VERTICAL MOVEMENT IN WOOD PLATFORM FRAME STRUCTURES:

Basics

Canadian Wood Council
Conseil canadien du bois

FPINNOVATIONS

Acknowledgements

The publication was developed by FPInnovations and Canadian Wood Council based on design and construction practice and relevant research. This publication would not have been possible without financial support of Forestry Innovation Investment of Province of British Columbia.

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INTRODUCTION

Movement in structures due to environmental condition changes and loads must be considered in design.

Movement in structures due to environmental condition changes and loads must be considered in design. Temperature changes will cause movement in concrete, steel and masonry structures. For wood materials, movement is primarily related to shrinkage or swelling caused by moisture loss or gain when the moisture content is below 28% (wood fiber saturation point). Other movement in wood structures may also include: settlement (bedding-in movement) due to closing of gaps between members and deformation due to compression loads, including instantaneous elastic deformation and creep. Differential movement can occur where wood frame is connected to rigid components such as masonry cladding, concrete elevator shafts, mechanical services and plumbing, and where mixed wood products such as lumber, timbers, and engineered wood products are used.

Evidence from long-term wood frame construction practices shows that for typical light frame construction up to three storeys high, differential movement can be relatively easily accommodated such as through specifying "S-Dry" lumber. However, differential movement over the height of wood-frame buildings becomes a very important consideration for taller buildings due to its cumulative effect. The APEGBC Technical and Practice Bulletin provides general design guidance and recommends the use of engineered wood products and dimension lumber with 12% moisture content for floor joists to reduce and accommodate differential movement in 5 and 6-storey wood frame buildings. Examples of differential movement concerns and solutions in wood-frame buildings can also be found in the Best Practice Guide published by the Canadian Mortgage and Housing Corporation and the Building Enclosure Design Guide –Wood Frame Multi-Unit Residential Buildings published by the Homeowner Protection Office of BC Housing.

This document illustrates the causes and other basic information related to vertical movement in wood platform frame buildings and recommendations on material handling and construction sequencing to protect wood from rain and reduce the vertical movement.

Wood moisture content

Moisture Content (MC) is a measure of how much water in a piece of wood. MC is expressed as a percentage and is calculated by dividing the weight of the water in the wood by the oven-dry weight of the wood substance. Of particular interest to designers are:

- MC of the wood at the time of purchase,
- MC of the wood when a building is closed in, and
- Equilibrium moisture content (EMC) that the wood will reach in service.

Lumber is generally dried before being shipped to users and the MC at the time of surfacing is shown on the grade stamp. Lumber designated as “S-Grn” (*Surfaced Green*) is not checked with MC when surfaced and its MC is usually above 19% at the time of surfacing. The “S-Dry” (*Surfaced Dry*) on a North American grade-stamp indicates that the lumber was surfaced at a MC of 19% or less, and “KD” (*Kiln Dried*) on a North American grade-stamp indicates that the lumber has been kiln dried to a MC of 19% or less. “S-Dry” and “KD” lumber is readily available; however, lumber dried to lower MCs are not common and would only be available on special orders.

Panel products such as plywood, Oriented Strand Board (OSB) and other engineered wood products (EWP) are manufactured at a lower MC than lumber. Typical MC ranges for various wood products at manufacturing are summarized below:

Table 1: Typical MC ranges of wood panel products, other engineered wood products, and “S-Dry” lumber at manufacturing

Product	MC Range (%)
S-Dry lumber	13-19
Structural Composite Lumber (SCL) (such as Parallel Strand Lumber (PSL), Laminated Strand Lumber (LSL), Laminated Veneer Lumber (LVL))	4-12
Glulam, Cross-laminated Timber (CLT)	7-15

The EMC that solid wood will achieve in service mainly depends on the relative humidity and temperature, and varies by region and fluctuates throughout the year within a certain range. Manufacturing processes and adhesives used in EWP usually slightly reduce the EMC in service. Typical EMC values of solid wood are:

Table 2: Typical EMC for different regions of Canada

Location		Average (%)	Winter (%)	Summer (%)
West coast	Indoors	10 – 11	8	12
	Outdoors under cover	15 – 16	18	13
Prairies	Indoors	6 – 7	5	8
	Outdoors under cover	11 – 12	12	10
Central Canada	Indoors	7 – 8	5	10
	Outdoors under cover	13 – 14	17	10
East coast	Indoors	8 – 9	7	10
	Outdoors under cover	14 – 15	19	12

Wood can dry rapidly when the conditions are favorable. For example, it takes only a few days for green lumber ranging from 50 to 120% in MC to reach a MC of 16% during high-temperature kiln drying. However, it may take weeks, months and even longer for wood products to reach EMC in service, especially when the product is initially wet and the environmental humidity is high.

The *Fiber Saturation Point* (FSP) is defined as the MC where the wood cell walls are fully saturated (with the so-called “bound water” or “hygroscopic water”) while the cell cavities do not hold any moisture (the so-called “free water” or “capillary water”). The FSP averages around 28%. Wood shrinks or swells as its MC changes, but only when the MC is below the FSP.

It is important to note that moisture that appears at the surface when the wood member is wetted may cause the surface texture to change, but it may not result in the same level of shrinkage or swelling in the interior portions. Similarly, an apparently dry surface does not mean that the wood member has a low MC.

Shrinkage due to changes in MC

Shrinkage is different in the three principle directions in wood. In a wood-frame structure, shrinkage occurs primarily in horizontal members such as wall plates and floor joists. In the parallel-to-grain direction, the dimensional change is approximately one fortieth of the dimensional changes perpendicular to grain and can be ignored in most low-rise buildings. It is recommended that the parallel-to-grain dimension change should be included in the shrinkage calculations, particularly in taller buildings, as it can be considerable in 5-6 storey buildings. Figure 1 shows typical shrinkage values of wood in the three grain orientations, with the shrinkage values expressed as percentages of the green dimensions. In service wood never experiences drying from “green” to “oven-dry”, therefore the related shrinkage amounts are usually much smaller.

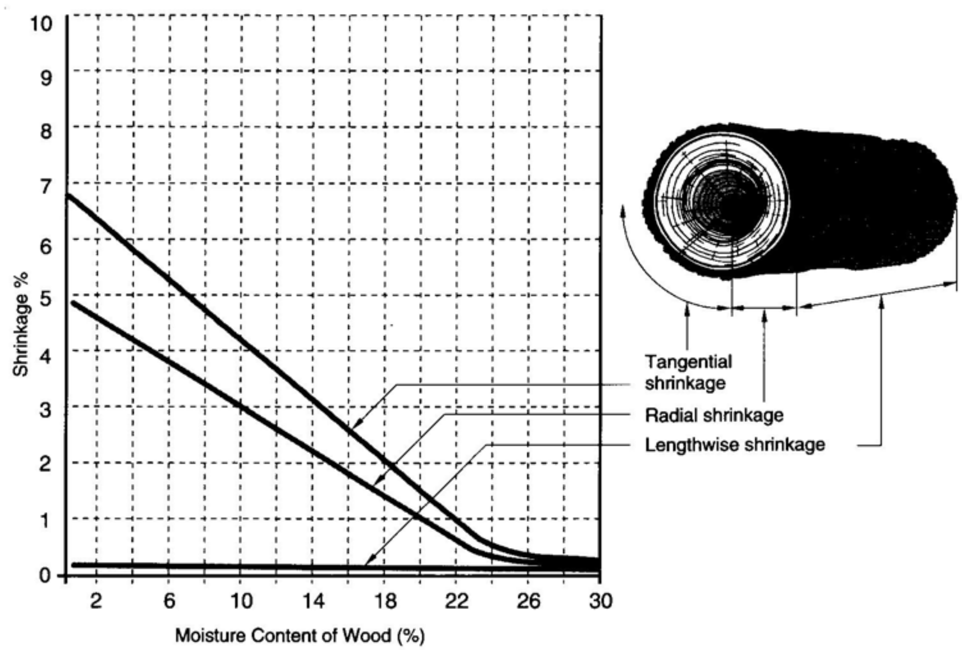

Figure 1: Typical shrinkage values of wood in different grain orientations

Wood is a naturally variable material. Its shrinkage varies between and within wood species. Since lumber is usually sold as a mixture of species in North America, such as “SPF” (spruce-pine-fir) and “Hem-fir” (hemlock-fir), and also always has mixed grain orientations, it is not possible to precisely predict shrinkage of wood for construction. Moreover, it is not necessary to calculate shrinkage so precisely due to the many other variations involved in construction. For purposes of design it is usually assumed that perpendicular-to-grain dimensions for major Canadian species groups will change approximately 1% for every 5% change in MC.

Other causes of vertical movement in wood structures

Shrinkage due to changes in MC is usually the major cause for vertical movement in platform frame construction. The following are the other causes of vertical movement that may also need to be considered in design, particularly for taller wood structures.

Movement due to vertical loads

Wood has a high modulus of elasticity (MOE) parallel to the grain, therefore the deformation of members loaded parallel to grain, such as studs, is very small and can usually be neglected. However wood members loaded perpendicular to grain may undergo appreciable instantaneous and time-dependent deformations under load. Instantaneous deformation will occur with the application of load, while the time-dependent deformation (also called creep) is additional deformation which develops over time. The time-dependent deformation is most pronounced where wood members are subjected to high levels of sustained loads in environments with frequent large changes in MC or under continuously wet service conditions. Whether instantaneous and time-dependent deformations need to be considered in design depends on factors such as structure, location, and the time of installation (construction sequence).

Movement due to closing of gaps between members (settlement)

Due to imperfections of product manufacturing and building construction, small gaps between framing members in the walls and floors are created during building construction. The amount of settlement can vary greatly with different products and construction practice, and as the construction proceeds, these gaps are usually gradually reduced with the increase in load. Based on the laboratory testing by FPInnovations to quantify the impact of moisture content changes and loads on vertical movement of wood frame construction, the settlement amount can be significant. The impact of such settlement depends on the building component (such as elevator shaft and cladding) and when it is installed. It should be considered in design.

General recommendations on material handling and construction sequencing to reduce vertical movement

Reducing the initial moisture content of wood and consequently the moisture content changes greatly reduces the amount of vertical movement that may occur. It is very important to protect wood from various water sources during construction and in service. Most building materials, even those intended for interior dry use, are often left outside for a length of time, where they are subjected to wetting caused by rain, snow, and ground moisture. Outdoor storage of wood products on the construction site should be minimized. Materials should be delivered just in time for installation in order to prevent potential wetting. Products such as “S-Dry” lumber are usually covered with wraps when they arrive on site. Plans should be made in advance to minimize on-site wetting. Lumber bundles should be kept under shelter, or in a well-drained and ventilated area. Dunnage should be used to keep wood off the ground. The wraps should be kept on the bundles until the lumber is ready to use. The lumber should be re-covered with waterproof tarps if the original wrapping is damaged. Also be aware that lumber wraps or tarps may also trap moisture and slow down drying if water is allowed to get into the bundles.

Wood-based composites and engineered wood products usually require more attention during storage and handling. Most of them are manufactured at a low MC with more end grains and other surfaces exposed and more gaps introduced during manufacturing. They may therefore be more susceptible than lumber to moisture uptake during wetting incidents. Factory finishing with special coatings and sealers can provide temporary protection, but these treatments may also trap moisture and slow down drying if water gets into the wood. In addition, all engineered and prefabricated products such as glulam and roof trusses require special care during storage and transportation to prevent structural damage.

Good construction sequencing also plays an important role in reducing wetting and the consequent shrinkage and other moisture-related issues. Once framing is started, make sure to install roof sheathing and membrane, and wall sheathing membrane as quickly as the construction allows. The use of prefabricated panels and roofs can improve construction efficiency. Wet construction such as the pouring of concrete topping should be completed at early stages. Wood products under protected conditions can dry out naturally when they are well ventilated and the humidity level of the air is not too high, and sufficient time should be provided for this drying to occur. Walls and roofs should not be enclosed until the framing materials have dried to an acceptable level of moisture. In cold and damp conditions, the use of space heating can efficiently dry wood and improve construction efficiency. Rigid services and other connected components, such as hard pipes, elevator shafts, and masonry cladding, should be installed as late as the construction allows, to maximize settling of the wood frame. Additional measures should be taken to accommodate any differential movement that may occur, particularly at upper floor levels.

Acknowledgement

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