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Expanding Wood Use Towards 2025: Modelling Guide for Timber Structures

Year 1

PROJECT NUMBER: 301014059

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FPInnovations

Computer modelling is an essential part in the analysis and design of mid- and high-rise residential and commercial buildings as well as long-span structures. It is also a valuable tool in the optimisation of wood-based products, connections, and systems. An FPInnovations' survey shows that practicing engineers are unfamiliar with timber structure modelling, and researchers generally lack resources for advanced modelling of timber systems. Furthermore, wood analysis and design modules currently implemented in a few structural analysis software are usually not suitable for complex or hybrid timber structures. This does not bode well given that performance-based design which is the future direction of building codes and material standards will rely even more on demonstrating the structural performance through computer modelling. In this project, a modelling guide for timber structures is being developed by FPInnovations with a global collaborative effort involving experts in various areas, with the aim of (a) assisting practicing engineers apply computer modelling to timber structures; (b) enriching researchers' resources for advanced computer modelling of timber systems; and (c) assisting software companies to identify the gaps and upgrade their programs accordingly to accommodate advanced computer modelling of timber structures.

Project number: 301014059

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1 INTRODUCTION

Computer modelling is an essential part in the analysis and design of mid- and high-rise residential and commercial buildings as well as long-span structures where traditional engineering hand calculations or spreadsheets that are typically adopted by the designers for low-rise timber buildings are no longer adequate. It is also a valuable tool in the optimisation of wood-based products, connections, and systems that improve structural performance. In the area of applying modelling to timber structures, an FPInnovations' survey (Chen, Karacabeyli, & Lum, 2017) shows that practicing engineers are unfamiliar with timber structure modelling, and engineering researchers generally lack resource for advanced modelling of timber systems. Furthermore, wood analysis and design modules currently implemented in a few structural analysis software are usually not suitable for complex or hybrid timber structures. This does not bode well given that performance-based design which is the future direction of building codes and material standards will rely even more on demonstrating the structural performance through computer modelling.

Therefore, a modelling guide for timber structures, with focus on the structural analysis of mid- to high-rise residential buildings and non-residential structures, is being developed in this project. The modelling guide will complement the overview of the analysis and design of tall wood buildings in FPInnovations' Technical Guide for the Design and Construction of Tall Wood Buildings in Canada (Karacabeyli & Lum, 2021), and the fundamental information and knowledge related to timber structure modelling in Canadian Wood Council's Advanced Wood Engineering Manual (CWC, 2021).

2 OBJECTIVES

The main objectives of this project, where a modelling guide focusing on structural analysis of timber structures will be developed, are to:

- assist practicing engineers to apply computer modelling to timber structures;
- enrich researchers' resources for advanced computer modelling of timber systems; and
- assist software companies to identify the gaps and upgrade programs accordingly to accommodate advanced computer modelling of timber structures.

3 APPROACH

The modelling guide for timber structures is being developed by:

- Selecting efficient modelling methodologies and analysis methods, and robust evaluation criteria for timber structures: seismic response, wind-induced response, and progressive collapse.
- Developing basic principles for the application of computer modelling in timber building design, including modelling assumptions, validation of assumptions and modelling results, and demonstrating compliance with the building code (i.e., through the Alternative Solutions path).

The guide is an open access publication developed by more than 40 collaborators from countries around the world. The author team is composed of

- Researchers who are well versed in computer modelling of timber structural engineering, progressive collapse, wind engineering, and earthquake engineering;
- Practicing engineers who have applied computer modelling to timber structures;
- Manufacturers of timber products and connections; and
- Structural analysis software companies with interest in structural analysis of timber-based structural systems.

4 PROJECT TEAM

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Global Collaboration Team: contributors from 1 government, 3 associations, 15 research institutes, 13 consulting firms, 5 manufactures of products and connections, and 4 software companies in 8 countries. Below is a preliminary list of the contributors.

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It should be noted that additional contributors who will participate as reviewers in the development of this modelling guide will be added in the next fiscal year (2021-2022).

5 DELIVERABLES

The main deliverable from this project is the Modelling Guide for Timber Structures (copyright to be held by FPInnovations). The following items will be provided as part of this project:

- Online version: free, downloadable, printable from FPInnovaitons' web site.
- Hard copies will be available as “print-on-demand” from an organization such as Amazon for purchasing.

6 CONTENTS AND ORGANIZATION

This modelling guide is written with practicing engineers and researchers in mind. It has been developed with the understanding that computer modeling of timber structures is a specialty to which many engineers and researchers have limited exposure in either education or practice. The organization and structure of the modelling guide are illustrated in Figures 1 and 2, while the contents of each chapter are briefly introduced below.

Chapter 01 Introduces the background, objectives, scope, contents, and organization of this modelling guide.

Chapter 02 compares timber structures to other structures in terms of structural behaviour and the approaches to modelling including assumptions. This Chapter helps those unfamiliar with modelling of timber structures learn about major differences and similarities between timber versus other commonly used construction materials.

Chapter 03 introduces modelling principles, methods, and techniques. Rules of general structural modelling and specific rules for timber-based systems are also provided.

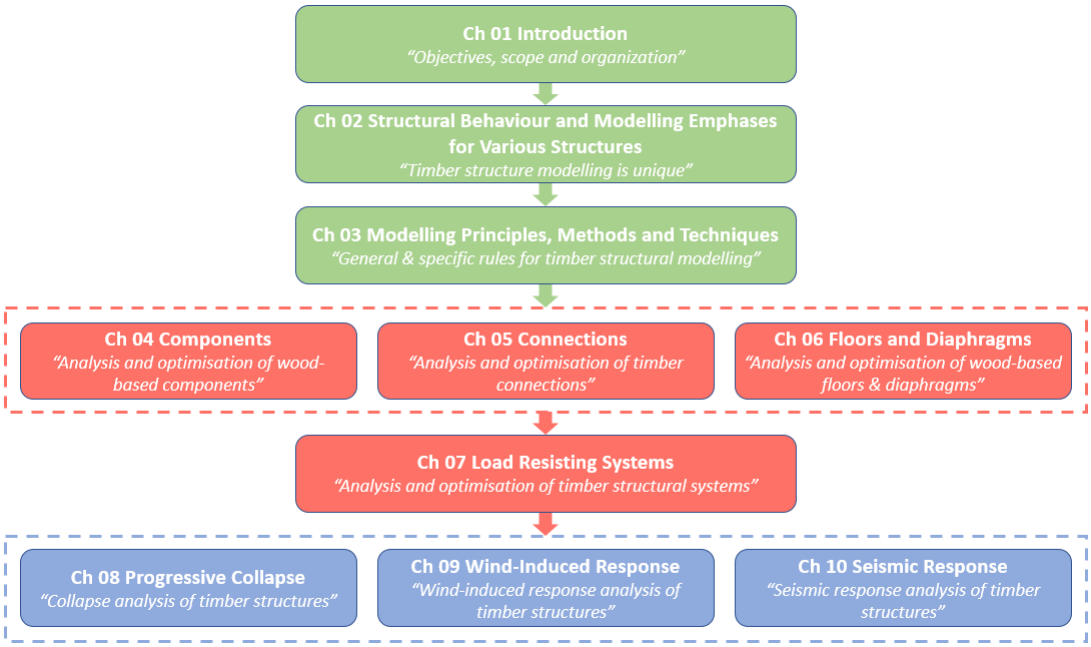

Figure 1. Organization of the modelling guide for timber structures

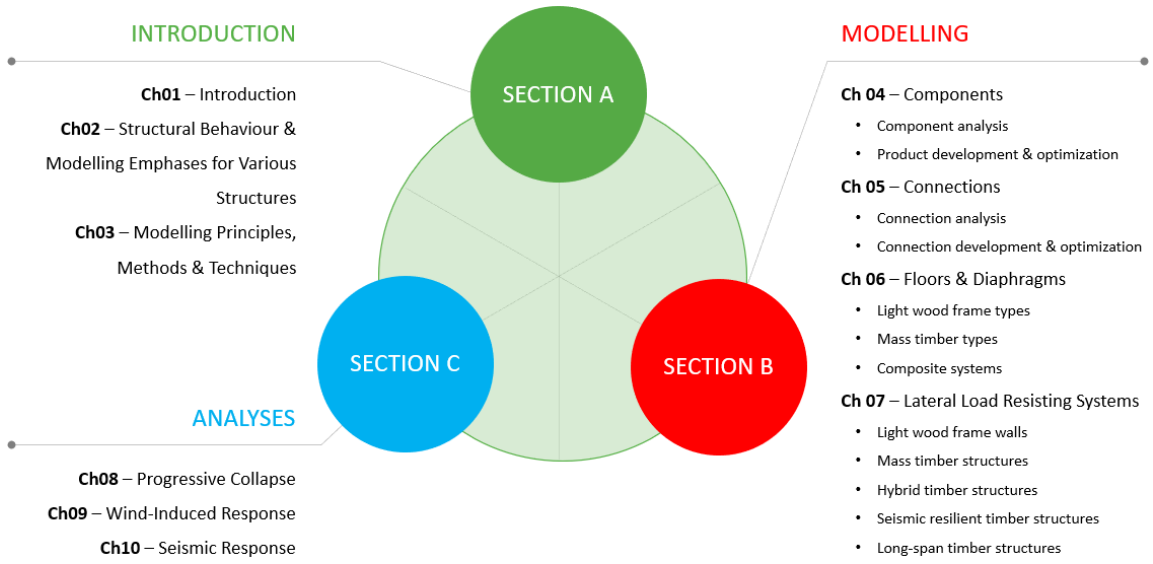

Figure 2. Structure of the modelling guide for timber structures

Chapter 04 highlights the key mechanical characteristics of wood for modelling. It introduces advanced and practical modelling solutions for the analysis and design of wood-based products. Moreover, modelling solutions are presented for the optimisation of wood-based products and experimental test plans.

Chapter 05 highlights the key roles and influencing factors of connections in timber systems. It presents advanced and practical modelling solutions for the analysis and design of timber connections. The application to optimise connections is also discussed.

Chapter 06 introduces modelling methods for the analysis and design of different types of floors and roofs, e.g., light wood frame, mass timber, and composite floor systems. The modelling of floors and roofs under gravity loads in out-of-plane directions, in terms of strengths, deflections and vibration, will be discussed, along with the modeling under lateral (in-plane) loads for properties like strength and deflection.

Chapter 07 discusses the advanced and practical modelling solutions for light wood-frame, mass timber, hybrid timber, resilient timber, and long-span timber structures.

Chapter 08 introduces the approaches to collapse analysis for timber structures, as well as advanced and practical modelling solutions for panelized, post-and-beam, and hybrid structures.

Chapter 09 introduces the behaviour and mechanism of timber buildings under wind loads, and application of computational fluid dynamics for modelling wind environments and determining cladding wind loads. It also presents advanced and practical modelling solutions for estimating the wind-induced response of timber structures.

Chapter 10 introduces the behaviour and mechanism of timber buildings under earthquake loads, selection and scaling methods of ground motions, as well as advanced and practical modelling solutions for estimating the seismic response of timber structures.

7 TIMELINE AND TASKS/ACTIVITIES

This is a two-year project commencing on April 1st, 2020 with a completion date of March 31st, 2022, as illustrated in Figure 3. Tasks/Activities and expected outputs are listed in Table 1.

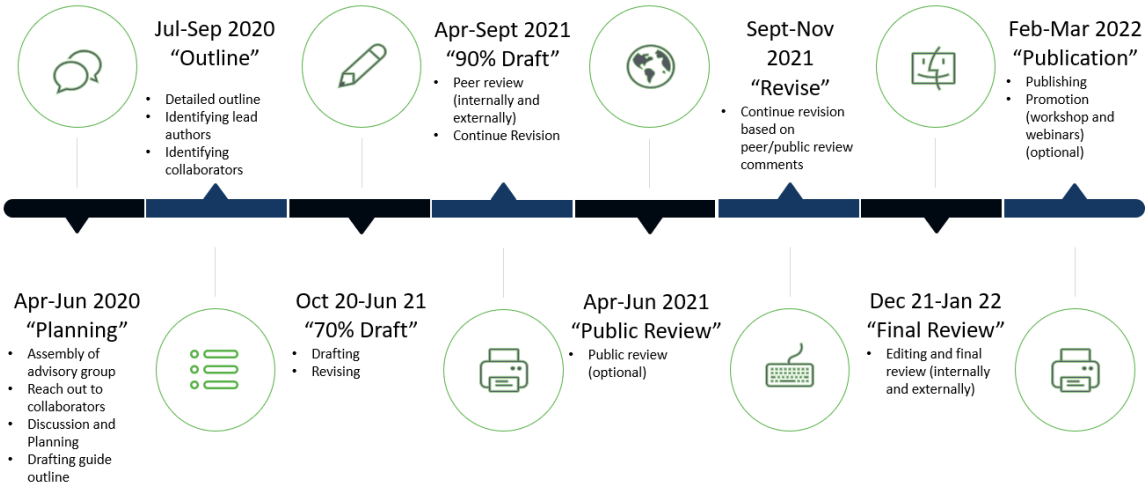

Figure 3. Workflow

Table 1. Tasks and outputs

Task		Description	Output
#	Name		
1	**Project Set-up and Planning** Apr-Sept 2020	• Assembly of advisory group • Identify collaborators • Agree on chapter contents with authors	• Agreement with collaborators • Detailed outline • List of authors
2	**Draft Chapters** Oct 2020-Jun 21	• Draft Chapters	• Preliminary (70%) draft
3	**Review and Publication** Apr 2021-Mar 22	• Conduct collaborator review of chapters and section approval of content • Public/peer review • Final technical review to ensure consistency between chapters • Create web-accessible online version • Print hard copies	• 90% draft agreed by all authors and editors • List of selected reviewers • Final technical draft (All chapters are agreed by the corresponding authors and editors) • On-line copy available for download • Print version of Modeling Guide (Optional)

During the first fiscal year (April 1st, 2020 – March 31st, 2021) the following activities are planned:

(a) Establish an Advisory Group to assist in the project implementation and identify collaborators consisting of consulting firms, research institutes, universities, software companies, as well as manufactures of wood products and connections;

(b) Prepare a detailed outline of the modelling guide along with the corresponding authors and collaborators for each chapter; and

(c) Prepare the 70% draft of the Guide.

During the second fiscal year (April 1st, 2021 – March 31st, 2022) the following activities are planned:

(a) Continue the preparation of the 70% draft of the Guide;

(b) Prepare the 90% draft of the Guide that is ready for the public and peer review;

(c) Complete the peer review of the Guide;

(d) Finalize the technical content of the Guide in consultation with the Advisory Group; and

(e) Finalize the format of the Guide and disseminate.

8 PROGRESS AND NEXT STEPS

During the first fiscal year (2020-2021), the following work items were complected:

- An Advisory Group was established. The Advisory Group had three meetings, reviewed the progress made, and recommended the action items.
- A global collaboration team, including experts from research institutes, consulting firms, manufactures of products and connections, and software companies, was recruited.
- Authors teams were assembled for 15 chapters/sub-chapters.
- Detailed outlines of 15 chapters/sub-chapters were developed based on the discussion within the author teams and have been reviewed by the advisory group.
- The globally selected authors have been developing the preliminary (70%) drafts for the corresponding chapters/sections (Table 2): the preliminary draft of five chapters has been prepared, while that of the rest chapters is still under development with a completion rate of 50%.

Table 2. Progress of chapters

Chapter #	Planning	Authors Assembly	Detailed Outline	70% Draft	Peer Review	90% Draft	Final Draft
Ch01	√	√	√	√			
Ch02	√	√	√	√			
Ch03	√	√	√	√			
Ch04	√	√	√	50%			
Ch05	√	√	√	50%			
Ch6.1	√	√	√	50%			
Ch6.2	√	√	√	50%			
Ch7.1	√	√	√	50%			
Ch7.2	√	√	√	50%			
Ch7.3	√	√	√	50%			
Ch7.4	√	√	√	50%			
Ch7.5	√	√	√	√			
Ch08	√	√	√	√			
Ch09	√	√	√	50%			
Ch10	√	√	√	50%			

For next fiscal year (2021-2022), the following work items will be completed:

- Preparation of the preliminary drafts for the rest chapters/subchapters;
- Peer review;
- Revision and preparation of 90% draft;
- Publication of the Guide.

9 BENEFITS

This project will help Canada's commitment to be a leader in using wood in mid- to high-rise residential buildings and large non-residential buildings. The Guide will also help facilitate new building options and increase the use of wood as a sustainable building material to assist Canada in meeting GHG and other climate change related goals.

The developed modelling guide will support the mainstream acceptance of timber structures and other transformative applications by providing efficient modelling solutions for practicing engineers, advanced modelling solutions for researchers, and helping software companies upgrade structural analysis programs. It will also help standardize the modelling and analysis methods, and the evaluation criteria which are best suitable for timber systems.

The guide will also be a great resource to support advanced wood education efforts, support the implemented changes in 2020 NBCC related to use of mass timber products up to 12 storeys and CLT as SFRS up to 10 storeys. It will also support the transition to future performance-based building codes.

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Chen, Z., Karacabeyli, E., & Lum, C. (2017). *A Survey on Modelling of Mass Timber*. Retrieved from Vancouver, Canada:

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1.1 Background and Objectives
1.2 Scope
1.3 Content and Organizations

Chapter 02 Structural Behaviour and Modelling Emphases for Various Structures

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2.1 General Structural Behaviour and Modelling Emphases
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Chapter 03 Modelling Principles, Methods and Techniques

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Chapter 7.3 Hybrid Timber Systems

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Chapter 7.4 Resilient Timber Systems

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Chapter 7.5 Long Span Timber Systems

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- 9.5.2 Dynamic (structural) fine tuning

9.6 Introduction to Performance-Based Wind Design

Chapter 10 Seismic Response

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10.5 Key Modelling Considerations

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