from experience

Wood Design for Shrinkage

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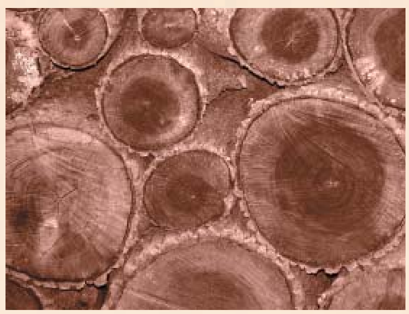
In the design of wood connections, considerations must be taken for the change in dimensions of the wood due to change in moisture content from the time of installation of the member to the stable in-use condition of the wood, and the lack of change in dimension in the other elements of the connection. Such oversights in design can result in failure of the connections and, in some cases, the failure of the supported member.

The rate of change of dimensions with change in moisture content in the wood varies for each species. For the purpose of this report, the wood species will be limited to Douglas-fir, Coast. The lumber will be limited to flat-sawn with the greater dimension in the cross section of the piece of lumber tangent to the annular growth rings of the tree.

The moisture content in the wood is the ratio of the weight of the water in the wood to the oven-dry weight of the wood expressed as a percentage. The average moisture content of Douglas-fir coast type (D. F.) in green and living trees is 37% in the heartwood and 115% in the sapwood. The fiber saturation point is the point where the walls of the wood cells are completely saturated with bound water, and there is no free water in the cavities of the wood cells. The fiber saturation point for D.F. is 30% moisture content in the wood. No change in dimensions will occur at or above this moisture content in D.F. The change in dimension from 30% to 0% moisture content in the wood for D.F. is 4.8% radial to the annular growth rings of the tree, 7.6% tangentially to the annular growth rings of the tree, and 0.41% parallel to the length of the tree. Determination of the change in the dimension of a single piece of lumber with a change in the moisture content is also subject to a coefficient of variation of approximately 15%. Ninety percent of the dimensional changes would range from 75% to 125% of the average value determined.



The equilibrium moisture content in the wood is the point at which the moisture content is in balance with the relative humidity and temperature of the air in contact with the wood. With a relative humidity of 60%, the moisture content in the wood would drop below 12%. At 45% relative humidity, the moisture content would be about 8%.

In the grade marking of solid sawn lumber, "S-GRN" indicates the moisture content in the wood exceeds 19% and "S-DRY" indicates the moisture content in the wood is 19% or less at the time of grading. A change from 19% ("S-DRY") to 8% for sawn lumber would result in a 2.09% to 3.48% loss in the nominal 12-inch depth of a nominal 2-inch by12-inch member.

In the fabrication of structural glued laminated timber members, the flat sawn lumber will be used as horizontal laminations with the depth of the member equal to the number of the laminations times the least dimension of the cross-section of the laminations. Unless specified otherwise, the maximum moisture content in the wood at the time of fabrication is limited to 16%. With this limitation, the maximum average moisture content at a cross-section in the member can be 14%. With a change in the moisture content in the wood from 14% to equilibrium moisture content at 8%, there will be a 0.72% to 1.20% loss in the height of the member and a 1.14% to 1.90% loss in the width of the member. For a 5 1/8-inch by 30-inch member, there would be a 0.22-inch to 0.36-inch loss in the depth and a 0.05-inch to 0.l0-inch loss in the width of the member.

The degree of play of a fastener in the hole in the wood is a factor that needs to be considered when dimensional changes occur across the grain as a result of the wood reaching equilibrium moisture content. Bolts are installed in oversize holes, i.e. in oversize holes 1/32-inch greater than the bolt diameter for bolts less than ¾-inch, and in oversize holes 1/16-inch greater than the bolt diameter for bolts ¾-inch and greater. It is assumed that the bolt is centered on the bore of the hole in the wood and the bore of the holes in the steel side plates, as required by recommended practice. For bolts in a line perpendicular to the grain of the wood in the wood member, the shrinkage in the wood between the bolts after a loss of moisture content in the wood, and, of course, no shrinkage in the steel side plates on each side of the wood member, will subject the wood in the bolt holes to compression perpendicular to the grain from contact with the shank of the bolt. The wood between the bolts is subject to tension perpendicular to the grain. The oversize bolt holes permit 1/32-inch or 1/16-inch shrinkage between the bolts. With shrinkage in excess of these amounts, a split in the wood can occur between the bolt holes due to the effect of tension perpendicular to the grain alone, or due to the combined effects of tension perpendicular the grain and horizontal shear.

Fasteners such as lag screws, wood screws, nails and spikes, drift pins and other fasteners require no pre-drilled holes or pre-drilled holes, with a diameter equal or less than the diameter of the shank of the fastener. Since there are no oversized holes, there will be no movement of the fastener in the holes before load from the fastener is transferred to the wood. As such, at the start of shrinkage of the wood between the fasteners in a line perpendicular to the grain of the wood in a member with steel side plates, the fasteners subject the wood to compression perpendicular to the grain which, in turn, subjects the wood to tension perpendicular to the grain between the fasteners.

Attention is directed to the latest edition of AITC l04, "Typical Construction Details," available from the American Institute of

Timber Construction. Appendix to AITC 104, "Connections Details to be Avoided," contains a description of past connections that resulted in problems that reflect the experiences of engineers in industry, private practice and research that have been and are members of the AITC Technical Advisory Committee. AITC l04 is subject to periodic review and updating by the AITC TAC and the AITC Board of Directors.

In summary, the following consid-erations should be applied to connection design.

1. *Steel Side Plates on Each Side of Wood Main Member*: For two or more rows of bolts parallel to the length of the main member with steel side plates on each side of the main wood member, use a maximum of 5-inches between the top row and the bottom row of bolts. A single steel strap for each row of bolts parallel to the length of the main member on each side of the main member may be used where the maximum distance between bolts at any cross-section of the main member exceeds five inches. Where all loads in the wood main member are parallel to the length of the member, a single steel side plate may be used on each side of the wood main member for two or more rows of bolts parallel to the length of the member, provided the bolt holes are slotted in the steel side plates with the long axis of the hole at a right angle to the length of the main member. Length of the slots would depend on the anticipated shrinkage in the wood of the main member between the rows of bolts. The bolt value may be limited by the transfer of load from the bolt to the slotted steel side plates. Details of the connection should indicate the location of the bolt in the slotted hole at the time of installation. Where green lumber has a moisture content in the wood at or above 30%, the 5-inch maximum spacing of bolts perpendicular to the grain for bolts in single plates on each side of the main member may require further evaluation due to excessive shrinkage of the wood.

2. *Bearing Type Connections with Steel Side Plates*: Where members are supported on either their top or bottom surfaces by bearing plates in a steel side plate connection, such as a saddle type hanger or cantilever hinge connection, provide for anticipated shrinkage between the bearing surface and any bolt through the steel side plates in the connection. Slotted holes are generally the answer.

3. *Slotted Holes*: Be conservative in the determination of the required length of the slotted hole. A good practice is to use 150% of the calculated shrinkage, and indicate the position of the bolt in the length of the slotted hole at the time of fabrication on the drawings. A slotted hole is not the answer when the force acting on the bolts is parallel to the length of the slotted hole.

4. *Vertical Wood Main Member to Two Horizontal Side Members*: Change in dimension due to change in moisture content in the wood along the length of the wood member is 8.5% of the shrinkage radial to the annular growth rings of the tree and 5.4% of the shrinkage tangent to the annular growth rings of the tree. As such, the connection of a vertical main member to two horizontal side wood members poses a similar problem that steel side plates pose. A row of bolts parallel to the vertical length of the wood main member is subject to the same limitations as the preceding Section 1. The maximum spacing between the top and bottom bolts in the connection would be 5-inch. Slotting of bolt holes would not be an option.

5. *Fabrication*: Tight quality control is required in the fabrication and assembly of wood connections to insure that the connections will function as designed. Most field problems are related to incorrect drilling of the holes in the wood, including over-drilling and back-drilling. This lack of workmanship results in different degrees of loading of bolts in a connection.

The design of wood members and their connections must take into account the change in dimensions of the wood member with the change in moisture content in the wood during the length of time the member is in place in the structure. Changes in end-use conditions can result in changes in relative humidity and temperature of the air in the structure. Such changes can result in dimensional changes in the wood in the structure and, as a result, may affect connection design.▪

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Renotations

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