Timber Design Guide 2019-18

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Title:	Moisture Considerations for Mass Timber Structures		

Introduction

In detailing any timber structure, consideration must be given to the effect of timber dimension changes associated with changes in moisture content. Timber frame structures are typically made with unseasoned green timbers that season and shrink in service. Timber joinery needs to be detailed to accommodate the anticipated dimension changes – for instance, mortises need to be cut deeper than the associated tenon length. Pegs in timber joints are sometimes draw bored to keep the joint tight when the timber seasons.

For glulam timber structures with bolted steel connection hardware, connections need to be configured to prevent restraint of cross grain shrinkage – see *TFEC Timber Design Guide 2019-16*.

Glulam timbers and Cross-Laminated Timber (CLT) panels are manufactured from kiln dried lumber that may experience swelling associated with excessive wetting during construction or in service. Failure to consider the effect of timber swelling can have unanticipated consequences.

Wood and Water

All wood contains some water unless it has been oven dried. The moisture content (MC) of wood is expressed as the ratio of the weight of water to the oven dry weight of wood. It is not uncommon for the sapwood of unseasoned timber to have a moisture content exceeding 100%.

The water contained in wood is either free water or bound water. Bound water is the water contained within the cell walls of the wood and free water is the water contained within the cell cavities, also referred to as lumen. As wood seasons and dries, the free water will be lost first. When all of the free water has evaporated, but the cell walls are still saturated, the wood is at its Fiber Saturation Point (FSP). The FSP varies between 28% MC and 30% MC.

As wood continues to season and dry below the FSP, the bound water will be lost until the wood reaches its Equilibrium Moisture Content (EMC). The EMC is a function of the temperature and relative humidity of the environment. For timber enclosed within a fully conditioned space, The EMC is typically between 6% MC and 8% MC.

Timber will not experience any dimension change if the MC is above the FSP. As the timber seasons to a MC below the FSP it will experience cross-grain shrinkage. The magnitude of the cross-grain shrinkage varies linearly from the FSP to oven dry. Similarly, timber will experience cross-grain swelling if the MC increases. The rate of cross-grain shrinkage or swelling is significantly greater in the tangential direction than in the radial direction due to the restraint of radial distortion provided by the medullary rays.

Shrinkage from FSP to Oven Dry

Species	Radial	Tangential	Average
Douglas Fir	4.8%	7.6%	6.2%
Southern Pine	4.8%	7.4%	6.1%
Black Spruce	4.1%	6.8%	5.5%

Source: Wood Handbook – USDA Forest Products Laboratory

Shrinkage and swelling in the longitudinal direction is insignificant and can be neglected, unless the timber contains reaction wood.

Weather Protection

Timber structures should never be directly exposed to the weather on a permanent basis unless the timber has been preservative treated or is the heartwood of a naturally decay resistant species such as cedar or black locust. If timber is allowed to remain at a moisture content above the FSP, fungal rot is inevitable.

The photo to the right shows exposed glulam arches protected by roofing. It would have been a good idea to also galvanize the exposed steel hardware and fasteners. Exposed steel connection hardware should be detailed to drain freely and not trap water.

Protection of timber structures from the weather during construction often does not get sufficient attention. In Europe, it has not been uncommon to have temporary weather protection of a timber structure during construction. In North America, temporary weather protection has not been common.

photo credit: StructureCraft

The photo to the right shows Dowel Laminated Timber (DLT) panels protected with water barrier sheathing.

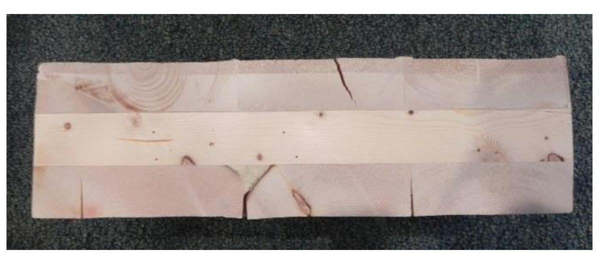
Leaving timbers exposed to the weather for an extended period during construction can lead to an increase in moisture content and unanticipated swelling as well as staining.

It is good practice to wrap glulam timbers and CLT panels with a protective covering for transportation to the site and storage at the site. The protective covering should be left in place as long as practical. The photo to the left shows wrapped glulam timbers. Once the timber structure has been erected, every effort should be made to making the structure weathertight as soon as practical.

Timber that has become wet during construction should be afforded an opportunity to dry. For instance, applying an unvented roofing directly over a wet roof deck can trap moisture and lead to timber deterioration or premature failure of the roofing.

It is advisable to place the thermal insulation on the exterior side of a timber structure to minimize the potential of condensation forming on the surface. This is particularly important in high humidity spaces such as swimming pools.

Dimension Change



Glulam timbers are typically manufactured at 15% MC and CLT panels are typically manufactured at 12% MC. The photo to the right shows a CLT that has seasoned to 6% MC, resulting in surface checking and joints opening. The internal stresses associated with the timber shrinkage tend to be relieved by the checks and joints. If the joints are bonded with adhesive, considerably more checking can be anticipated. If a CLT panel experiences wetting above 12% MC, the resulting swelling is restrained by the cross laminations resulting in significant internal stresses. The long-term effect of these internal stresses is not well understood.

It is prudent to detail glulam and CLT structures to accommodate the dimension changes associated with wetting during construction and subsequent drying. It is reasonable to assume 8% MC fluctuations. This relates to a cross-grain dimension change of 1.6 % (average of radial and tangential).

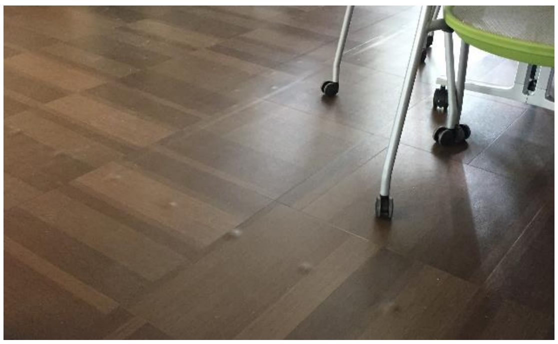


photo credit: KL&A

The photo to the left shows dimpling of the finish flooring over CLT panels where screw heads were not sufficiently countersunk.

When subjected to an 8% MC increase, a 24" glulam timber will swell 3/8" and a 48" glulam timber will swell ¾". If long fully threaded screws have been installed in the timber, the swelling can fracture the screws.

When subjected to an 8% MC increase, a 5-ply CLT will swell 1/8" in thickness. This can result in joints between CLT wall panels opening up if butt joints are used at corners and intersections – see *TFEC Timber Design Guide 2019-15.*

For Nail-Laminated Timber (NLT) construction, it is advisable to leave gaps between NLT panels to allow for timber swelling during construction. Typically, 1 ½" gaps are left between 10-foot-wide NLT panels. The gaps are filled after the structure is weather tight and the panels have dried. NLT panels are often augmented with plywood sheathing to improve their diaphragm performance. If the plywood sheathing is installed in the shop, there is a potential for the NLT panels to curl when the timber swells.

In conclusion, when engineering a mass timber project, it is important to specify appropriate weather protection during construction, and to also detail the structure to accommodate timber dimension changes associated with the inevitable wetting of the timber elements during construction and subsequent drying.