Sourcing Timbers from Quebec
Guide to Basic Timber Framing

Quebec Wood
Export Bureau

Foreword

The Quebec Wood Export Bureau (QWEB) is a non-profit organization created in 1996 whose mission is to develop export markets for Quebec's structural, industrial, and architectural wood products manufacturers. Its main objective is to ensure market access for those products by promoting the use of wood in international markets. QWEB's membership includes approximately 125 export companies divided in five distinct groups: softwood lumber and value-added softwood products, hardwood lumber and value-added hardwood products, wood flooring, wood construction, and wood pellets.

To achieve its objectives regarding market development and market access, QWEB has program managers that work with the five product groups. In addition, the organization has specialists in three international markets: United Kingdom, Japan and the United States.

QWEB is also actively involved with several major international consultation and negotiation forums where wood use is being deliberated as an appropriate solution to tackle climate change. This is the case of the Sustainable Buildings and Climate Initiative of the United Nations Environment Programme (UNEP).

Scope

The goal of this technical document is to consolidate in one place useful information pertaining to timber and decking products manufactured in the Province of Quebec. It should be noted that Quebec timber sawmills draw most of their log supplies from the United States and the timbers and decking elements extracted from the logs are mainly utilised in Northeastern US. Architects, engineers, builders, designers, and end users are the audiences targeted by the guide. Since the design of timber frame structures must be code compliant, several references are made in this document to US Codes and Standards.

Acknowledgements

We are pleased to recognize the vision and the leadership of Natural Resources Canada, the funder of this project. We would also like to express our gratitude to the industry members who have provided their support in providing constructive ideas toward the realisation of this Resource Guide. We would also like to express our gratitude to Cecobois for their expertise and constructive comments and for allowing us to use several illustrations taken from some of their technical guides.

Disclaimer

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Introduction

This guide was written with one clear goal in mind; to present relevant technical information about the design of timber frame elements and structures originating from sawmills located in the Province of Quebec. Essential technical information ranging from available species and sizes to wood properties and structural systems can be found in this document. Hence, the reader should acquire the necessary basic knowledge to appreciate the potential offered by timber framing construction.

Key Advantages of Building with Wood

The construction and operation of residential, industrial, and commercial buildings are major contributors to greenhouse gas emissions. Wood, as the only sustainable construction material, can play a significant role to reduce those emissions. Some of the key benefits of building with wood are:

- Timbers extracted from sustainably managed forests are renewable and have a lower carbon footprint compared to other building materials. Timber production also generates fewer emissions because it requires less energy for its manufacturing process.
- Trees sequester carbon from the atmosphere. When transformed into durable finished products such as timber frames, wood acts as a carbon sink.
- Wood has many biophilic benefits. Studies have shown that wood has an innate tendency to connect human to nature and can reduce stress, enhance creativity and clarity of thought, improve well-being, and accelerate healing.
- Heavy/Mass Timber Structures (as defined by the International Building Code) have good natural fire resistance properties.

Wood products sourced from well-managed forests are not only good for the environment but for society in general. This is especially the case when you admire the beauty of a timber structure and you can sense an environment that is conducive to physical and emotional health.

Figure 1 ▪ A Timber Components Shipment Ready for Delivery to a Timber Framer for Fabrication

Timber Frame or Heavy Timber Structures?

Without a doubt, there is renewed passion for constructing mass timber structures, and environmental and biophilic benefits are two of the main driving forces leading this noticeable trend. In the context of this guide, it is important to explain the differences between Timber Frame and Heavy Timber. Timber Frame refers to the generic use of timber elements in various structures for diverse end uses (e.g., buildings, park shelters and bridges) whereas Heavy Timber refers to the building code definition of a building type (Type IV in the International Building Code and NFPA Standard) whose fire performance was established by the historic performance of traditional "brick and timber" construction common in heritage industrial buildings and churches. More information is provided about Heavy Timber in the Fire Performance section of this guide.

Product Availability - Timber and Wood Decking

In an era of long-distance commodity transportation, it is reassuring to many sustainability advocates to know that timbers for their projects can be regionally sourced. In some cases, the use of locally sourced products can help achieve LEED certification.
Two timber species sawn in the province of Quebec are available in Northeastern US: Eastern White Pine and Eastern Hemlock. In addition, Red Pine products maybe available on a special-order basis.
A detailed description of the characteristics of Eastern White Pine and Eastern Hemlock can be found in the first chapter of the "Wood Handbook: Wood as an Engineering Material," published by the United States Department of Agriculture – Forest Products Laboratory. Figure 2 shows the forest areas where the trees are typically being harvested.

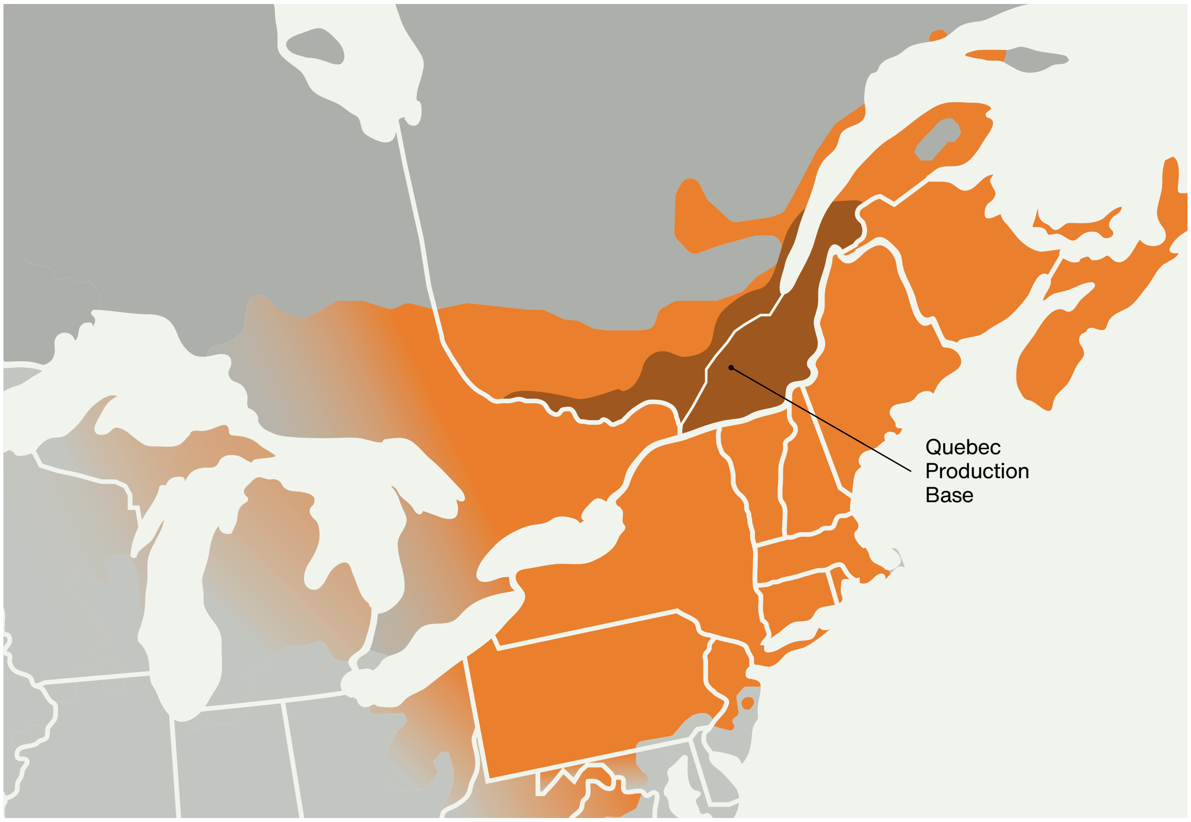

Figure 2 ▪ Forest Areas where the Trees are Harvested.

Table 1 shows the four-product categories currently available from Quebec. These categories are important because specific design values are assigned to each category and grade. To be considered timber, the minimum nominal width must be 5”. Many secondary elements such as roof or floor purlins may often have a nominal thickness of 4”. Structural elements having nominal thicknesses of between 2” to 4” fall under the Dimension Lumber category but are nevertheless referenced in this guide.

The main purpose of segregating wood elements in distinct species and grades is to achieve consistent appearance and similar mechanical and structural properties. Several characteristics such as knots, checks, splits, holes, shake, slope of grain and wane are considered when grading timber.

Before finalizing the design of a Timber Frame structure, it is always appropriate to validate the cost of available grades for various combinations of sizes and grades. For instance, in some cases, it may be more economical to increase the size of a structural element to use a #2 grade instead of a smaller #1 section. In some cases, a single defect such as slope of grain, may not allow the timber components to be graded as #1. Posts & Timbers and Beams & Stringers are typically not available in the Select Structural grade because they cannot achieve the stringent requirements due to their natural characteristics. More information on available grades is provided in the Reference Design Values section.

Table 1 ▪ Product Categories

Product Categories	Grades	Notes
Dimension Lumber	#1 and #2	Nominal thickness 2”- 4”
Decking	Commercial and Select	Manufactured as per standard or tailored patterns. 2X6, single tongue and groove, green or dry 3X6 and 4X6, double tongue and groove, green
Posts and Timbers	#1 and #2	Minimum nominal width 5” The depth does not exceed the width by more than 2” Sawed full dimensions or slightly scant
Beams and Stringers	#1 and #2	Minimum nominal width 5” The depth exceeds the width by more than 2” Sawed full dimensions or slightly scant

Table 1 notes:

- Dimensional lumber only available in 4” thickness.
- The standard nominal widths and depths of Posts and Timbers, and Beams and Stringers are: 6”, 8”, 10”and 12”. Timbers are usually sawed full nominal dimensions (or in some cases slightly scant) and the standard dressed (after planing) sizes are ½” less than the nominal dimensions excepted for 4” dimension lumber where the dressed depth is ¾” less than the nominal for depths of 8” or more.
- The standard lengths are 8’ to 16’ in even increments.
- It should be noted that depending on log availability, larger dimensions up to 16” or 18” and longer lengths up to 24’ (sometimes more) can be produced.
- Scant refers to slightly undersized products due to processing.

Physical, Mechanical and Design Properties of Timbers

Internal Structure of Wood

The fact that wood is a natural building material having different physical and mechanical properties with respect to three mutually perpendicular axes makes it an interesting and complex construction material. Figure 3 shows a microscopic view of a softwood section where the composition of its internal structure can be observed.

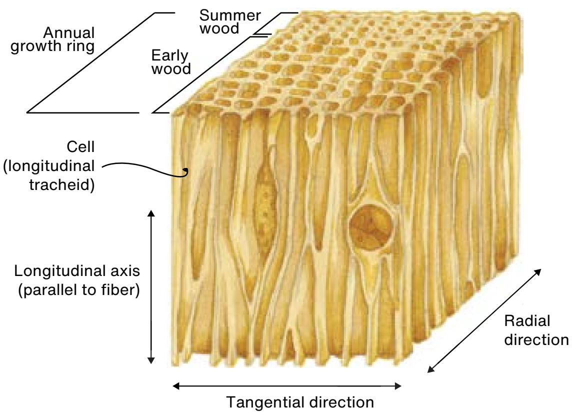

Figure 3 ▪ Microscopic Structure of a Softwood (figure from Cecobois)

It is important to understand the distinctive characteristics of timber as an engineering material. The hygroscopic properties, fire performance, thermal resistance, and durability attributes of timber will be briefly discussed in the following sections.

Hygroscopic Properties of Wood

It is essential to develop a good understanding of the hygroscopic properties of wood to design well thought out timber frame structures. Water within wood can be chemically bonded or free. The chemically bonded water is found in the cell wall while the free water within the cell. One important notion to understand about the hygroscopic properties of wood is the fiber saturation point. The fiber saturation point is attained when the chemically bonded water volume has peaked in the cell walls. For practical purposes, the average moisture content of wood at fiber saturation is usually 30%. The moisture content is defined as the weight ratio of water over dry wood and is usually expressed as a percentage. There are no volumetric changes of wood unless the moisture content decreases below 30% as the free water within the wood cells can evaporate without impacting the geometry of the cells. When wood dries below the 30% fiber saturation point, volumetric changes (shrinkage) will start to take place as the water content decreases within the cell walls.

Volumetric changes of wood are different along the longitudinal, tangential, and radial directions. For design purposes, an average tangential and radial shrinkage factor of 0.2% for every 1% change in moisture content should be used because most timber components produced in the Province of Quebec will have boxed heart (the pith is usually located near the center of the timber). The shrinkage factor parallel to the longitudinal axis of the fiber is .005% which is 40 times less than the average tangential and radial shrinkage factor.

Once in service, the moisture content of wood will be influenced by the temperature and the relative humidity of the surrounding air.
With sufficient time, under stable air relative humidity and temperature conditions, wood will reach a constant moisture content. This state is called equilibrium moisture content. Figure 4 shows equilibrium moisture content curves in function of the relative humidity of the air for 4 air temperature levels ranging from 50°F (10 C) to 167°F (75 C). For the Northeastern quadrant of North America, the equilibrium moisture content of wood for an exposed structure inside a heated building is in the 7% to 9% range.
The equilibrium moisture content range for exterior covered structures is 12% to15%. Considering a typical initial moisture content of 40% for sawed green timbers, shrinkage can be quite significant. The following graph and calculations illustrate this fact.

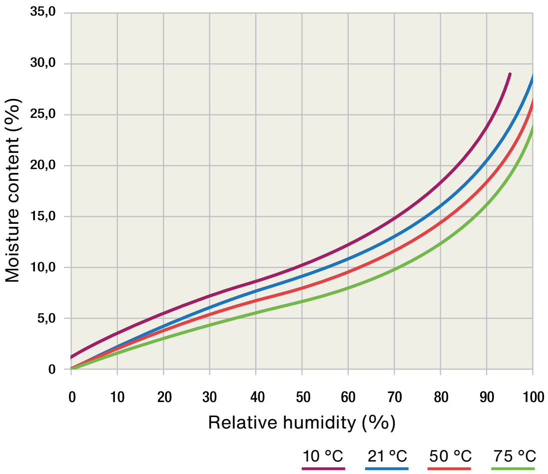

Figure 4 ▪ Equilibrium Moisture Content at Different Temperatures Levels (figure from Cecobois)

Shrinkage Calculation Examples

A green 12 x 16 timber (S4S dimensions of 11.5'' x 15.5", with initial moisture content of 40%) will be used in a heated building. The designer wants to know what the approximate dimensional shrinkage will be for the width and the depth of the timber.

Solution: The equilibrium moisture content of wood inside a heated building is usually in the 7-9% range. Using a midpoint figure of 8%, the shrinkage can be calculated as follows:

Shrinkage for the width =
11.5" x (30%[1] - 8%) x 0.2/100 = 0.5" (½")

Shrinkage for the depth =
15.5" x (30%[1] - 8%) x 0.2/100 = 0.68"
(approx. 11/16")

Assuming that the length of the structural component of the above example is 16', what will be the longitudinal movement?

Using the same moisture content differential, the reduction in length can be calculated as follows:

Length reduction =
16' x 12"/1' x (30%[1] - 8%) x .005/100 = 0.21"
(approx. 7/32")

As seen in our example, green timber shrinkage perpendicular to the fiber can be important and usually needs to be considered (especially for connections and architectural detailing) whereas shrinkage parallel to the longitudinal fiber axis can be ignored in most cases. Timber movements associated to moisture content reduction will be further discussed in the Design for Durability section.

As green timber dries and reaches equilibrium moisture content, checks might develop. These checks appear when the outer wood fibers of a timber tend to dry more rapidly than the wood fibers located near the center.

The formation of checks is normal during the drying phase of large green timber, especially in a heated building. It should be noted that most timbers are sawed green. In some cases, partially air-dried timber may be available. Some drying facilities exist in Quebec and can reduce the moisture content of the outer fiber to a specific level. Figure 5 shows expected dimensional changes associated with the drying of green timbers.

Figure 5 ▪ Dimensional Changes Associated with the Drying of a Green Timber Elements

1. Even if the initial moisture content of the timber is 40%, 30% is used for our calculations, because during the drying process, no dimensional changes take place when the moisture content is above 30%.

Fire Performance of Timber Frame Structures

Larger timbers, due to their increased cross sections when compared to lumber, possess good inherent fire-resistant properties. The good fire performance of larger timber elements has been demonstrated for centuries. The large cross sections of timbers allow them to retain their strength for a long time during severe fires. This is due to the protection provided by the char layer that is formed during a fire. The formation rate of the char layer is usually constant, which confers to timbers a predictable fire performance behavior. Recent research programs have concluded that mass timber construction can be expected to remain relatively unscathed during fires, and that upon burnout of contents the fire will decay and ultimately burn out.

In addition to the predictable fire performance behavior that can be calculated by a Fire Protection Engineer, prescriptive approaches for historic building types are recognized by the International Building Code (IBC). IBC's Type IV Construction was originally created to codify the strong fire performance of historic "brick and timber" buildings. It defines a mix of structural timber elements meeting the prescribed minimum sizes indicated in IBC Table 2304.11 (other requirements are applicable). Decking is allowed at prescriptive minimum sizes as well, but concealed spaces are strictly controlled. When all the above conditions are met, including the sizing of the structural timber elements that meet these minimum size requirements, the building is then classified as Heavy Timber. A building area allowance table from IBC shows the allowed building sizes for this construction type.

Thermal Resistance of Wood

The relative light weight of wood (with respect to other structural building materials) is an indication that its cavities are partially filled with air, which offers good thermal resistance. The thermal resistance of wood is inversely proportional to its density, moisture content and temperature.
The fiber orientation of wood also influences the thermal resistance of wood. The thermal resistance of wood is 2 to 3 times less in the longitudinal axis (of the wood fiber) but in practice this seldom constitutes an issue. An imperial R value of 1.5 per inch can be used for practical purposes (0.275 RSI). Figure 6 compares the thermal resistance of wood, concrete, and steel.

Despite its good thermal properties, extending timber beams beyond the exterior walls and through the building envelope does not constitute a good practice, as the anticipated shrinkage and the development of checks will make it difficult to maintain airtightness.

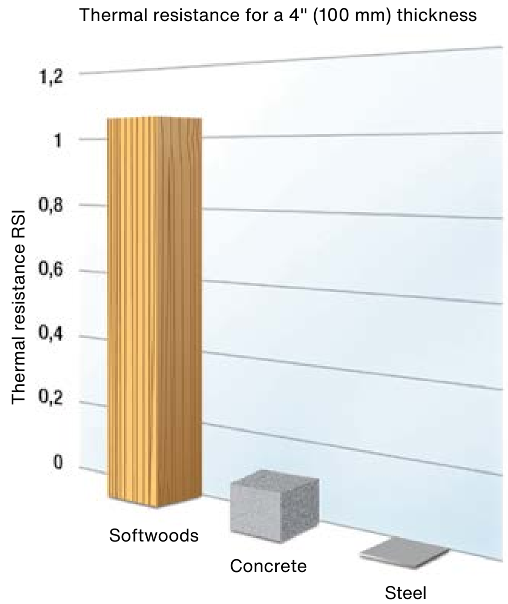

Figure 6 ▪ Thermal Resistance of Wood, Concrete, and Steel for a 4" Thickness (figure from Cecobois)

Durability of Wood

In existing technical literature, the word durability often refers to several different concepts. In this document, the word durability is associated with the concept of maintaining two crucial attributes of wood: appearance and structural integrity. To ensure timber frame structures are resilient, proper steps and procedures must be followed along the entire manufacturing and supply chain process (proper log storage, timber handling and storage), and through the engineering, architectural detailing, and interior air management design phases for all enclosed structures.

Understanding the conditions that must be present for the development of mold and decay in timber structures is of outmost importance because of the severe impact they can have on durability. Four conditions are required for the development of mold and decay.

1. The presence of oxygen.
2. Adequate temperatures (typically 50°-90°F).
3. Moisture content exceeding 19% for an extended period.
4. Food (the wood itself).

Once a building is in service, there is no practical approach to control the presence of oxygen and to significantly regulate temperatures outside the typical range favorable to the development of decay fungi. On the other hand, wood moisture content can be controlled through adequate architectural detailing and sound indoor air management practices. More information on proper architectural detailing is provided in the Design Section.

Early in the process (harvesting and sawmilling) it is possible for manufacturers to adopt good practices to minimize the development of stains. For instance, many sawmills will harvest and saw logs during the winter, when molds are not present. Otherwise during warmer months, logs can be kept wet by water sprinkling to control the presence of oxygen and to lower temperatures, resulting in slow mold growth.

Once sawed, timber should be protected from ground contact and rain, stack layered with stick spacers (stickered), bundled, and protected as much as possible from direct sunlight to avoid rapid drying that could induce the development of splits and checks (Figure 7).

Untreated timbers should only be used in dry service conditions where the maximum moisture content in use should be 19% or less, regardless of the moisture content of the wood at the time of manufacture. Most exterior covered structures will meet this requirement.

When dry service criteria cannot be met, the timbers must be pressure treated. Depending on the intended usage, different chemical agents and retention levels can be specified for preserving wood, and in some cases, incisions may be required. Particular care must be exercised when selecting a preservative treatment because of existing regulations and the impact the chemical agents might have on the steel connectors (some preservative agents may accelerate corrosion). More information can be found about various wood treatments and regulations on the American Wood Protection Association web site (https://awpa.com/).

Figure 7 ▪ Well Stickered and Bundled Heavy Timber components

Mechanical Properties of Wood

Because of its orthotropic nature, wood has well-defined mechanical properties influenced by the direction of the applied load with respect to the fiber axis. Figure 8 shows forces parallel to the longitudinal axis of the fiber while Figure 9 shows forces perpendicular to the longitudinal axis of the fiber.

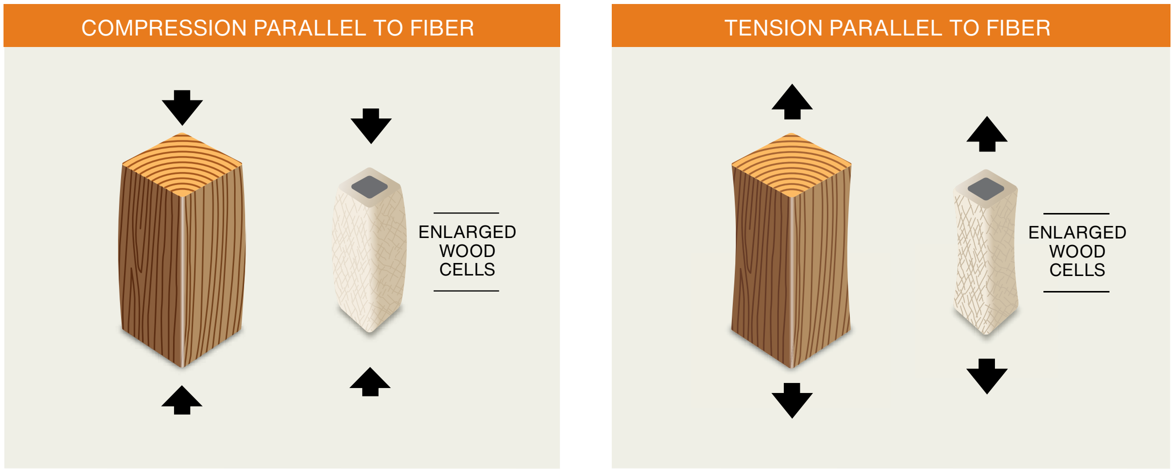

Figure 8 ▪ Compression and Tension Forces Parallel to the Longitudinal Axis of the Fiber (figure from Cecobois)

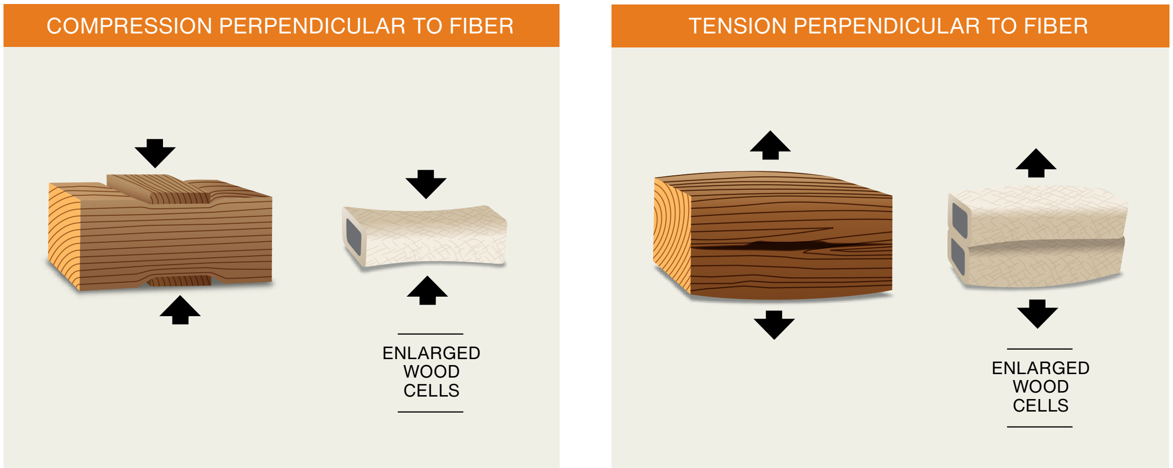

Figure 9 ▪ Compression and Tension Forces Perpendicular to the Longitudinal Axis of the Fiber (figure from Cecobois)

When examining Figures 8 and 9, you realize that due to its internal configuration, wood is much stronger to resist forces parallel to the longitudinal axis of the fiber than to resist forces perpendicular to the longitudinal axis of the fiber. Compression perpendicular to the fiber axis can be addressed by providing larger wood-to-wood bearing areas and when not possible by adding steel bearing plates. Tension perpendicular to the fiber length can be addressed by adequate design. In addition to the 4 specific forces shown in Figures 8 and 9, for which distinct design values are assigned, deflection (a serviceability criteria) is another important consideration. The Modulus of Elasticity, E, (or Young's Modulus) measures the stiffness of materials and the deformation of a structural member can be calculated using specific formulas once we know the Modulus of Elasticity, the type of loading, the bearing configuration and member size.

Since wood is not a perfectly elastic material, deformation is not constant over time. When subjecting a wood beam to a sustained load, an instant deformation will take place followed by a longer-term time-dependent deformation.

The longer-term time-dependent deformation of wood is called creep. Hence, wood should be treated as a viscoelastic material. Among other factors to consider is the impact of the following factors on creep deformation:

- Dead load to live load ratio. A higher ratio of sustained load will result in a higher creep deformation.
- Drying. Structural members drying under sustained loads will creep more.
- Moisture content and temperature. Varying moisture content and to a lesser extent varying temperature will result in higher creep.

Common to many building materials, creep deformation needs to be considered under heavier dead loads where deflection might be a concern to avoid aesthetic and functional issues. Timber beams graded #1 or #2 are rarely governed by deflection, so in practice, creep may often be ignored excepted in structures displaying a high (more than 1,0) dead load to live load ratio.

Reference Design Values

Most engineers design structures using the Allowable Stress Design (ASD) Method. The ASD design values can be found in the NDS Supplement tables referenced in Table 2 below. The reference design values themselves are not reproduced in this guide because many specific adjustment factors requiring engineering judgment need to be applied before obtaining the actual design stresses. The reference design values are based on the grading rules published by one of the 6 American rules-writing agencies accredited by the American Lumber Standard Committee (ALSC). For this guide, it is assumed that the structural components are graded under the Northeastern Lumber Manufacturers Association (NELMA) grading rules (https://www.nelma.org/the-grade-rule-book/).

For aesthetic reasons, timber frame elements are typically not grade stamped. Nevertheless, it is important for design purposes to have a commercial invoice stating the specie and the grade for traceability purposes.

Table 2 ▪ Where to Find Reference Design Values in the NDS Supplement

Species or Species Combinations	Size Classification	Grading Rules	Table from NDS Supplement 2018 Edition
Eastern Hemlock – Tamarack	Dimension Lumber	NELMA	4A
	Beams and Stringers	NELMA	4D
	Posts and Timbers	NELMA	4D
	Decking	NELMA	4E
Eastern White Pine	Dimension Lumber	NELMA	4A
	Beams and Stringers	NELMA	4D
	Posts and Timbers	NELMA	4D
	Decking	NELMA	4E

Timber Frame Structures

Because of their many attributes (e.g., larger cross-section, structural properties, low embodied energy, fire performance, appearance, and workmanship), timber elements are proudly displayed in countless structures such as residential and commercial buildings, bridges, and outdoor recreational facilities. Timber framed structures have withstood the test of time, as many structures still in use today were built in the 1800s.

Timber elements are suitable for many different structural systems ranging from traditional Posts and Beams to more sophisticated Truss Systems and Rigid Frames. Structural systems made of timbers can be designed to resist only gravitational loads or lateral loads as well. As previously stated, similarly to all other structural building materials, timber frame structures require engineering and architectural design assistance to meet code requirements and become resilient. Below, is a quick review of some timber frame structural systems.

Posts and Beams

The most ancient (and simple) structural application of timber elements is the Posts and Beams system (Figure 10). The system has several advantages:

- Ease of analysis, design, fabrication, and erection.
- Reduced connection cost, as most connections are load bearing (wood beams sitting on wood posts).
- Flexible structural grid typically ranging from 12' to 20' for roof or residential floor loadings.
- Large size Post and Beam structures express the natural warmth and beauty of wood.

Figure 10 ▪ Traditional Posts and Beams System

In this system, all gravity loads are firstly resisted by horizontal elements (decking, purlins, and beams) before being transferred to the vertical elements (posts). The horizontal elements resist the imposed loads by developing bending and shear stresses and the vertical elements by developing axial compression stresses.

A variance to the Posts and Beams system is the Gerber System where the main beams are cantilevered over the columns to reduce the bending stresses and the deflection. Smaller dropped sections are then inserted between the ends of the cantilevered beams. The Gerber System allows longer span with the same beam section and the reduced depth of the drop section may facilitate the integration of some mechanical services.

Rigid Timber Frame

The main difference between a regular Post and Beam System and a Rigid Timber Frame System is that the latter is designed to resist lateral loads in addition to gravitational loads. The design of Rigid Timber Frames is therefore more complex as the whole building (or at least a section of a building) needs to be considered to determine the wind and seismic loads. It can nevertheless constitute an ingenious solution when limited options exist to brace some areas of a building. One of the key advantages of using Rigid Timber Frame systems is that they can be shaped in an infinite number of geometries and configurations (Figure 11).

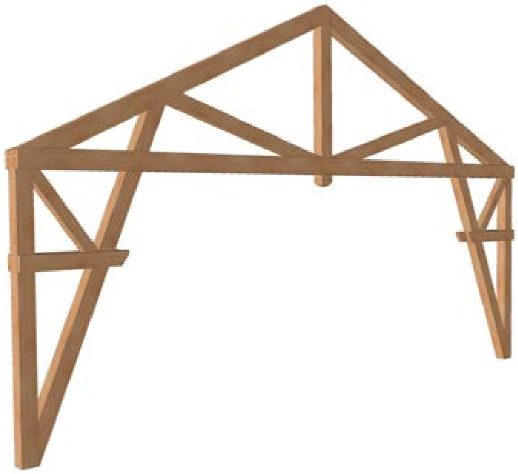

Figure 11 ▪ An Example of a Rigid Timber Frame

Timber Truss System

In a Timber Truss System (TTS), the trusses are the main structural elements transferring the imposed gravitational loads to the bearing locations. The truss members (webs and chords) are typically arranged in a triangular pattern to transfer the internal forces through axial efforts. The timber trusses usually directly support the decking or the purlins. Typical truss spacing will vary between 4' to 16'. Below are some of the main advantages of using a TTS:

- Longer span up to 40' or more can be achieved (more in the case of bridges).
- Infinite number of configurations (shape, depth, slope, panel length). The most common truss shapes are triangular, scissor, parallel chord and monopitch.
- Depending on size and transportation costs, the timber trusses can be pre-assembled in the shop or on the job site prior to erection.
- Reduced wood sections.
- Ample space to facilitate the integration of mechanical services.
- In some cases, a single truss can provide the optimal solution for a roof ridge support.

Timber trusses are more design and fabrication intensive than traditional Post and Beam systems. This higher cost is often offset by the architectural flexibility offered by a TTS. In most applications, only gravitational loads need to be considered when designing timber trusses, however special considerations must be made for the design of connections.

Figure 12 ▪ Fabrication of a Timber Flat Roof Truss

Figure 13 ▪ Traditional Roof Trusses

Complementary Elements for Timber Frame Structures

As described in previous sections, timber elements can be designed and manufactured to construct various kinds of efficient structural systems suitable for many building types (including Heavy Timber Type IV construction).
The versatility of timber as a structural material can sometimes be further enhanced by the addition of complementary structural elements. Below are a few examples:

- Longer span solutions: The use of key beams can provide a cost-effective solution when longer spans are required over a few bays. A key beam is formed by connecting two identical beams one on top of the other. When assembled, the shear flow between the two beam sections is resisted by structural keys (Figure 14). As the structural keys need to be precision-fit to avoid slippage and stress concentrations, CNC machining or experienced handcrafting is preferred. Alternatively, if insufficient height is available for a timber truss, some glulam or steel beams could be incorporated in the structural grid.
- The addition of Light Framing Panels (LFP) can be a judicious addition to a timber frame structure (Figure 15). In floor applications, the use of LFP in lieu of solid decking yield sizeable benefits: cost reduction with respect to solid decking, the cavity space can be used for acoustic insulation, the integration of mechanical services and finally it may function as a structural diaphragm. Similar benefits can be achieved in wall applications where the LFP can be used for shear walls.
- Structural Insulated Panels (SIP) can provide similar benefits as LFP for roof and wall applications. SIPs are easy to install and provide superior thermal insulation. The integration of mechanical services must be carefully planned with SIP.
- For longer spans, Timber Trusses often provide the best structural solution when sufficient depth is available. As previously stated, timber trusses can carry heavier loads over longer spans with less timber volume. One trade-off is the increased connection cost when compared to a traditional posts and beams system.
One option to optimize the connection cost of a timber truss is to replace the timber members resisting higher tension loads with steel elements (rod, plate or HSS). The replacement of higher tension timber members by steel elements will usually result in an economical alternative and simpler connection details.

Figure 14 ▪ Key Beam Girders

Figure 15 ▪ Light Framing Roof and Wall Panels Used in Conjunction with Timber Trusses.

Design

Beyond important architectural considerations pertaining to the arrangement of interior spaces common to all projects, the design of timber frame projects must be centered around maximizing all the inherent benefits of using timber. Some key points will be presented in the following section about the design process and durability concepts.

A Few Words About the Design Process

At the beginning of a project, once a preliminary suitable structural grid is defined, it is important to investigate the availability of the required timber elements to help determine what would be the most appropriate structural system. Some key questions to address include:

1) Considering the end use (roof, residential or commercial floor) and the regional availability of the timber elements, can a simple post and beam system work efficiently or are some spans too long that some key beams, glulam beams, steel beams or trusses maybe required?
2) Will there be enough solid exterior wall segments for bracing? If not, can rigid timber frames provide the best solution in one direction?
3) Depending on the building envelope, will bracing consist of timber cross-braces, steel braces, SIP, or light framing shear walls?
4) What type of timber connectors would accentuate best the character and beauty of the timber structure and of the architectural concept?

Due to the versatility of timber frame systems, there is not a unique answer to each of the above questions. This is where architects can best put their creativity to work. Two projects having the same function may highlight distinctive styles, perhaps one reflecting the traditional charm of timber frame construction while the other expressing a modern and sophisticated character.

Connections

Without connections, timber structures would be nonexistent! Whether it is a simple beam to column connection or a complex tension-compression brace connection, all connections need to be carefully designed. The complexity of timber connections is primarily caused by three factors:

1. Wood is an orthotropic structural material. It has strong resistance to forces parallel to the longitudinal direction of the fiber and is much weaker when resisting forces perpendicular to the longitudinal direction of the fiber.
2. Wood is a hygroscopic structural material. Below 30% fiber saturation point, the reduction in moisture content will induce volumetric changes (shrinkage). The moisture content of wood will stabilize when the equilibrium moisture content is reached (see Figure 4). Since most Timber Frame structures are installed green, the hygroscopic nature of wood cannot be neglected when designing connections.
3. Because timber framed structures are mostly left exposed, connections must meet all engineering requirements while remaining refined and in symbiosis with the architectural concept.

To design sound and elegant timber connections, adequate engineering judgment and a flawless understanding of the behavior of timber as an orthotropic and hygroscopic structural material is required. This is true whether considering traditional joinery with wood pegs, mortices and tenons, dovetails, or steel connections (including steel plates, welded assemblies, bolts, lag screws, structural screws, self-drilling tight fit pins with knife plates, and pre-engineered connections). Diverse types of traditional joinery and steel connections are shown in Figure 16 A, and 16 B, respectively.

A.

Posts and Beams Connection with Wood Pegs

Different Types of Traditional Joinery

B.

Truss Connections with inserted steel plates and bolts

Complex roof connection with a welded assembly

Figure 16 ▪ A and B. Examples of Traditional Joinery and Steel Connections

Sometimes, the architectural concept allows bolts and steel plates to be prescribed to connect timber components. If bolted connections are desired, it is a good practice to design the connections in such a way that they will remain accessible once the structure is erected and completed. The main reason for this is that due to volumetric changes that will affect the structure during its first few years of services, the connections will likely need to be retightened. Bolted connections with steel plates cause an additional challenge because the number of bolt rows perpendicular to the fiber must be limited to avoid the development of splits perpendicular to the fiber. Where possible, the use of multiple steel plates may prove useful to avoid wood splitting caused by shrinkage.

Design for Durability

As previously stated, appearance and structural integrity are the two main attributes that need to be maintained over time to obtain a durable timber structure. This constitutes the essence of durability in the context of this guide. Mastering the following two concepts is sufficient to achieve the design of a resilient timber structure:

1. Consider the hygroscopic properties of wood for all design and construction details. (Refer to the section on Hygroscopic Properties of Wood)
2. Avoid the combination of factors that will induce decay in timber elements. (Refer to the section on the Durability of Wood)

Here are some design tips that support those two requirements:

For exterior structures:

- Use roof overhangs where possible to protect the exposed timber components. Cut roof purlins at a angle or use metal flashing to prevent direct rain contact with the end grain (figure 17).
- Protect the timber posts by providing enough space between the ground and the base of the post to avoid direct water contact. In addition, ensure that the steel base connection is designed so there is no water accumulation (figure 18).
- To avoid UV discoloration, use finishing products that contain UV inhibitors designed to allow the wood to breathe such as a pigmented stain or timber oil.
- Use treated timbers where, by design, it is not possible to maintain the moisture content below 19%.
- Inspect the exterior timber structures periodically for the early detection of problematic situations.

For interior timber members, the key challenges to ensure durability relate to the management of volumetric changes (shrinkage) in heated buildings:

- All connections must be designed to accommodate the anticipated shrinkage.
- For vertical load transfer in two-level structures, favor end grain to end grain post connections through steel plates to avoid cumulative vertical movement.
- Architectural details must be conceived for allowing timber shrinkage and movements. Never enclosed green timber elements within the building envelope.
- Use end sealer to slow the drying of the timber components.
- Provide a gap between the bottom of the timber posts and the floor to avoid occasional wetting during cleaning.

Figure 17 ▪ Well-Designed Roof Eave

Figure 18 ▪ Good Post Base Design

Closing Remarks

White Pine and Eastern Hemlock Timbers (most of them harvested in the Northeastern US) manufactured in the Province of Quebec are available in diverse sizes and lengths which make them suitable for your upcoming timber frame projects. Timber structures are characterized by low embodied energy, inherent beauty, offer design flexibility and positively impact the well-being of its occupants.

The purpose of this Guide was to compile under one document useful information about timber framed structures. We hope that the elemental information found in this guide provided a good overview of the design and construction details that need to be addressed to successfully construct a timber frame structure. Additional information can be found on the Timber Framers Guild web site at https://www.tfguild.org/

Happy Timber Framing!

Reference and Resource List

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