An Introduction to Moisture Effects

Introduction

There is a great deal of confusion about the effects of moisture on lumber products. Although Trus Joist® structural composite lumber (SCL) products have many well-known advantages over sawn lumber; the degree to which moisture affects these products requires some clarification. Much of the following discussion applies equally to any wood member, except where Weyerhaeuser® SCL products are specifically mentioned.

This discussion addresses the main effects of moisture on lumber products and gives some guidance on the expected results of given conditions. However, keep in mind that moisture content changes continuously and will vary from species to species, tree to tree, member to member, and even within members.

Definitions and Background

Moisture Content (MC)

The solid portion of wood is made of a complex cellulose-lignin compound. In addition to the solid material, wood contains water. MC is the percentage of water and is usually expressed as a percentage based on the weight of an in-service piece of wood divided by the oven-dry (dried to zero moisture) weight of that same piece.

Moisture Content of Living Trees

Living trees (green wood) have moisture contents from 30 to 200%. In green softwoods, the MC of heartwood is generally much less than sapwood; the moisture contents of Douglas fir and southern pine trees are usually about 35% and 120%, respectively.

Fiber Saturation (FS)

FS is the MC above which no further dimensional or property changes occur in the wood. FS (usually about 30%) is the amount of water required to saturate the cell walls. Above FS, additional moisture is free water in the cells and other cavities in the wood.

The Cellular Composition of Wood

Wood is made up of cells that are long, hollow tubes. For softwood species, cells range from 0.1" to 0.3" long and are about 0.003" in diameter. Latewood cells (the darker band in the annual ring) are usually longer and have much thicker walls than early wood cells. The latewood cells provide most of the strength and stiffness of softwood species.

Cells are made of submicroscopic fibers and some bonding agents. This cell-wall matter (for all species, both softwoods and hardwoods) is actually about 50% more dense than water. A very dense piece of softwood may have a specific gravity (SG) of 0.5 (that is, it weighs half as much as the same volume of water), but the cell-wall matter has an SG of about 1.5, so the wood is actually about two-thirds air.

Hardwoods vs. Softwoods

These wood type names are misleading; some hardwood species actually have much lower densities than some softwood species. The main differences between hardwoods and softwoods lie in the cell structure and the type of leaf and seed. Hardwoods may be classified as broad-leaf deciduous trees and softwoods as narrow-leaf evergreens.

The cell structure of hardwood is much more complicated than that of softwood, as hardwoods have cells perpendicular to, as well as parallel to, the tree axis. Also, there are two general hardwood types: ring-porous (such as oak) and diffuse-porous (such as aspen and yellow poplar). In diffuse-porous hardwoods there is little difference between early wood and latewood, and the annual rings can be difficult to distinguish.

Equilibrium Moisture Content (EMC)

For a given temperature and relative humidity (RH), wood will eventually reach a stable MC. Trus Joist® Microllam® LVL and Parallam® PSL each have an EMC that is 20% lower than sawn lumber, and Trus Joist® TimberStrand® LSL has an EMC that is 35% lower than sawn lumber. The time it takes for wood to reach EMC varies. Generally, Weyerhaeuser SCL products can reach EMC if they have been in fairly stable environmental conditions for a few weeks.

Weyerhaeuser SCL products are manufactured at an MC of 5 to 7%, while sawn lumber is kiln-dried to about 15% (large variations occur). Therefore, they will gain moisture in most environments, while the MC of sawn lumber is likely to decrease.

The term "dry wood" usually refers to wood at EMC in normal protected use. Structural composite lumber (SCL) products (such as Microllam® LVL, Parallam® PSL, and TimberStrand® LSL) are assigned design properties in accordance with ASTM D 5456, which dictates that properties be based on an EMC that is reached at 65% relative humidity and 70°F. In these environmental conditions, the EMC of Microllam® LVL and Parallam® PSL is about 10%, and the EMC of TimberStrand® LSL is approximately 8%. The MC of wood in buildings varies by climate, season, design details, and use of the building. The expected range of EMC is 6 to 15%, but there may be exceptions.

Measuring MC
The only reliable method for measuring MC is to weigh a sample at EMC, then dry it in an oven in accordance with published standards, and then weigh the oven-dried (OD) sample. As stated above, MC is stated as a percentage of the dry weight to EMC weight.

There is a wide range of sophisticated devices used in saw mills to measure an approximate MC, but the most common is a handheld, electric resistance meter with a needle probe. These meters are fairly accurate in the range of 5 to 20% when corrected for species and temperature. These corrections are made by using information provided by the manufacturer. Generally, the recommended procedure is to drive the probes in about one-quarter of the member's thickness to get the average MC in the member; if there are only two probes, they should be inserted so they read along the grain.

Glue lines affect electric resistance, and cause readings to be higher than the actual MC. So with Weyerhaeuser SCL products, handheld meters usually report higher than actual moisture contents. When a wood surface is wet, most meters will pick up the surface moisture and give inaccurately high readings.

Obtaining accurate MC measurements of in-situ members is difficult, but fortunately an approximation is usually all that is needed. One simple way to determine if a member is experiencing high moisture content is to measure its dimensions. For example, measure a beam's width, and if it is significantly wider than nominal published dimensions, then it probably has a moisture content that is high enough to cause problems.

Moisture Effects on Weyerhaeuser SCL Products and Sawn Lumber

Strength
Many wood strength properties decrease as MC increases beyond dry-use conditions, until FS is reached. Beyond FS, the mechanical properties remain constant. Elevated temperatures also decrease the strength of wood. These factors are considered when setting design values for dry-service conditions. The *National Design Specification (NDS) for Wood Construction* gives guidance for reducing design values for applications where elevated moisture and/or temperatures are present.

Be aware of unusual environmental effects associated with special-use structures (i.e. swimming pools, industrial environments, saltwater applications, etc.) and consult a professional for guidance. The effects of high moisture and other unusual environmental factors need to be considered for each job.

Temporary high moisture conditions can also create problems related to strength. When it is necessary to estimate strength above FS, assume a loss of 30% for tension and bending; and 40% for compression parallel, compression perpendicular, shear, and all connections. These are rough numbers that can be applied to all wood members, including all Weyerhaeuser SCL products.

When temporarily wet wood members are dried back to normal EMC, it is typical to assume a return to full strength, though small losses are likely. Repeated wet/dry cycles eventually produce strength loss, which must be evaluated on a case-by-case basis.

Stiffness and Creep
High moisture contents can affect stiffness and creep performance and can lead to serious problems. For most wood, raising the MC from normal-use conditions to FS decreases stiffness by about 25%, thereby causing an immediate deflection of about one-third more than calculated.

Creep is an increase in deflection that occurs over time under sustained load. Wood members at "dry" EMCs (i.e., EMC <16%) will eventually creep about 50% of initial deflection. The amount of creep is somewhat dependent on stress levels, but the 50% rule can be used as a fairly reliable average. For example, if a member is loaded to produce an initial deflection of 1.0", over time, the deflection will reach about 1.5". When considering creep, it is common to apply the increase only to the dead load deflection; live load deflection is assumed to be too short to produce creep. Also, when load is removed, some of the creep deflection is recovered, but some will be permanent.

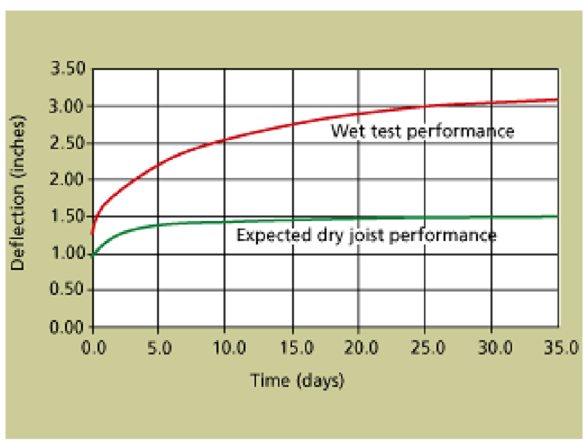
Permanent creep may approach the total creep, depending on moisture changes and time loaded. If the load increases, additional creep may occur. For a roof in heavy snow areas, creep should be considered for the anticipated live load, but probably only for the amount of snow in an average year.

All of the above is applicable only to wood at constant EMC. High MC and large MC changes have a significant effect on creep. An EMC greater than 16% over a long term may result in more than the expected 50% increase in creep deflection. The amount of additional deflection seems to depend on the degree of moisture change. Members in the roof of an unheated shed will experience greater seasonal creep than those in a climate-controlled building. However, these creep "steps" diminish with each moisture cycle and will nearly vanish after three or four cycles. If seasonal MC changes are greater than a couple of percentage points, the initial deflection may double in two or three years.

For example, a Microllam® LVL header exposed to rain has an MC above 20% when installed. Rapid application of dead load yields an immediate deflection of 1.3 times the calculated deflection. Creep deflection would normally be expected to be an additional 50% of the immediate deflection, but high MC and drying under load may increase the creep deflection by a factor of 3 or more. This is common when members are installed wet or unseasoned. The severity of a creep deflection depends on the application, how much load is applied, how rapidly it is applied, and the actual magnitude of the deflection. Once dried, the member will perform normally under additional loads, but the creep incurred during drying is permanent.

Below is a plot of the actual deflections from a load test of TJI® Joists. The test approximated a field application where joists were installed wet and 3½" to 5" of regular weight concrete was poured on the deck. The results shown on the plot below show the creep performance during the test.

Similar results have been obtained in tests of Microllam® LVL and other wood members. Notice that much of the creep experienced happens rapidly, but there is really no precise way of quantifying the rate.



Decay

The conditions needed for fungi to attack wood are air, water, favorable temperatures, and an available food source. Variable moisture and temperature conditions make it difficult for fungal organisms to become established. Moisture content must be above 28% for decay fungi to become established, after which levels above 20% can support most fungi types. Note that the 28% MC level can be in the form of a localized pocket of moisture. Whether or not decay occurs depends on the conditions that a wood member may experience. For instance, exposed members subjected to wet conditions that do not have adequate air circulation on all sides may experience damaging decay; however, the same exposed member may last indefinitely in dry conditions. Note the use of "conditions" instead of "climate". An exterior wood deck located in the southwest that is consistently wetted several times a week by lawn sprinklers can decay almost as fast as a deck located in the southeast where humidity levels are high all year long. On the other hand, wood submerged in fresh water will last indefinitely because of a lack of oxygen.

In order to protect against decay, Weyerhaeuser offers preservative treated structural composite lumber products. See the Weyerhaeuser's *Preservative Treatment Guide* (*TJ-1020*) for more information.

Weathering

"Weathering" is a general term for the deterioration of wood over time when exposed to the elements. Aside from the chance of decay, most of these effects are due to MC cycling. Minor weathering is anticipated during transport, storage, and installation and may be ignored unless circumstances lead to prolonged exposure. Weathering also includes minor discoloration due to exposure to ultraviolet rays.

Dimensional Stability

Sawn lumber remains dimensionally stable when above the fiber saturation point; however, when below the fiber saturation point, wood shrinks or swells with changing moisture content. Wood is an anisotropic material, which means shrinkage in wood differs along the longitudinal (parallel to wood fiber), tangential (perpendicular to grain and tangential to growth rings), and radial (perpendicular to the grain in the radial direction) axes. The following table indicates average percentage changes with respect to the radial, tangential, and longitudinal axes. Values for specific wood species may be found in wood reference manuals.

Change in Moisture Content	Direction of Dimensional Change		
	Radial	Tangential	Longitudinal
From Fiber Saturation Point to Oven-Dry OR Oven-Dry to Fiber Saturation Point (~30%)	4 – 5%	7 – 8%	0.1 – 0.2%

Dimensional changes due to moisture along the longitudinal axis are typically ignored. The dimensional change in the tangential axis is approximately two times that of the radial axis. Dimensional change percentages in the above table assume a 30% change in MC. Smaller changes in MC will result in smaller dimensional changes, which is linearly proportional to the change in moisture content from fiber saturation point.

Weyerhaeuser SCL products are slightly different than sawn lumber products because they are densified and are comprised of many layers of strands or veneer. Therefore, an engineered lumber product averages the effects of the growth ring angles, knots, grain deviations, etc., meaning that Microllam® LVL, Parallam® PSL, and TimberStrand® LSL have lower linear expansion across the width as compared to sawn lumber. The required densification of the strands increases thickness swell when exposed to water.

Water enters SCL products most rapidly on the ends, to a lesser degree along the edges, and to the least degree along the face. The degree of swell depends on the length of exposure and size of the member. The percentage of swell recovered after drying is related to the densification required by the manufacturing process. TimberStrand® LSL requires a higher degree of densification (in the thickness only) and therefore will not fully recover thickness swell when dried.

Checking, Splitting, and Delaminating

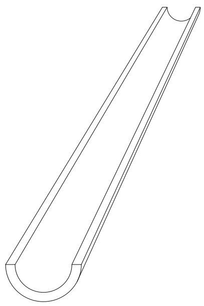
When wood dries, the shrinkage is never uniform because of varying characteristics within each member and because the surfaces dry first. When one side of a member shrinks or swells relative to another, internal stresses may cause surface splits, also known as seasoning checks. A check becomes a split when it projects completely through the piece. Repeated wetting and drying cycles often lead to progressively larger checks.

When exposed to two or more wetting and drying cycles, Microllam® LVL and Parallam® PSL develop small surface checks that do virtually no damage. These small checks help relieve the differential stresses, so additional checks grow at a slower rate after the first few cycles. End splits also occur because of moisture cycles, but they are rarely of a significant length. The slow growth of checks and splits in Microllam® LVL and Parallam® PSL is a great advantage compared to sawn lumber.

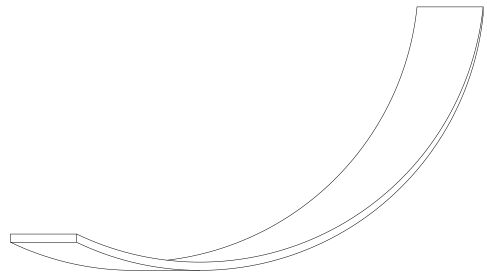
Delaminating is the absence of an adhesive bond between veneers or strands in an engineered wood product and can be caused by poor adhesive bond or induced by moisture cycling. When veneers are exposed to moisture they will shrink or swell at varying rates and stresses will develop at the glue line. When the glue bond is adequate, the wood adjacent to the glue line may fail, so what first may appear as a veneer delaminating is actually a check in the wood.

Warp

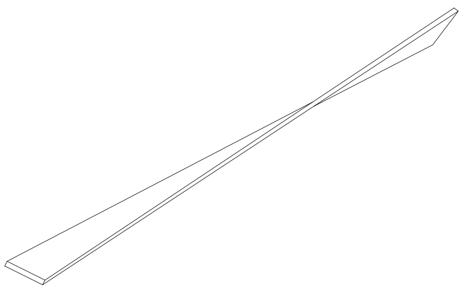
Warp is defined as any deviation from a true or plane surface. Warp may be in the form of bow, crook, cup, twist, or any combination of these. See the figures below for a graphic representation of the forms of warp.



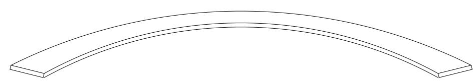
Cup



Bow



Twist



Crook

Warp is caused by differential dimensional changes that can result from the drying or uneven wetting of a member. It is more prevalent in lower grades of sawn lumber because of higher grain angles and the increased frequency of juvenile, compression, and tension wood. Warp is a lesser problem with engineered lumber products because the many layers of veneer or strands randomize differential dimensional changes.

Bow, crook, and twist are usually negligible in Weyerhaeuser SCL products due to the randomization caused by multiple layers of strands or veneer. However, cup may occur because of the high degree of grain alignment, which produces high bending strength and stiffness properties and reduces resistance against cup. Differential wetting between product faces induces bending stresses that cause cupping. Cup becomes more evident as the product depth increases and the thickness decreases.

Cup forces can be considerable and should not be resisted through nailing or clamping the member. These actions can split the member, making it unusable. Movement during drying can result in serious detail problems, such as ceiling damage. Severe cup can also seriously reduce the member's structural capacity, depending on the method of loading.

Preventative Measures and Conclusions

High moisture, large cyclical moisture changes, and severe moisture gradients are undesirable for all wood members, unless carefully anticipated in design. Weyerhaeuser SCL products resist many moisture effects more effectively than sawn lumber. A disadvantage common to all veneer products is their increased rate of moisture absorption. Some moisture effects may appear exaggerated in veneer products because they are larger than common, conventional framing members.

Preventative Measures and Conclusions

- Promote adequate storage, both in product yards and at job sites. Keep products covered and as far off the ground as possible.
- Anticipate the effects of high temporary moisture if it happens accidentally. Study details for adverse effects of dimensional changes and make sure moisture content is stable before finishing.
- Break down wet packages and sticker them to dry. Mildew stains can occur rapidly.
- Avoid applications that may promote decay and properly consider all unusual use environments.

Weyerhaeuser Reduces the Effects of Temporary Moisture Exposure By:

- Applying a Watershed™ overlay to Microllam® LVL eastern species headers and beams to limit cup.
- Sealers are applied to the ends of Parallam® PSL.

The measures above are intended to alleviate the effects of accidental or temporary exposure to moisture. To avoid unanticipated effects there is only one answer: **KEEP WOOD DRY!!**