fire conditions, achieving optimal flexural efficiency across serviceability, ultimate, and fire limit states remains a significant challenge. Placing an interlayer between the CLT slab and the top concrete layer, such as an insulation layer, not only enhances the thermal and acoustic characteristics of such composite floor systems but also increases their strength and stiffness by providing a more extended lever arm for their resisting moment. Unlike shear connections mainly made of metal fasteners, notch shear connections can easily accommodate such an interlayer without compromising the composite section's efficiency and are renowned for their robustness and cost-effectiveness. This paper presents the results of fire endurance tests on two full-size, one-way CLT-concrete composite floor slabs exposed to elevated temperatures conforming to the CAN/ULC-S101 standard time-temperature curves while subjected to a total service load of 9.80 kPa. The obtained experimental results demonstrate the high flexural efficiency of the CLT-concrete composite slabs with the two proposed configurations of individual notch shear connections with an interlayer of insulation. Both test slabs successfully enhanced the fire resistance of the 143-mm, 5-ply CLT floor panel from one to two hours with increased service loads from 4.40 to 9.80 kPa.	Sam	Salem	Lakehead University
1E	TESP Engineering Fire Engineering	Timber Engineering & Structural Performance - Engineering Focus	CASE STUDY OF ENGINEERING THERMAL AND STRUCTURAL ANALYSIS OF TIMBER IN OFFICE TRAVELLING FIRE – FIRE DYNAMICS SIMULATOR AND SAFIR	This work presents a case study of traveling fire in an office containing exposed timber. The fire performance of a composite timber-concrete floor system is evaluated in terms of heat impact, flame spread and heat release contribution. Real fire scenarios were implemented for determining the heat impact on the exposed wooden surfaces using computational fluid dynamics. An engineering pyrolysis model allowed for determining the combustible material heat release contribution to the fire, as well as its charring, which is directly related to its loss in structural performance. Different fire scenarios and different configurations of the wood/concrete system, representing different levels of combustible surface exposure were compared in terms of the calculated flammability quantities.	Alain	Coimbra	CSTB
1E	TESP Engineering Fire Engineering	Material Performance & Durability - Engineering Focus, Timber Engineering & Structural Performance - Engineering Focus, Education, Innovation & Challengers - Engineering Focus	COMPARING IN-DEPTH TEMPERATURE MEASUREMENT TECHNIQUES IN LARGE-SCALE TIMBER FIRE EXPERIMENTS	Large-scale timber fire experiments commonly utilize solid-phase thermocouples inserted from the 'back' of the timber elements, perpendicular to the heated surface, to estimate charring rates and characterise the heat transfer through the section. This thermocouple orientation can induce significant measurement errors, but it is often chosen due to the difficulty of inserting thermocouples from the 'side' in large panels. This paper investigates an alternative method of inserting thermocouples parallel to the heated surface in instrumented timber cylinders, which can be inserted into larger panels. This method was applied in a large-scale timber compartment fire experiment and compared with measurements from thermocouples inserted from the back. Thermocouples inserted from the back initially underpredicted the charring rate and in-depth temperature rise, but this error decreased over time. By minimising the thermal disturbance error, the instrumented cylinders provide more accurate temperature measurements during the early heating phase, but over time, they can induce other errors unless they are specifically designed to avoid this.	Ian	Pope	DBI - The Danish Institute of Fire and Security Technology
1F	TESP / MPD - Engineering - Digital Imaging Correlation	Session Chair: PROFESSOR LECH MUSZYNSKI / OREGON STATE UNIVERSITY					
1F	TESP / MPD - Engineering - Digital Imaging Correlation	Material Performance & Durability - Engineering Focus, Timber Engineering & Structural Performance - Engineering Focus	Derivation of shear modulus of the RPF adhesive layer in block shear tests using Digital Image Correlation	In order accurately to evaluate the strength of wood-based materials, not only the physical properties of wood but also the shear performance of the adhesive layer are important. However, since the adhesive layer is much thinner than the element, it has been difficult to observe the behavior of the adhesive layer. On the other hand, recent developments in optical and image processing technologies made a non-contact strain measurement method called Digital Image Correlation (DIC) more familiar. DIC is a measurement technique using a camera and it is possible to measure strain in small areas such as the adhesive layer, depending on the camera performance. Therefore, the purpose of this study was to determine the shear modulus of the adhesive layer of a block shear specimen by measuring the shear strain of the adhesive layer using DIC. The specimens were made from three types of softwoods (Japanese cedar, Japanese cypress, Japanese larch) and resorcinol phenol formaldehyde (RPF) resin adhesive. The laminas were divided into two parts along the LT surface, and the cut surfaces were glued together using RPF to prepare the specimens. Specimens without the adhesive layer were also machined from the same lamina, and the effect of the adhesive layer on the shear modulus was considered. The test results showed that there was no significant difference in shear modulus between glued and unglued specimens of either species. One possible reason for this phenomenon is that the shear modulus of RPF adhesive may be similar to that of wood. However, since little is known about the shear modulus of RPF itself, further research is needed. Conversely, when Japanese cedar and Japanese larch were used, the coefficients of variation (C.V.) of the shear modulus for glued specimens were smaller than unglued specimens.	Koki	Kawano	Forestry and Forest Products Research Institute

Session No.	Session Topic	Abstract Topic	Submission Title	Summary	First Name	Last Name	Company
1F	TESP / MPD - Engineering - Digital Imaging Correlation	Timber Engineering & Structural Performance - Engineering Focus	Wood based fasteners for a timber earth slab	One method of constructing timber-earth slabs involves using small timber cross-sections with interstitial spaces filled with an earth mix. The earth enhances construction physics properties and naturally regulate indoor climate, while the timber structure carries the loads. Local mechanical connections are employed to facilitate geometrically unrestricted robotic manufacturing and potential material reuse. This study investigates the efficacy of beech nails, staples (each with and without adhesive), and beech dowels as fasteners. Conventional bonded intersections serve as the reference. Push-out tests were conducted on specimens featuring two shear joints each. Displacement transducers and digital image recording capture relative displacement while the forces at each shear joint are measured. The fracture failure is analyzed photographically. For small intersections, nail-bonded connections promise high stiffness and load bearing values combined with robotic manufacturing, although reuse is limited.	Dominik	Merk	Technical University of Munich
1F	TESP / MPD - Engineering - Digital Imaging Correlation	Timber Engineering & Structural Performance - Engineering Focus	Understanding the Effect of Lamination Thickness Variations on Bond Integrity in Cross-Laminated Timber (CLT)	Integrity of the adhesive bond is an imperative criterion for qualifying layered engineered wood-based composites (EWP) for structural use. In cross laminated timber (CLT) even moderate variations in lamination thickness within the same layer can significantly affect the pressure distribution at the intersections of laminations, this study aims to address the strict criteria set by the North American CLT product performance standard ANSI/APA PRG320, which are not yet supported by theoretical or experimental data. By employing Digital Image Correlation (DIC) techniques, the goal of this study is to determine the effect of thickness variation in CLT laminations on bond formation and the resulting integrity in CLT lay-up while also addressing a critical knowledge gap regarding the fundamental aspects of cross-laminated panel construction, ultimately providing valuable insights for CLT manufacturers. The approach in this study involves the use of empirical tests and coupled with numerical modelling. The specific objectives were to (1) determine the effect of thickness variation in adjacent lamination on pressure transfer and adhesive bond formation between layers (2) measurement of adhesive bond integrity distribution in lab specimens with known thickness variation, (3) determination of structural performance in panels fabricated with lamella of known thickness tolerance. The research expects that CLT with tight thickness tolerance have a better pressure transfer and bond integrity.	Samson M.	Idoghor	OREGON STATE UNIVERSITY
1F	TESP / MPD - Engineering - Digital Imaging Correlation	Timber Engineering & Structural Performance - Engineering Focus	Enhancing the Racking Resistance of Timber Shear Walls with Structural Glass: An Experimental and Computational Study	This work analyses the behaviour of structural timber-glass wall elements by carrying out experimental shear wall tests and calibrating a finite element model. Hybrid timber-glass wall elements are a novel structural solution to increase the in-plane stiffness of façades in timber frame buildings. The solution is particularly interesting when large glass façades are desired in buildings with fewer inner structural walls. Therefore, this study investigates a hybrid system that activates the stiffness of the glass windows, using a structural silicone adhesive, to increase the structural stability of the timber façade. For these timber-glass systems, no existing design codes are applicable. A finite element model is developed in this contribution, simulating the mechanical behaviour of the system, including the timber-glass connections. This model is calibrated using small-scale connection tests. Additionally, eight shear experiments are performed on timber-glass façade elements to evaluate the strength and stiffness of the system. The behaviour of the various materials and connections is precisely captured using multiple measurement techniques, including Fibre Bragg Gratings embedded in the glass panes, Digital Image Correlation, and strain gauges. The experimental results are compared to the numerical model to assess its suitability.	Tine	Engelen	Hasselt University
1F	TESP / MPD - Engineering - Digital Imaging Correlation	Timber Engineering & Structural Performance - Engineering Focus	INFLUENCE OF KNOTS ON STRAIN DISTRIBUTIONS IN GLUED LAMINATED TIMBER BEAMS	A glued laminated timber (GLT) beam is an engineered wood product made by gluing finger-jointed timber boards (lamellae) to create structural elements for various construction applications. The mechanical properties of GLT beams depend significantly on the mechanical properties of the timber boards and local defects, such as knots. This paper examines the influence of knots on the mechanical behavior (strain distributions) of GLT beams. Twenty-two GLT beams (5 m long) were tested in four-point bending. Strains were measured in the constant bending moment region of the beams using the digital image correlation (DIC) method. The effect of knots on the longitudinal and the transversal strain distributions is investigated. The paper focuses on the knots and their interactions that cause significant strain concentrations extending to adjacent lamellae. Moreover, the ratio between the transversal and the longitudinal strains in the knot zones is studied.	Farid	Vafadar	Aalto University
1F	TESP / MPD - Engineering - Digital Imaging Correlation	Material Performance & Durability - Engineering Focus, Timber Engineering & Structural Performance - Engineering Focus	FRICTIONAL CHARACTERISTICS OF THE SURFACE OF HINOKI OLD WOOD TAKEN FROM JAPANESE TRADITIONAL WOODEN BUILDINGS IN THE LATE EDO PERIOD	In this study, friction tests were conducted using two methods: the sliding method and the horizontal method. The aim was to determine the actual friction coefficient of old and new hinoki wood taken from a traditional wooden building built about 350 years ago and to clarify the surface characteristics. The results showed that the surface friction coefficient of the old wood was 0.57, while that of the new wood was 0.43, indicating that the old wood had a coefficient 1.33 times higher. Scanning electron microscope (SEM) images were also taken to observe the morphology, fine irregularities, and dents of the wood surface. The surface of the old wood was more irregular than that of the new wood, and degradation and fluff of the cell walls were observed. This suggests that the degradation of the old wood may contribute to the increase in the surface friction coefficient.	JUNGYEON	HONG	Toyo University
1F	TESP / MPD - Engineering	Timber Engineering & Structural Performance - Engineering Focus	COMPRESSIVE STRENGTH AND STIFFNESS OF GLULAM IN CONTACT WITH MORTAR	In recent years, many kinds of timber-concrete composite components have been introduced in large-scale timber buildings. In the design process of these components, it is important to accurately evaluate the behavior of the contact surface between glulam in parallel to grain direction and concrete under compression. However, there is no established method to evaluate such behavior. This study investigates the compressive behavior of glulam in contact with several materials (steel plate, mortar, mortar with epoxy adhesive, and mortar with waterproof paint) near the butt-end and proposes an effect factor of the materials in contact with glulam. Compression tests were conducted on Fourteen series with a combination of parameters and a total of 108 specimens. The test results showed that, compared to the glulam-only specimens, the strength and the stiffness of the specimens in direct contact with mortar decreased, and those of the specimens with a waterproof layer between the mortar and glulam were almost the same. As for the specimens with an epoxy adhesive layer between the mortar and glulam, the strength and stiffness significantly increased. Our study revealed that, based on the results of the specimens with a waterproof layer, the reduction in the compressive strength and stiffness could be caused by moisture in the mortar and, the results of the specimens with an epoxy adhesive layer show that epoxy adhesive affects increasing stiffness. Future works include applying the rate of change to actual building design and proposing design methodologies.	Yuichi	Kanaya	Chiba University
1G	TESP - Engineering - modular construction	Session Chair: CALIL NETO / REWOOD					

Session No.	Session Topic	Abstract Topic	Submission Title	Summary	First Name	Last Name	Company
1G	TESP - Engineering - modular construction	Timber Engineering & Structural Performance - Engineering Focus	SUSTAINABLE AND TEMPORARY USE OF VACANT BUILDINGS AND SITES THROUGH SIMPLE AND MODULAR STRUCTURAL MEASURES	Temporary uses increase the attractiveness of a location, generate added value for society and conserve the resource of building land. Thanks to a modular system developed by researchers at BFH, it will be possible to quickly and easily "furnish" vacant spaces and areas on a temporary basis. The modules consist of very light timber elements and layers as they must be mounted by hand by two persons only. Clever connections allow to erect, dismantle and adapt the modules for upcoming usages many times. A central component is a digital planning, fabrication and visualization tool. The conversion of vacant buildings and sites is of great importance to society. Such vacancies often hide great potential for temporary uses where innovative and dynamic work and creative spaces create new identities. Resources are further developed and sustainably valorized, leading to ecological, economic and social added value. In a first step house in house solutions are developed that may be adapted for outside applications. The scalable modular system offers a huge market potential for flexible structures for recurring uses such as (sports) events, emergency accommodation and temporary living in unused spaces. The goal of the project is to bring the modules to market maturity.	Christophe	Sigrist	BFH
1G	TESP - Engineering - modular construction	Timber Engineering & Structural Performance - Engineering Focus	COMPARATIVE STUDY OF CONVENTIONAL CONNECTIONS AND NOVEL INTERLOCKING CONNECTIONS IN CLT SHEAR WALLS	The study compares conventional and novel interlocking connections in Cross Laminated Timber (CLT) shear walls. CLT, popular for its environmental benefits and efficiency, faces challenges with traditional connections that are labor-intensive and mechanically limited. The new interlocking system simplifies construction, enhances reusability, and maintains mechanical integrity with less damage. Overall, the numerical shear wall analyses showed that this system offers better ductility in a damage-controlled manner, though lower stiffness was also found. This suggests that the interlocking connections improve robustness and sustainability in modular CLT constructions, while further geometric refinement is needed.	Zhengyao	Li	University of Leeds
1G	TESP - Engineering - modular construction	Timber Engineering & Structural Performance - Engineering Focus	A novel hybrid wooden structural system for multi-storey buildings in seismic prone areas	Timber structures have become a valuable alternative to traditional materials, mainly due to their light weight, speed of construction and the high strength-to-weight ratio of timber, especially in seismic prone areas. The use of timber structures, however, has been mainly confined to low to mid-rise buildings, mainly due to limited resistance of proprietary mechanical anchors. The HyWood4Buildings project aims to overcome the existing constraints in the timber sector, proposing a novel hybrid structural system for taller timber buildings. This system combines two distinct but interacting components: a modular hybrid steel-timber lateral load resisting (HyST-LaR) system and a solid-sawn wall (SoN-Wall) system. The HyST-LaR bracing system consists of a multi-storey steel frame coupled with CLT panels. HyST-LaR connections between the CLT panel and steel frame are subjected to shear load only, whereas the tensile load due to the cumulative bending moment of the shearwall is transferred directly to the foundation by the steel columns. Experimental shearwall tests and numerical analyses are being carried out in order to investigate the behaviour of HyWood4Buildings proposed systems.	Matilde	Benatti	National Research Council of Italy (CNR-IBE)
1G	TESP - Engineering - modular construction	Timber Engineering & Structural Performance - Engineering Focus	Advanced Seismic-Resilient Connection for Modular Mass Timber Structures	Recent studies conducted on a series of shake table test has revealed that CLT PMMT buildings constructed with prefabricated CLT panels are relatively stiff, and the connection between the prefabricated CLT panels solely provides the ductility and energy dissipation in the system. Additionally, the SOFIE project also reported a floor acceleration of 3.8g at the upper level (7th level) of the building due to the stiff nature of the building. Such high acceleration could lead to serious injuries and fatalities to the building occupants. Moreover, a quasi static experimental test on a two-story CLT house also revealed that ductility as high as 3.0 can be achieved with conventional connections. However, the reduction in stiffness and strength could compromise the system's structural integrity, making it vulnerable to aftershock. Nails and self-tapping screws with metal brackets is the most established method for wall-to-wall connections, while bolts and metal hold-downs are used to connect the walls to the floors in a Prefabricated Modular Mass Timber (PMMT) construction. However, these conventional connection methods have a significant drawback. When subjected to lateral loads during seismic events, the connections have to yield to dissipate the earthquake-induced energy and provide the necessary ductility in the system. The yielding of the metal connections exhibits considerable strength and stiffness degradation. This irreversible damage conflicts with the principles of seismic resilience, which aim to minimize post-earthquake repair and downtime. The current connection systems, therefore, fall short of achieving true seismic resilience in PMMT buildings.	Rajnil	Lal	The University of Auckland
1G	TESP - Engineering - modular construction	Timber Engineering & Structural Performance - Engineering Focus	Vibration Response of Cross-Laminated Timber-Steel Composite Floors with Sand Infill	The sensitivity of lightweight timber-based floors to human activity is well documented in the literature, and their design is often governed by serviceability limit state considerations such as deflection and vibration performance requirements specified in codes. Vibration mitigation measures such as addition of concrete topping, deployment of active damping mechanisms, increase in the thickness of floor slabs, and breaking floor spans have been proffered in the literature with varied results. In this study, the vibration response of a modular prefabricated cross-laminated timber-steel composite floor was investigated, considering the sand-infill of beams as a passive damping solution. Improvements in the vibration serviceability metrics of the floor were observed, revealing the potential of sand in mitigating objectionable vibration in such high-performance lightweight floors.	Cristiano	Loss	The University of British Columbia
1G	TESP - Engineering - modular construction	Timber Engineering & Structural Performance - Engineering Focus	BENCHMARKING OF A FINITE ELEMENT MODELLING METHODOLOGY FOR TIMBER CONNECTIONS	Mass timber modular construction requires high detail of their components during the design process. Special attention is given to intermodular connections, which are required to transfer the gravity loads from one module to another and provide horizontal continuity as a floor diaphragm to maintain the modules together while they transfer the lateral loads, playing an important role in the seismic performance of high-rise modular buildings. This research focuses on the finite element methodology used to simulate intermodular connections for volumetric mass timber modular buildings and the evaluation of the designed intermodular connection. A previously developed user subroutine based on continuum damage mechanics was used to simulate damage in mass timber bolted connections. Similar methodologies used to simulate steel modular connections and bolted timber joints were applied to evaluate the influence of the geometric configuration of the designed connection through a parametric analysis. The finite element model of the connection was subjected to monotonic and cyclic loading to estimate the shear and moment capacity. The connection stiffness was controlled by the number of bolts at the columns and the geometric configuration of the intermediate connection plate.	Erica	Fischer	Oregon State University

Session No.	Session Topic	Abstract Topic	Submission Title	Summary	First Name	Last Name	Company
1G	TESP - Engineering - modular construction	Timber Engineering & Structural Performance - Engineering Focus	ALTERNATIVE LOAD PATH ANALYSIS OF TIMBER POST-AND-BEAM MODULAR BUILDINGS	Timber modular buildings are an emerging construction method, due to the environmental and construction speed benefits. However, the inherent discontinuity and limited deformation capacity, hinders the ability to effectively redistribute loads under accidental load cases and thus, their robustness. A method to quantify the robustness of a building is to assess its behavior under notional element removal. In order to understand the overall robustness of this building typology, the behavior of a hypothetical five-story timber post-and-beam modular building was numerically simulated under accidental load cases represented by notional element removals. Five element removal scenarios were considered, two full-module and three individual column removals. It was found that the structure could develop sufficient alternative load paths to carry the accidental limit state loading for most removal scenarios, except for the double intermediate façade column removal. For this scenario, it was found that the preferred load redistribution mechanism was catenary action, thus the inter-module connection was redesigned to provide sufficient deformation capacity. It was found that the optimal method for redesigning the inter-module connection for catenary action was the implementation of a fuse element, increasing the ductility of the system. These findings can contribute to further implementation of modular buildings in practice.	Maria	Felicita	Empa
1H	ECCS - Engineering - Structural Behaviour	Session Chair: PROF BENOIT GILBERT / GRIFFITH UNIVERSITY					
1H	ECCS - Engineering - Structural Behaviour	Exemplars & Construction Case Studies - Engineering Focus	PERFORMANCE-BASED SEISMIC DESIGN OF STEEL-TIMBER COMPOSITE STRUCTURES USING ENDURANCE TIME METHOD	This study covers the experimental measurement and numerical modelling of vibration and noise transmission in prefabricated timber-framed townhouses in Australia. The studied structures utilize fully finished prefabricated walls and floors, transported, and assembled on-site using a crane and a minimal work crew. Operational modal analysis was employed to characterize the floor vibration response, providing essential data for the refinement of a numerical model constructed in Abaqus. Impact and airborne noise transmission assessments were conducted in accordance with ISO standards, evaluating acoustic performance between laterally adjacent tenancies and vertically adjacent rooms. Findings are benchmarked against both Australian and international building code standards. This comprehensive study elucidates the acoustic and vibrational dynamics of prefabricated timber construction, offering critical insights for advancing construction practices to meet rigorous building performance criteria.	Alireza	Chiniforush	University of Melbourne
1H	ECCS - Engineering - Structural Behaviour	Timber Engineering & Structural Performance - Engineering Focus, Exemplars & Construction Case Studies - Engineering Focus	VIBRATION BEHAVIOR OF CLT FLOORS IN A 5-STORY BUILDING PROTOTYPE UNDER HUMAN-INDUCED EXCITATION	This paper presents the results of the vibration performance of 4 CLT slabs in a 5-story building. The CLT slabs are 165 mm thick, 4.2 m long, and 6.6 m wide, with different non-structural cladding on their top and bottom faces. The experimental campaign considered two types of vibration tests. The first was a modal impact test to determine the main dynamic properties of the slabs. For this purpose, seven uniaxial accelerometers were installed on the slabs. The second was a walking test in which people of different body masses walked on the CLT slabs at different step frequencies along a predefined trajectory. The vibration dose value (VDV) indicator was used to evaluate the vibration level. Three relevant dynamic properties were detected, with vibration frequencies between 23 Hz and 36 Hz and damping ratios between 2.4% and 4.2%. On the other hand, the VDV obtained were in intermediate ranges, predicting a low probability of generating adverse comments from users. The results suggest that in real buildings, the vibration performance of CLT floors could be better than the estimations from some standards; therefore, future work is required to calibrate the numerical models of the CLT slabs to have more accurate predictions.	Alexander	Opazo-Vega	Universidad del Bío-Bío
1H	ECCS - Engineering - Structural Behaviour	Timber Engineering & Structural Performance - Engineering Focus	Vibration Tests on Long-Span CLT-GLT Composite Floor	The focus of this experimental study is on the vibrational behaviour of a long-span Cross-Laminated Timber (CLT) and Glued-Laminated timber (GLT) composite floor system. The research includes the fabrication of two full-scale 12.2 m clear span length floors with a CLT panel with 2.44 m width at the top, another CLT panel with 1.83 m at the bottom of the floor system, and two GLT beams between these CLT panels. To connect these pieces together, screws with adhesive and screws with sharp metal have been used. Then, vibrational tests before and after cutting openings on CLT and GLT will be conducted so the effects of openings on vibrational behaviour will be explored. The excitation includes heel drop at a specified point on the floor, and data acquisition includes collecting force through three load cells and acceleration through twelve sensors. In the post-processing stage, the data will be analyzed through mathematical methods, and the frequency of the floor, damping ratio, and mode shapes of the floor system will be extracted.	Weichiang	Pang	Clemson university
1H	ECCS - Engineering - Structural Behaviour	Timber Engineering & Structural Performance - Engineering Focus, Exemplars & Construction Case Studies - Engineering Focus	Case Study of a Base-Isolated 6-Storey Timber Frame Building in a High Seismic Region	This paper will present a case study for a high profile 6-storey mass timber office building located in Wellington, New Zealand. The region has very high seismicity and innovative approaches were taken to maximise the use of mass timber in the building. Key requirements of the project brief included Importance Level 4 (1.8 times higher loads than a standard office building), as well as very high sustainability goals (targeting Greenstar 6 and Carbon Net Zero) and low damage seismic design. These combined goals resulted in a mass timber frame (braced frame and post-tensioned moment frame in the two orthogonal directions) with CLT diaphragms supported on a damped base-isolated podium. The paper will present various detailing and design considerations encountered during the design, preconstruction, and construction process for this unique project.	Kiran	Makan	Holmes NZ LP
1H	ECCS - Engineering - Structural Behaviour	Timber Engineering & Structural Performance - Engineering Focus, Exemplars & Construction Case Studies - Engineering Focus	TIMBER ROOF STRUCTURE WITH COMBINATION OF RIGIDITY INCREASE EFFECT OF FOLDED PLATE SHAPES AND RECIPROCAL SUPPORT EFFECT OF LATTICE FRAME	The Toyota Mobility Shin-Osaka Neyagawa Store is a construction project for a single-story automobile dealership in Osaka Prefecture, Japan. The structural type is a hybrid of timber and steel, with the steel frame resisting seismic forces. The showroom portion of the building utilized the rigidity effect of the folded-plate structure and the mutual support effect of the two-way lattice beams to achieve a large-span timber roof structure. The orientation of the two-way lattice beams was determined by considering the structurally optimal placement based on geometric shapes utilizing computational design and the preferred placement from an architectural design perspective. Throughout the phases from design to manufacturing, the workflow was established around 3D modeling, and we as designers collaborated with the fabricator and the constructor from an early stage. This collaborative approach allowed for accurate modeling with both quality and workability. As a result, manufacturing problems were solved smoothly, and a foundation for digital fabrication of timber components was established.	Yui	Amano	Takenaka Corporation
1H	ECCS - Engineering - Structural Behaviour	Timber Engineering & Structural Performance - Engineering Focus, Education, Innovation & Challengers - Engineering Focus, Exemplars & Construction Case Studies - Engineering Focus	Balloon-type CLT shear wall construction - a review of current projects and design challenges	With the ever-expanding use of mass timber in buildings, new timber structural systems and typologies are regularly developed and implemented. One such system to resist lateral loads is CLT shear wall construction with a balloon-type framing approach. Designed to achieve structural efficiency and avoid high perpendicular-to-grain compression stresses experienced in traditional platform-type framing, balloon-type CLT shear walls could allow the development of taller CLT buildings. However, balloon-framed CLT shear walls are still in their nascency and have only been used in a limited number of projects internationally. This study discusses the value proposition of the technology and investigates current projects that have implemented it. Relevant research and experimental testing projects are also reviewed. Finally, current design challenges that hinder more widespread adoption of this system are discussed.	Kilian	Krauss	The University of British Columbia

Session No.	Session Topic	Abstract Topic	Submission Title	Summary	First Name	Last Name	Company
1H	ECCS - Engineering - Structural Behaviour	Timber Engineering & Structural Performance - Engineering Focus, Education, Innovation & Challengers - Engineering Focus, Exemplars & Construction Case Studies - Engineering Focus	DESIGN UNCERTAINTY IN LONG SPAN MASS TIMBER FLOORS: PROPOSED BAND-BEAM SOLUTION	One of the challenges open plan, long span construction poses for mass timber floors is accommodating the large depth of panels and support beams used to satisfy vibration performance criteria, therefore increasing the floor-to-floor height. Seeking a solution which allows for shallower beams with design flexibility and comparable floor stiffness, cross-laminated timber (CLT) band-beams are considered as a design solution and as an alternative to traditional post-and-beam configurations. This study has been comprised of several phases: (1) mass timber floors designed to traditional spans (6 m) were experimentally assessed in-situ returning the first natural frequency (~11.7 Hz), acceleration (< 0.5 %/g), and damping (~3.3%) within the limits prescribed by the American Institute of Steel Construction (AISC) Design Guide 11. This study then (2) evaluated the satisfactory serviceability performance of CLT band-beams through static deflection testing (0.26 mm under 1 kN point load) according to Australian Standard AS 1170.0. Numerical modelling (3) was then applied to propose a re-designed version of the in-situ floor(s) from (1) using the CLT band-beam performance from (2) to extend the span beyond 6 m while still conforming to the standards.	Adam	Faircloth	Department of Agriculture and Fisheries
1I	TESP - Engineering - Protective Design	Session Chair: DR GARY RAFTERY / THE UNIVERSITY OF AUCKLAND					
1I	TESP - Engineering - Protective Design	Timber Engineering & Structural Performance - Engineering Focus	Impact behaviour of hybrid timber beams	Recent technological developments in the manufacturing of engineered wood products (EWP) have positioned mass solid timber (MST) systems as front-runners as a viable alternative construction material due to their lightweight character and low carbon footprint. Key limitations associated with the MST systems are their brittle behaviour and low stiffness. These limitations are exacerbated in the event of a critical structural member's failure due to deliberate or accidental extreme loads, such as impacts and blasts, which could lead to the progressive collapse of a building. This study aims to investigate the performance of timber beams specifically laminated veneer lumber (LVL) and the effects of hybridizing timber beams with fibre-reinforced polymer (FRP) and steel as a solution to overcome these shortcomings. A series of control and hybrid beams, fabricated with commercially available LVL, were studied under impact load conditions. The LVL beams were strengthened with surface-mounted carbon fibre-reinforced polymer (CFRP) sheets, near-surface mounted glass fibre-reinforced polymer (GFRP) rods, and screwed-in steel sheets. Dynamic impact loads were simulated using a free-falling drop hammer test setup, with a high-speed data acquisition system recording the impact loads and associated displacements. Additionally, a high-speed 3D Digital Image Correlation (DIC) system was employed to capture a comprehensive three-dimensional strain field and inspect the modes of failure. This allowed for a thorough examination and comparative assessment of the performance levels of the hybrid timber beams under dynamic impact loads.	Bryan	Thevarajah	University of Wollongong
1I	TESP - Engineering - Protective Design	Timber Engineering & Structural Performance - Engineering Focus	Impact behaviour of hybrid CLT panels	Recent advancements in construction materials have led to an increased interest in Cross-Laminated Timber (CLT) panels as sustainable alternatives to traditional building materials as they are less carbon intensive and significant potential for recycling at the end of life cycle. The brittle failure mechanisms of CLT can be critical in an extreme loading event and lead to progressive collapse of the timber building. Combining CLT with a high-strength materials in a complementing way could produce a sustainable and resilient hybrid system. This study investigates the performance of CLT panels under dynamic impact loads, focusing on both control panels and hybrid panels strengthened with surface mounted Carbon Fiber Reinforced Polymer (CFRP) fabric and steel sheets. Commercially available CLT panels were tested using a free-falling drop hammer setup to simulate impact loads of varying intensity. A high-speed data acquisition system recorded impact forces, associated midspan displacements, and strain measurements, while a high-speed camera captured the modes of failure. The experimental setup and methodology enabled detailed analysis of impact resistance and structural response. Preliminary findings indicate enhanced impact resistance and increased ductility in the CFRP and steel-strengthened CLT panels compared to control panels.	Bryan	Thevarajah	University of Wollongong
1I	TESP - Engineering - Protective Design	Material Performance & Durability - Engineering Focus, Timber Engineering & Structural Performance - Engineering Focus	ARENA BLAST TESTING OF REINFORCED CROSS-LAMINATED TIMBER	Previous studies involving blast, ballistic, and forced entry testing on Cross-Laminated Timber (CLT) indicated that CLT provides greater protection than conventional wood construction, but that it needs some form of reinforcement to comply with stringent antiterrorism requirements. Recent quasi-static testing has shown that embedding steel plates in CLT can increase both the flexural strength and ductility of the panel, which implies an improved blast response when compared to an unreinforced panel. This paper describes a test program in which six CLT panels were reinforced with embedded steel plates and subjected to blast loading. Prior to dynamic testing, three of the six panels were subjected to six months of outdoor weathering to investigate dimensional stability and the potential for delamination under temperature and moisture cycling that could occur during construction. The six panels were then subjected to arena blast testing to demonstrate the ability of reinforced CLT (RCLT) to exhibit a ductile post-peak response. The RCLT panels generally exhibited qualitative damage that was consistent with Heavy Damage or better for significant blast loads. This paper describes the selection and fabrication of the panels, documents the observed degradation during the weathering period, and provides results from the blast tests.	Eric	Kjolsing	Karagozian And Case
1I	TESP - Engineering - Protective Design	Timber Engineering & Structural Performance - Engineering Focus	Overview of the Behaviour of Mass-Timber Members Subjected to Contact Charge Detonations and Near-field Blast Loads	Research on the performance of timber structures subjected to near-field blast loads and contact charge detonations is lacking, and a holistic approach is required in order to develop effective design guidelines and retrofits. A comprehensive research programme is currently underway to investigate the performance of mass-timber structural elements subjected to extreme dynamic loads using full-scale experimental testing and high-fidelity modelling. This paper provides an overview on some of the initial experimental results of an ongoing research programme investigating cross-laminated timber (CLT) panels. Key results on the effect of these loads on the material behaviour, including localized and global failure modes, are discussed. The overarching results of this research programme will provide the knowledge required to develop design methods for mass-timber structures subjected to contact charge detonations and near-field blast loads, as well as develop and validate simplified analytical and high-fidelity modelling tools.	Christian	Viau	Carleton University
1I	TESP - Engineering - Protective Design	Timber Engineering & Structural Performance - Engineering Focus	High-Fidelity Finite Element Modelling of Mass-Timber Members Subjected to Simulated Far-Field Blast Loads	This paper presents a numerical study using the finite element (FE) method through LS-DYNA investigating the behaviour of glued laminated timber (glulam) beams and cross-laminated timber (CLT) panels subjected to shock-tube simulated blast loads. The modeling approach is validated with experimental shock-tube test results. The study shows that the FE models capture the overall failure modes and damage extent for glulam and CLT members with reasonable accuracy. Additionally, high-fidelity modelling shows the potential to accurately predict the dynamic behaviour of heavy timber elements in terms of displacement-time history and resistance curves, which is important for designing safer timber structures subjected to far-field blast loads.	Mehdi	Saloo	Carleton University

SESSION 1
Monday 23rd June 2025
11am to 1pm

Session No.	Session Topic	Abstract Topic	Submission Title	Summary	First Name	Last Name	Company
1I	TESP - Engineering - Protective Design	Timber Engineering & Structural Performance - Engineering Focus	Modelling of Cross-Laminated Timber Panels Subjected to Contact Charge Detonations and Near-Field Blast Loads	Despite recent progress in terms of developing protective design provisions and standards for mass-timber structures against far-field blast loads, little to no work has been conducted on how these relatively novel systems behave under close-in live explosives. This paper presents the results of a numerical study investigating the behaviour of cross-laminated timber (CLT) panels subjected to contact charge detonations and near-field blast explosions. The finite element software LS-DYNA was utilized, with material inputs derived from the built-in model and recent experimental test programs. Experimental contact and near-field blast testing was conducted to be used for the validation of the model, where the modelling results showed good agreement. This numerical modelling tool will allow for the response of mass-timber elements subjected to contact charge detonations and near-field explosions to be predicted without the need for costly experimental blast testing.	Mehdi	Saloo	Carleton University
1I	TESP - Engineering - Protective Design	Material Performance & Durability - Engineering Focus, Timber Engineering & Structural Performance - Engineering Focus, Timber Architecture & Biophilic Design - Engineering Focus	OPTIMIZING TARGET PROXIMITY FOR CROSS-LAMINATED TIMBER (CLT) MULTI-IMPACT BALLISITIC EXPERIMENTS	Cross-laminated timber (CLT) is an engineered, multi-layered wood product with alternating ply orientations. This innovative material has gained traction in the United States due to its sustainability, constructability, and high strength-to-weight ratio. Recent research indicates that CLT performs exceptionally well under extreme loading conditions, such as blast and ballistic impacts, and therefore, has high potential to be implemented into force-protected infrastructure. However, integrating CLT into defensive structures requires extensive data collection to fully characterize its ballistic and blast resistance. Current ballistic testing standards for CLT are based on pervious experiments with thin metallic plates, despite their fundamentally different properties. Unlike steel, CLT exhibits more localized damage, allowing for a greater density of projectile impacts within a single specimen. In contrast, metallic plates require increased spacing between impact sites to prevent shot path interactions. To optimize multi-impact ballistic testing on CLT, seven Loblolly CLT panels were tested with varying projectile target proximities and subjected to 96 shots using 0.50-inch (1.27 cm) steel sphere projectiles. Results suggest that no shot path interaction occurs when impacts are spaced at least 2-inches (5-cm) apart. Consequently, this study recommends reducing the standard shot spacing for future CLT partial penetration tests with 0.50-inch (1.27 cm) steel spherical projectiles from 7-inches (17.78 cm) to a minimum of 2-inches (5-cm). This experiment provides a significant contribution to the field by establishing a more efficient ballistic testing methodology tailored to CLT. The optimized approach allows for the collection of substantially more data while improving resource efficiency and reducing testing time.	Juliet	Swinea	Georgia Institute of Technology