Project Code : T4-1-C0	Project Title : Environmental Performance of Innovative Wood Building Systems using Life-Cycle Analysis
Session # IV: Carbon Footprint of Wood Construction	Presenter: Sylvie Alain, Université Laval

Background and objectives:

Buildings construction and operation have a significant impact on the environment. Life-cycle assessment (LCA) aims at quantifying the real impacts on the environment of products and services. To perform the LCA of a building, 2 types of tools can be used: a specialized tool, such as the Athena Impact Estimator for buildings (Athena), or a general tool, such as SimaPro. Athena is easier to use and has an adapted database, while SimaPro is more complex but allows more flexibility and transparency. The literature review revealed that LCA being a recently developed method, there are still many articles on methodology development. Several papers also discuss the comparison between LCA tools. Other research projects report on LCA of wood products. Finally, although this is less abundant, there are more and more LCA studies on whole buildings.

The objective of the project is to identify the context for which it is most appropriate to use the two LCA tools: Athena Impact Estimator for building and SimaPro to evaluate an innovative wood building. We want to identify the strengths and the limits in the utilisation of each of the two LCA tools for two contexts: “professional design of buildings” and “research on the sustainability of innovative wood buildings”. Finally areas for further improvement will be identified for both tools in each of the two contexts.

Research method/approach

Literature review has been almost completed. An exploratory study was also first conducted to get familiarized with the two tools. Second, the main case study will perform LCA of an innovative wood building - the *Fondaction* building. This six storey-office building is currently the tallest post and beam modern wood construction in North America.

The functional unit has been defined as the construction and operation of the six-storey office building for a period of 50 years in Quebec City. Three versions of the building will be studied: a conventional concrete structure, the current wooden building, and a hypothetical building with more wood products.

Summary of results to-date

Athena and SimaPro will be used for to evaluate potential impact on the environment. The results will be discussed to determine the best context for using the two tools

Expected key output and potential impact of research

Expected results at the end of this research project are: to identify the advantages and limitations of these two tools for this case study for two contexts of utilisation (professional design and research), to list the missing information required to perform the ideal LCA with these two tools in their respective context, and to discuss possible improvement to be brought to the two tools to enhance their efficiency for the evaluation of wood structures, from both a R&D and a professional design context

Project Code : T1-6-C1	Project Title : Influence of Manufacturing Parameters on CLT Plate to Resist Out-of-plane Loading
Session # : V: Cross Laminated Timber Construction	Presenter : Yue Chen

Background and objectives

Influence of manufacturing parameters, such as material properties, number of layers, fiber direction in each individual layer, is very important to understand the mechanical characteristics of CLT structures and provide advice on what should be considered during the design process. Experimental investigations, which can be a good strategy, are time consuming, expensive and on occasions practically difficult to perform. Therefore, the use of computer aided numerical modeling can be a realistic scientific option. The main objective of this phase of the work is to develop three dimensional finite element models, which can be used to analyze the resistance of CLT plate to out-of-plane loading, and verify the models by comparing predicted results with measured data obtained from experimental studies.

Research method/approach

Comprehensive three dimensional finite element models, which can predict bending behavior of CLT under out-of-plane loading, have been developed using a commercial software package ANSYS® (version 11.0). This model is capable of predicting the out of plane deflection, stress, strain etc. of CLT systems in static environments. The challenge of the approach is the lack of North America commercial CLT product; therefore, CLT product used in the work was made locally.

Summary of results to-date

Bending stiffness of all the specimens were calculated based on the experimental measurements and compared with computer model predictions. Models were verified by good agreement between numerical results and test data. Influence of manufacturing parameters was analyzed and based on this recommendations were made.

Expected key output and potential impact of research

This research can lead to a comprehensive understanding of the influence of manufacturing parameters on CLT plate to resist out-of-plane loading. It can provide a design tool for more complicated CLT systems used in floor applications and serves as a strong foundation for future work in developing, manufacturing and promoting various CLT products in the North American construction market.

Project Code : T3-3-C7	Project Title : Fire Behaviour of Cross Laminated Timber Panels
Session # : V	Presenter : Marc Aguanno, Carleton University

Background and Objectives

There has been a considerable increase in interest from the wood and construction industries as well as government natural resources and forestry departments in the use of high-performance wood technology to significantly increase the amount of wood fiber used in residential, office, school and commercial buildings. One such technology is cross laminated timber panels. However, despite an increase in its use in Europe, there is very little information published on the fire performance of CLT.

Therefore, the objectives of this project are:

- To conduct a series of medium-scale and full-scale experiments to study the behaviour of CLT panels exposed to both standard and non-standard time-temperature curve fires.
- To conduct room fire tests to study the impact of CLT panels on design fires in terms of their additional heat release rate.
- To modify Carleton University's current finite-element heat and mass transfer computer model (CUWoodFrame) based on data from the aforementioned experiments.
- To compare and validate the newly modified CUWoodFrame model to the CLT medium-scale and full-scale experiments.
- To perform a sensitivity analysis of CUWoodFrame to determine the impact of wood properties on the behaviour of CLT.
- To use CUWoodFrame to model the performance of CLT panels under real fires.
- To develop a module for CUrisk and use CUrisk to calculate the safety levels in CLT buildings

Research Method/Approach

A series of medium-scale CLT floor experiments will be conducted using Carleton University's furnace, currently under construction, to determine the performance of these floors when exposed to the standard and non-standard time-temperature curves in terms of their charring rate and fire resistance. A standard full-scale CLT wall test under load will be conducted using the wall furnace at the National Research Council to validate both the thermal model as well as structural calculations using the reduced cross-section predicted by the thermal model.

The temperatures within the CLT panels and charring rates observed will be used in the thermal computer models, Gypro and CUWoodFrame. The results will then be used to develop a module for CUrisk. With the module, CUrisk can be used to calculate the overall safety levels in CLT buildings and compare it to the safety levels of similar buildings that comply with the current requirements of the National Building Code of Canada.

Summary of Results To-Date

- Literature review started
- Design and construction of a medium size furnace under way
- Simulations are being carried out to study the performance of the pyrolysis computer model Gypro.

Expected Key Output and Potential Impact of Research

Furnace construction is scheduled to be ready by March. Experimental findings will serve as input to the models. Later, used in CUrisk to calculate the overall safety levels in CLT buildings.

Project Code :T4-5-C10	Project Title : Developing durable building envelope assemblies for CLT construction
Session # : V	Presenter : Ruth McClung, Robert Lepage

Background and objectives

Cross laminated timber is a relatively new engineered wood product. Due to its fabrication from multiple plies of perpendicularly oriented slats, the assembly scale moisture characteristics are not fully understood. Specifically, there is concern that construction moisture may pose durability issues to the CLT panel, especially when integrated into wall assemblies. The current objectives of the project are to determine the one-dimensional wetting and drying behavior of CLT panels in a laboratory setting, and their hygrothermal performance when integrated in wall assemblies during field testing. After these tests are performed, recommendations will be made for the implementation of CLT construction in North America.

Research method/approach

The approached used to determine the susceptibility of CLT panels to moisture is to utilize empirical tests to obtain moisture properties to populate a hygrothermal model. The laboratory empirical tests were comprised of both gravimetric and resistance tests to determine the moisture content; the former to assess total moisture content, the latter for the moisture content distribution. Once the computer model is calibrated with this data, the panels may be subjected to a multitude of simulated conditions. A variety of wall assemblies including wetted CLT panels will then be constructed in a test hut and instrumented to monitor moisture contents across the CLT panels, temperature, and relative humidity. The drying capacity and hygrothermal performance of the wall assemblies including materials of different vapour permeabilities will be analysed based on data collected from the panels over one year.

Summary of results to-date

At present, the laboratory tests are being conducted, and the field testing is expected to commence in spring. Four 25kg samples are currently in a large scale balance. Data are being collected every 5 minutes from the load cells and averaged every half-hour. Resistance moisture content readings are taking approximately every other day. Data analysis is ongoing.

Expected key output and potential impact of research

Some of the key outputs of the research are a refined understanding of assembly level moisture characteristics, specifically those related to capillarity. These are then used in a computer model to provide suggestions for applicable uses of CLT panels, as well as improvements to reduce the consequences of construction moisture. Field testing will confirm the laboratory results and will lead to the development of guidelines for the use of CLT in North America, facilitating market penetration.

Project Code : **T2 – 5 – C2**	Project Title : **Predicting Lateral Drift and Natural Period of Mid-rise Wood and Hybrid Buildings**
Session # VI	Presenter : Nidaa Shooman (MSc4-T2), University of Ottawa

Background and objectives

An important tool that is currently missing in Canadian design standards is a reliable approach to predict the natural period of mid-rise buildings wood light frame and hybrid buildings. This information is required for the calculation of design forces under seismic and dynamic wind gust loads based on the simplified static procedures of the National Building Code of Canada 2005. The NBCC provides an empirical formula to estimate the natural periods of buildings as a function of building height. However this formula has not been calibrated to mid-rise wood frame buildings and its application is doubtful. Errors in the evaluation of natural periods of buildings may give rise to large errors in the evaluation of the seismic base shear demands. Phase 1 of Project T2-5-C2 addresses the issue of predicting natural periods of wood buildings. The main goal is to develop a data base of in situ measurements of natural frequencies, mode shapes and internal damping of wood light-frame constructions and hybrid structures to derive appropriate predictive models.

Research method/approach

The primary focus of this master's research is on field measurements in low- and mid-rise wood frame buildings using ambient vibration testing (AVT) to extract their dynamic characteristics. A unique feature of the research is that the measurements to be made on a few new 6-storey buildings in British Columbia will be conducted during and after the completion of the building construction. This will allow the effects of architectural components such as gypsum boards and siding to be evaluated. Combining with data collected by McGill University on lower-rise wood buildings and on buildings built with other materials, this work will develop empirical or semi-empirical models, based on building dimensions and stiffness of sub-systems, for predicting natural periods of mid-rise buildings that can be incorporated into NBCC. The AVT equipment (7 stand-alone dynamic sensors) has been acquired by McGill University in the late spring of 2010 with funds from an NSERC RTI grant (PI G. McClure, Dr. Chui was a co-applicant).

Main challenges

To date, the main project challenge has been to establish links with 6-storey wood building owners to get permission to make AVM tests in their buildings. Tests on low-rise existing buildings also yield valuable results, especially to assess damping and its variability. However, structural details are not readily available for each building/house tested so only general results are of interest.

Summary of results to-date

We have results for 6 low-rise residential buildings (1 bungalow and 5 2-storey cottages) located on the South Shore of Montreal on soils of Category D. These residences were constructed between 1981 and 2000. The fundamental natural frequencies of these constructions varied from 6 to 9 Hz (the stiffer was the bungalow) and damping was in the range of 3 to 7%.

Expected key output and potential impact of research

The key output of this project is the collection of in situ data on dynamic properties of wood buildings. If sufficient data are collected to achieve statistical significance, a simple predictive model for fundamental natural frequency will be proposed. The data base will later serve to validate/calibrate detailed computational models of the buildings to be developed in the second phase of the project that will address drift prediction.

Project Code : T2-8-C4	Project Title : Development of Hybrid Bracing Solutions for Light-wood Frame Buildings
Session # : VI	Presenter : Andi Asiz

Background and objectives

Lateral load resistance of light wood frame buildings is generally provided by walls sheathed with panels or lumber boards. From an architectural perspective the requirement for shear wall may lead to problems with respective to space usage in a building and prevent building plans with open space concept. This issue is compounded when the storey height limit is raised. There is a need to provide alternative bracing solutions that will provide the required lateral resistance but still allow for open space buildings. Wood portal frame systems have been identified by engineers and builders as a viable option to meet this need. The second issue that has been capturing the attention of designers in relation to the 5-6 storey light frame initiative is the use of gypsum wall boards in engineered light wood frame buildings. The Canadian wood design standard, CSA O86, provides design information to allow designers to consider the contribution of gypsum wallboard to the overall structural capacity of shear walls. However, the current provisions are limited to light wood frame buildings up to 4 storeys in height. The specific objectives of this project are:

- to develop technical information that can be used to derive engineering design specifications for wood-based portal frame that can be incorporated into wood design standard and building codes.
- to expand Table 9.5.4 'Maximum percentage of total shear forces resisted by gypsum wallboard (GWB) in a storey' in CSA O86 to cover 5-6 storey buildings.

Research method/approach

The main method is extensive numerical analyses of multi-storey light wood frame buildings (LWFB) subjected to lateral loads. Available software such as SAPWood and finite element ABAQUS are used to obtain structural responses such as storey drifts, storey forces, and component forces as a function of lateral load parameters (e.g. seismic accelerations, wind forces). Failure (or collapse) behaviours of the buildings are also investigated based on these outputs. Available test data on shear walls, gypsum wall boards, portal wood-based frames, and connections are used as input into the 3-d building model.

Summary of results to-date

Analysis results of multi-storey LWFB that incorporated GWB in the wood based shear walls that indicated the importance of incorporating stiffness as well as strength to determine shear storey contribution of GWB.

Expected key output and potential impact of research

- Design method/procedure on how to incorporate portal wood-based (or steel-based) frames into multi-storey LWFB.
- Rational design method to incorporate gypsum wallboard contributions on the strength and stiffness of multi-storey LWFB.

Potential impact of research:

- More options on utilizing wood in LWFB applications due to flexibility in accommodating wider or more spacious rooms.

Project Code : T2 – 9 – C6	Project Title : Structural Response of Mid-rise Hybrid Building System Consisting of a Light Wood Frame Structure and Stiff Core
Session # : VI	Presenter : Lina Zhou

Background and objectives:

Recent changes in building regulations have raised the storey limit of light wood frame buildings from 4 to 6. The increase in height leads to more flexible buildings, potentially necessitating the need to rely on the stiff elevator and stair-well core to provide partial lateral resistance which is usually made of reinforced concrete or masonry. There is a knowledge gap on performance of hybrid mid-rise light wood frame structure (LWFS) when it is attached with a masonry core that has vastly different physical (shrinkage) and mechanical (stiffness) properties. The main goal of this project is to develop a better understanding of the interaction of LWFS and stiff core in a hybrid building system and how the responses are influenced by the characteristics of the connections. Specific objectives of this project are:

1. To develop 3-D computer modeling techniques which are capable of simulating the performance of hybrid wood buildings under structural and moisture induced loads.
2. To compare the structural responses of hybrid systems with various configurations to seismic and moisture induced loads when the two sub-structures are connected and unconnected.
3. To provide recommendations on connection characteristics between light wood frame and stiff core sub-structures in a hybrid building system.

Research method/approach:

The key tool to study the interaction between LWFS and stiff core is a 3-d structural model. 3-D finite element modeling approach is adopted through the use of commercial software ABAQUS to analyze the performance of a six-storey light wood frame building connected to reinforced masonry core by a ductile connection system. Focus of the study is on the load distribution between the two sub-structures and the stress-strain development at the connection system. Concept of super-element is adopted for modeling both of the shear walls and floor and roof diaphragms to reduce the total degrees of freedom of the whole structure. Hysteresis property of shear walls will be extracted from more detailed wall modeling analysis. Laboratory test data on wood-masonry connection is used as initial input into the 3-D model which may be modified later to investigate its effects on performance of the hybrid structure.

Summary of results to-date:

Up to now, wood concrete-block connection test has been conducted in the laboratory to generate load-deformation response which will be required for subsequent structural analysis of the building under seismic and moisture induced loads.

Expected key output and potential impact of research:

The research effort made in this project will provide a better understanding of the interaction between the reinforced masonry core and light wood frame system and may lead to design guidelines that can be adopted by design professionals and builders to effectively deal with the design of mid-rise hybrid wood frame buildings.

Project Code : T2 – 13 – C3	Project Title : Solutions for alternative bracing systems in light-wood frame buildings.
Session # : 2010-2012	Presenter : Abdullah Al Mamun

Background and objectives

With the increasing demand for larger structures, wider openings and open concept design, there is a need to consider other bracing systems other than wood based light-wood shear walls that would be able to provide designers with more flexibility without compromising the integrity of the structural system. Objectives of the research work:

- Providing modifications and improvements to the detailing of the portal frame in order to use it interchangeably with light frame shear walls.
- Increase the capacity of traditional portal frames to resist higher lateral load providing more rigidity to wood structures.
- Provide different possibilities for corner details including the use of FRP to increase the sheathing tension capacity
- Validate the experimental result with finite element models.

Research method/approach

The key to high capacity portal frame is the amount of moment a corner can resist. The research methodology will be to investigate different details in order to improve the moment capacity of the corner joint. Reduced scale corner tests, together with FE modeling will be used as a precursor to conducting full scale tests on portal frames. Some of the joint details envisioned are: the use of high strength and stiffness materials such as CLT together with self tapping screws; the use of fiber reinforced polymers (FRP) to increase the joints tension capacity and confine the joint, which is especially useful when dealing with OSB on lumber studs; investigating different boundary conditions to enhance the strength and rigidity of the portal frame.

Summary of results to-date

- Literature review is completed
- Preliminary joint tests using FRP are scheduled for January 2011
- Joint tests using CLT is schedule in March 2011
- Full scale tests of portal frames scheduled for summer 2011

Expected key output and potential impact of research

- The joint tests will serve as an inexpensive measure to evaluate the strength increase in the corner moment capacity based on detail modifications. The full scale tests will shed light on the performance of portal frames using new materials and new details. It will also serve as input to a detailed FE model that will later on investigate the force transfer between portal frames and other bracing systems.
- In general, the research will provide flexibility to the designer to meet the increasing demand for larger structures, wider openings, and open concept design without compromising the integrity of the structural system.

Project Code : T2-1-C4	Project Title : Techniques for forming multi-functional construction interfaces in hybrid-buildings
Session # : VII	Presenter : Jan Weckendorf

Background and objectives

Because any instances of poor performance in multiple or high occupancy buildings have greater consequences than poor performance of single or limited occupancy buildings, robust design of large and/or tall buildings calls for great attention to details and a thorough understanding of multiple performance issues. Areas of interest include structural and fire safety; preventing disproportional or catastrophic damage; isolation of occupancies with respect to vibration and sound transmission.

Objectives include the definition of the functional requirements for construction interfaces, so that they will meet existing and anticipated regulatory and possibly other requirements, setting of criteria for practical decisions about placement of multi-functional construction interfaces, with initial emphasis on the Canadian environment, definition of technical performance requirements that materials/material combinations in construction interfaces must meet and identification and proof of promising construction interface construction methods.

Research method/approach

- Developing initial ideas and defining scope of study by literature review and discussion with experts in various relevant fields at meetings and conferences (T2(-1-C4) meetings, WCTE 2010, etc.)
- Presenting ideas to and discussing them with industrial and research partners (FPI, Nordic, McGill, etc.)
- Furthering ideas to concretize concepts (Defining type of structure, structural materials and design with respect to vibration/seismic, sound and fire performance)
- Defining work to be tackled in a related project (e.g. on energy dissipation in tall hybrid buildings)
- Arranging workshops with focus on multi-functional interfaces to obtain valuable input from (inter)national experts in relevant fields (Topics: Fire, Vibrations, Acoustics, etc.)
- Investigating feasibility and/or effectiveness of concepts by carrying out experimental, analytical and numerical studies (static and dynamic tests, fire tests if practical, FE analysis of tall hybrid buildings and structural components such as global and local vibration performance, analysis of obtained and existing test data)
- Obtaining input from network partners for enhancement of design concepts

Summary of results to-date

Initial ideas have been formulated, presented and discussed with network partners. Groundwork for a workshop with international experts is arranged so as to obtain valuable contribution with respect to fire, acoustical and vibrational design, etc. Studies and discussions suggest focusing on tall, slender hybrid buildings, preferably constructed with RC cores and frames, with CLT floors and possibly CLT walls. Investigation of implementation of relatively simple and economic damping mechanisms is also underway for control of the building's dynamic response.

Expected key output and potential impact of research

- Definition of horizontal and vertical occupancy separations in tall hybrid buildings, which will allow for comfortable (serviceable) living environment due to optimized structural design with respect to sound and vibrations, and acceptance of timber for use in high-rise buildings by application of appropriate fire design concepts
- Definition of relatively simple, economic damping mechanisms to be implemented in tall hybrid (timber-RC) buildings to enhance energy 'dissipation' during vibrations and therefore control of the structure's dynamic response

Project Code : T2-2-C4	Project Title : Niche for and Feasibility of RC-frame Multi-material Mid-rise Hybrid Systems
Session # :	Presenter : Jeffrey Blaylock

Background and objectives:

- The first objective is to identify niche areas for hybrid wood-concrete systems in mid- to high-rise structures using traditional light-frame wood construction. There is currently no literature that addresses light-frame wood and concrete systems for mid-rise structures.
- The second objective is to further develop one of the potential niches, specifically the use of exterior non-loadbearing wood frame infill walls in reinforced concrete structures. The project will investigate structural aspects including connection detailing, tolerance and deformation criteria and durability issues.
- This type of construction is uncommon in North America but has been implemented throughout parts of Europe. There is no literature that addresses potential issues and height limitations.

Research method:

- A spectrum of wood-concrete hybrid systems has been investigated to identify new and existing niches.
- A literature of review of wood-concrete systems has been simultaneously conducted.
- A simplified feasibility analysis has been carried out to assess the maximum spans and number of storeys that are possible for the hybrid systems investigated. The compressive capacity of loadbearing dimensional lumber, as specified by CAN/CSA-O86-01, has been used as the restricting factor for this study.

Summary of results to-date:

- Niche areas for short-term investigation:
    - Wood-Concrete hybrid flooring and topping in residential Wood Structure
        - Current practice limits this type of design to 4-5 storeys.
    - Wood Structure with Concrete Lateral Load Resisting System
        - Currently being addressed by Project T2-9-C6.
    - Exterior Non-loadbearing Wood Infill walls in Reinforced Concrete High-rise Structure
- Niche areas for long-term investigation:
    - Combining various niche areas with the focus of creating a compartmentalized high-rise wood-concrete hybrid structure that optimizes the use of both materials.

Expected key output and potential impact of research:

- The feasibility study allows niche areas to be identified to help direct the future research of others within the network, as well as the focus of this project.
- Pursing exterior non-loadbearing wood infill walls in R/C structures could develop an opportunity for the Canadian wood industry in high-rise structures that did not previously exist.
- Developing the proper design criteria for this form of construction will also allow a further understanding of the wood-concrete hybrid system at a basic level.

Project Code : **T2-3-C4**	Project Title : **Steel-wood Based Mid-Rise Hybrid Systems**
Session # : **VII**	Presenters : Caroline Villiard and Carla Dickof

Background and objectives

Researchers around the world have studied hybrid structures using concrete combined with steel or wood. The objective of this project is the use the advantages from a steel and timber hybrid to increase the height of buildings

Research method/approach

Initially we reviewed the many publications on hybrid systems and narrowed our focus to building level hybridization. We performed structural analysis using ANSYS on a simple steel frame with wood shear walls. After review it was decided ANSYS was the best software to model the future, more complex models

Summary of results to-date

The literature review revealed many studies at the component level. We will apply the concepts of these at the building level to get the most of each material characteristic

We also modeled one slice of a 5 story building with ANSYS in 3 different versions to compare building drift with different amounts of wood shear walls. As expected deflections were reduced

Expected key output and potential impact of research

The result of the case study indicates that wood shear wall greatly reduce the lateral deflection of a steel frame. Future study will look at reducing the steel member sizes due to the reduced lateral load carried. Further study will provide more insight on economically optimized member combinations and structural dimensions. The connection and compatibility between steel and timber remains a crucial design issue to be resolved.

Project Code : T2-4-C3	Project Title : Innovative Post-tensioned Composite Systems for Long-span Floor Construction
Session # : VII	Presenter : Chao Zhang

The objective of this research project is to develop and validate a post-tensioned timber and concrete composite floor system that can be easily prefabricated. The purpose is to extend the current span of timber beams through composite action and improve construction efficiency through prefabrication.

A number of studies in the past have demonstrated the effectiveness of composite cast-in-place concrete floor slabs in increasing the allowable span of timber beams. Our research will carry on the scientific background of those studies and explore ways for improvements. For instance, in addition to the composite action of concrete and timber, we are seeking techniques to add post-tensioning into the system to further enhance strength and structural performance. In addition, instead of waiting for in-situ cast-in-place concrete to set, prefabricated concrete panels can be manufactured off site with high quality controls and installed rapidly. Maximizing prefabrication can not only cut down construction time and costs, but also improve the overall quality of the structure.

To produce timber-concrete systems with high degrees of composite action, the shear between the timber beam and the concrete floor slab needs to be transmitted effectively. Therefore, developing a reliable shear connection is the first step of the project. There are a large variety of shear connectors available in the market. However, a series of development studies and experimental tests is required to determine the most suitable connector for the system. As of today, progressive steps have been made through preliminary development studies from relevant literature. The studies will continue in the winter and spring months of 2011 with greater depth and more specific focus. The studies will help us define the important parameters needed for the experimental work, which we expect to take place from the summer 2011.

In addition to the timber-concrete shear connection, the precast concrete floor panels require transverse joint to be connected. The development of the transverse joint will take place immediately after the completion of the shear connector, and will involve both analytical and experimental work. The next stage is to validate suitable methods to incorporate post-tensioning into the system. This task will primarily involve development studies and analytical work. In the meantime, we would also like to assess the long-term performance of the composite system with special attention on creep in wood and its relative structural impact.

We are positive about this promising research, as everything is moving at a steady and progressive pace. We will provide research updates from time to time and more definite findings as our work progresses.

Project Code : T2 – 10 – C6	Project Title : Movements and Deformation Incompatibilities of Materials in Glulam Heavy-Frame Hybrid Buildings
Session # : VII	Presenter : Henry Meleki

Background.

Deformation incompatibilities occur when interconnected parts of structural systems in timber hybrid buildings distort differently under influences affecting them as a whole or in part. For example: wood and concrete deform differently while they come into equilibrium with or respond to changes in temperature or relative humidity of surrounding air. This potentially causes damaging stresses to build up in one or more parts of systems. Current practices for avoiding deformation incompatibility problems in timber buildings have been learned empirically and may be unreliable if applied in situations like construction of larger or taller buildings, new combinations of materials and when construction details are altered. Need exists for scientific understanding and modeling of deformations in timber hybrid buildings. Applications for which knowledge is required include buildings employing heavy-frame structural systems with glulam members and reinforced concrete shear walls.

The objectives of this study are:

- To understand the causes and develop the ability to predict temporally varying movements/deformations in structural components of glulam heavy-frame hybrid buildings.
- To create finite element numerical models capable of predicting deformations in building with glulam heavy-frame structural systems based on scientific understanding of how materials behave under combined influences that occur in real buildings.
- To facilitate application of advanced understanding in support of using glulam as a mid- and high-rise construction material which can be used in combination with other material to optimize system performance.

Research method/approach

- Taking account of the observations based on a 6-storey building at Quebec City (including collecting data related to moisture, and internal & external loading).
- Performing laboratory tests to determine the responses of critical macro elements to environmental and loading conditions
- Conducting laboratory tests for scaled model on the response of varying environment and loading conditions
- Development of numerical Finite Element Method model that replicates temporally varying field responses of buildings

Summary of results to-date

- Developed preliminary system model by using SAP2000 commercial software to study the effect of differential movement due to shrinkage of wood and concrete in eight storey building
- Developed preliminary finite element model for connection by using ABAQUS commercial software to study the effect of movement due to shrinkage in more detail
- Conducted laboratory experiments for concrete and Glulam for shrinkage monitoring

Expected key output and potential impact of research

- Creating knowhow & tools for moderating the potential for loss of function in buildings caused by deformation incompatibilities.
- Making contributions to scientific literature on systems level design of buildings.

Plan for future work.

- Laboratory tests (at 1/4 or 1/6 scale), on progress and planned to be completed by the end of 2011
- Enhancing and updating the finite element numerical model

Project Code :T4-2-C10	Project Title : Characterizing wind-driven rain load and the effectiveness of overhang on reducing wind-driven rain wetting for mid-rise buildings
Session # : VIII	Presenter : Hua Ge

Background and objectives

Rain load is one of the most important outdoor climatic parameters and moisture intrusion by wind-driven rain is the major source of moisture causing failures in building envelopes. However, there is very limited data on the amount of wind-driven rain impacting buildings, especially six to eight storey buildings with overhangs. Given the level of skepticism in the construction community on the effectiveness of overhangs on taller building and the need for architectural design creativity it is essential that data be generated to develop overhang design options for major climate zones in Canada. The long-term goal of the research is to develop a methodology to assess the wind-driven rain load on a given mid-rise building and to evaluate the impact of wind-driven rain on building envelopes so that appropriate technical solutions can be developed to reduce building envelope failures related to wind-driven rain. The scope of the proposed project is to 1) characterize wind-driven rain loads on buildings with 6 to 8 storey height in three representative locations in Canada and 2) evaluate the effectiveness of roof overhang designs on reducing wind-driven rain loads.

Research method/approach

The approach used in this project is through field measurements. We propose to use an existing 6-storey building in the lower mainland of British Columbia for the investigation of effectiveness of overhang configurations. In consultation with industry practitioners, overhang designs with various widths and shapes will be developed, manufactured and installed as roof extensions of that building. Driving rain gauges together with wetness sensors will be installed on the façade at different heights to determine the level of wind-driven rain protection by various overhang designs. The second phase of this project is to instrument a total of nine mid-rise buildings in three locations, Lower mainland BC, Ontario/Quebec, and the Maritime, to collect wind-driven rain data. Effort will be made to choose buildings with aspect ratio that represents the typical building shape of six-storey wood-frame constructions and with three different overhang sizes.

Summary of results to-date

This project is at the initial starting point. We are in discussion with the building owner and the city of Vancouver in term of getting access to instrument the existing six-story building and getting permit to add additional overhangs.

Expected key output and potential impact of research

The outcome of the research projects will fill the critical data gap that now exists in durability assessment of mid-rise buildings and validation of CFD models. The collected data will be used in the development of wind-driven load prediction methodology and hygrothermal performance assessment of Cross-Laminated-Timber (CLT). The key deliverables of the projects are: 1) wind-driven rain data of nine mid-rise buildings in three Canadian regions that have distinct wind-driven rain characteristics, 2) recommendation on the effectiveness of various roof overhang configurations in reducing wind-driven rain load, and 3) propose overhang designs for low and mid-rise buildings.

Project Code : **T4-4-C11**	Project Title : Borate Pretreatments to Protect Building Envelope Components from Decay and Mould Associated with Ingress or Condensation
Session # :	Presenter: Md. Nazmus Saadat, Prof. P.A. Cooper

Background and objectives

Timber components in buildings are vulnerable to decay and mould growth due to water ingress or condensation and the problem is greater for areas difficult to access after construction or costly to repair. The project's objective is to identify the areas in mid-rise buildings most vulnerable to moisture accumulation and fungal attack and simultaneously more critical to building performance or the part most difficult to reach or expensive to repair. Appropriate borate treatment procedures will be evaluated and developed for timber components, joints and other vulnerable areas. The other objective is to investigate variables affecting vulnerability and borate movement.

Research method/approach

The main challenges are to identify susceptible areas that are candidates for pretreatment with diffusing compounds and to balance the need for mobility of the compound with the risk of its leaching especially in areas where there is ground contact or continuous water ingression. From the research point of view, there is limited specific information available in terms of observed distribution rate and extent as a function of species, grain direction and wood moisture content; there is inadequate quantitative information to develop a comprehensive borate distribution model. Data are necessary on the lower moisture content limits that allow significant preservative movement, on the relationship between amounts of chemical applied in different ways and the volume of wood effectively protected from deterioration and about the relative costs, benefits and performance for different modes of application and formulations.

To approach these problems identification of vulnerable areas will be done by review of building science principles and case histories of buildings in different geographic regions with the help from the collaborators like FPI Innovations, Sansin Corp. and Genics Corp. Different wood treatment procedures like pressure treatment with Tim-bor, surface treatment with borate glycol solutions or copper/borate mixture and treatment with fused borate rods will be developed and evaluated in the laboratory. Results will be analyzed for mobility and distribution of borate compounds with the correlation of variables like direction of water movement, configuration of the structure, treatment method, wood moisture content and ambient temperature.

Summary of results to-date

Relevant literature has been reviewed and summarized for research gap or needs. Preparation of lab procedures will start from February 2011. Analysis of tall building configuration to identify vulnerable areas where moisture may accumulate will be continued simultaneously.

Expected key output and potential impact of research

Quantitative information will be developed on factors affecting borate distribution with specific information about the variables affecting the distribution. A diffusion based distribution model will be developed for prediction of borate distribution under defined scenarios. Suitable methods will be identified for factory treatment or 'in-situ' treatment for tall timber structure components.

Project Code : T3–1–C7	Project Title : Fire Risk Analysis
Session # :	Presenter : Xiao Li

Background and objectives

CUrisk is a fire risk analysis model aimed to assess the performance of a building's fire safety measures. The model consists of a system model and a number of interacting sub-models. The objective of this project is to develop new and modify existing CUrisk sub-models for integration into CUrisk so that it can evaluate fire risks in mid-rise hybrid buildings. New sub-models will calculate the probability of failure to contain the fire of building members and the probability of fire spread throughout the building. The outcome of other Theme 3 Projects will also be used in the model. This enhanced CUrisk model can be used to develop design guidelines for mid-rise buildings.

Research method/approach

The project will develop CUrisk sub-models and their integration in the system model so the CUrisk can be used evaluate the risks from fires in mid-rise hybrid buildings. To extent the model to mid-rise hybrid buildings, a number of new sub-models need to be developed and some of the existing sub-models modified. For example, the current version of CUrisk does not consider the failure of building elements by the fire and the effects of fire spread through a building. New models will be integrated in CUrisk to perform these calculations. Also using the outcomes of the work in projects T3-2-C9 and T3-3-C7, models will be developed to calculate the probability of failure of building elements to contain the fire and to compute the probability of fire spread through the building.

Summary of results to-date

- Familiarize with CUrisk
- Literature review on risk analysis
- Review fire spread model

Expected key output and potential impact of research

CUrisk sub-models will be developed or modified to make sure that CUrisk can be used to evaluate the risks from fires in mid-rise hybrid buildings. Also using the outcomes of the work proposed in projects T3-2-C9 and T3-3-C7, models will be developed to calculate the structural reliability of structural building members and the probability of fire spread through the building. The enhanced CUrisk model will then be used to evaluate different fire protection options to ensure that proposed designs offer similar, or better, fire safety levels as in buildings constructed following the current requirements of the NBCC.

Project Code : T3-2-C9	**Project Title :** Rationalization of Life Safety - Code Requirements for Mid-rise Buildings
Session # :	**Presenter :** Michael Kruszelnicki

Background and objectives

The main question:

- Why are the current limitations on combustible construction what they are?

Objective:

- Assess the *rationale* behind current building code requirements pertaining to fire safety of mid-rise buildings.
- Discuss the potential impact on life safety that could result due to relaxing the imposed limitations.

Research method/approach

- Review of existing building code (NBCC focus) in order to assess the rationale and intent for these requirements.
- Historical data/basis for current codes and standards.
- Comparison of NBCC with other current codes and standards (provincial, NFPA, IBC, etc).
- Evaluation of objective-based alternative solutions.
- Review of various scenarios to discuss impact on life safety.
- Use of algebraic models where necessary.

Summary of results to-date

- Data gathering
  - Collecting historical data.
  - Discussions with NFPA & CWC.
- Analysis of code requirements
  - Review of objective and function statements.

Expected key output and potential impact of research

- Creation of a framework for understanding current code limitations.
- Providing an alternative-solution approach to achieving a solution that meets the objectives and function statements of the NBCC.
- Provide guidance to future code committees.
- Provide life-safety impact-assessments.

Project Code : T3-4-C5	Project Title :Fire Performance of Hybrid Timber Connections
Session # : IX	Presenter : Sabah Ali, Shivanand R. Wasan – Carleton Univesity

Background and objectives

While dominant in the homebuilding sector, wood has been effectively barred from the industrial/commercial / institutional (ICI) sector because of its flammability. Hybrid building systems that could involve building with a mix of construction materials, like heavy timber / CLT and steel or concrete can be developed and adopted in the construction of mid rise buildings. Understanding the fire performance of heavy timber connections is particularly important because they are recognized as the weakest link in heavy timber buildings under fire attack

Previous research was carried out at Carleton University to investigate the fire performance of different types of timber to timber connections. This project will expand on the previous research by focusing on the fire performance of the types of connections, that have the potential to be used in mid rise building, hybrid heavy frame and CLT buildings.

The analysis of the fire performance of hybrid timber connections is complex due to:

- The geometries and fastener arrangements.
- Significant variability in the properties of wood and char at elevated temperature.
- The different properties and behaviour of concrete and steel that are connected to timber in fire environment.

During fire exposure, the temperature of the metal fasteners rises quickly causing increased heat transfer in to the wood members. Therefore, the capacity of connections can be reduced to a significant extent when metal components are employed. The objectives of this project are to study the influence of the various parameters governing the fire performance of connections using full scale experiments and computer modeling and to develop design guidelines for these connections in fire.

Research method/approach

Experimental and theoretical investigation including the use of a general purpose finite element program, ABAQUS that is capable of simulating transient heat conduction in a solid body and heat exchange between members, will be used to study the performance of hybrid building connections under fire attack. The experiments will be conducted in Carleton University's full-scale test facility designed specifically for testing connections in fire environments. The test specimens will be constructed and loaded based on their design load and will be tested following the standard time temperature curve.

The interior dimensions of the furnace are 2.7 m× 2.7m× 2.2 m (B×L× H). The interior ceiling and walls are insulated with a layer of mineral blanket (1" or 25 mm thick) from Fibrefrax®. The furnace provides an economical and effective solution of testing the fire performance of construction elements in either standard fires or arbitrary fires.

Summary of results to-date

As expected in this early stage of the project, review of the previous research and literature is being carried out to study the different connections existing in building industry.

Expected key output and potential impact of research

The validated computer models of the different connection types will be used to predict the impact of various parameters on the performance of connections. These predictions will assist the development of simple correlations that can be used to design hybrid timber connections. These correlations will be submitted to code committees for incorporation in building codes. In addition, recommendations will be made to appropriate NBCC and Canadian wood design standard (CSA O86) committees about contextualized acceptability of certain types of connections

Project Code : **T4 – 3 – C11**	Project Title : **Intumescent Coatings to Protect Engineered Wood Products**
Session # : **January 17th, 2011**	Presenter : Atmane Ait kheddache

Background and objectives:

Engineered wood products (EWP) are susceptible to early failure during fire exposure due to thermal degradation of thin section components or due to rapid loss in strength of some adhesives used for laminating or finger jointing. Other interior finish components require a degree of flame spread reduction to meet building code requirements. Different approaches to protecting combustible wood structures were developed over the years. Intumescent coatings are among the most promising and efficient fire protection strategies. It can also serve as a complementary protective treatment to other approaches. The coating can be factory applied at the site of manufacture of the EWP or can be applied or retrofitted onto material prior to or after installation.

The long term goal of this project is to evaluate coating products to enhance protection of wooden building components from fire. The specific objectives are: 1) to identify effective intumescent coatings to protect susceptible components of EWP from thermal degradation; 2) to develop appropriate quality control procedures to ensure that the coatings meet the target performance; 3) to evaluate the weathering behaviour and resistance to mechanical damage of the coatings.

Research method/approach:

In this project, work will focus on commercial fire-retardant coatings already available on the market. Despite the availability of a wide range of intumescent coatings, very few studies have examined their effectiveness for the protection of EWP. This study will focus on the evaluation of the performance of 5 commercial intumescent coatings. The coatings that will be tested will be based on the selection criteria including but not be limited to: easy application and fast curing to insure on-site application; good weathering behavior; availability at reasonable cost; transparent coating to keep the natural aesthetic of wood

The surface of solid wood, reconstituted wood products such as LVL and OSB will be coated using commercial coats. Factors to be tested include the nature of the coat, its basis weight, method of application and drying time. To test the efficiency of the treatment, several traditional methods to evaluate the thermal properties and flammability will be used. These include thermo-gravimetric Analysis (TGA), differential scanning calorimetry (DSC), differential thermal analysis (DTA), flame propagation, critical oxygen index, etc. In addition, intumescent coatings of EWP will be exposed to a cycle of accelerated aging to study their behavior over the long term. To understand the mechanism of interaction between wood and the intumescent coat advanced techniques of material characterization will be used including XPS, FTIR, SEM and DTMA.

Summary of results to-date

The results of the study are not available yet.

Expected key output and potential impact of research

The key outputs of the research are:

- Training of High qualified personal (HQP)
- Identification of commercial intumescent coatings for EWP which are available, effective and easy to apply.
- Development of a quality control procedure to test the efficiency of intumescent coatings on EWP.

The potential impact of the research includes the promotion of EWP for uses in institutional and industrial uses (Such uses are subject to regulations with regard to their performance when exposwed to fire).