Dimensional Changes In Structural Glued Laminated Timber

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Introduction

Dimensional changes in the length, depth and width of structural glued laminated timber (glulam) due to changes in moisture content are minimized in comparison to sawn timbers and lumber. This is primarily a result of the glulam manufacturing process, which uses dimension lumber, typically dried to a moisture content of 16% or less. The result is finished glulam products with average moisture contents in the 12-14% range, or lower, at the time of manufacture. Small dimensional changes are still possible, however, as glulam members stabilize with their in-service environment. This acclimatization may result in dimensional increases or decreases but these can be predicted and accounted for in the design process when necessary.

Dimensional changes in glulam due to moisture content increases are typically temporary and may occur if members undergo moisture content changes when exposed to the elements during transit, interim storage periods or jobsite storage over prolonged periods. Glulam may also shrink dimensionally when stored or exposed to high temperature and low humidity conditions such as in arid climates or when subjected to dry heated environments following installation.

Reasonable estimates can be made for dimensional changes of glulam using calculations based on estimates of net moisture content changes. Dimensional changes do not occur equally in all directions of lumber grain orientation, so a factor accounting for grain orientation must also be considered. For the examples that follow, assumed average moisture content values at the time of manufacture are used as the basis for determining the mean net dimensional changes. Note that dimensional tolerances permitted at the time of manufacture must also be considered.

Dimensional Tolerances at the Time of Manufacture

Glulam products identified with *APA EWS* trademarks are manufactured in accordance with provisions of *ANSI A190.1, American National Standard For Wood Products – Structural Glued Laminated Timber.* The following permissible dimensional tolerances – listed in *ANSI A190.1* – are applicable at the time of manufacture:

Width – Plus or minus 1/16 in.

Depth – Plus 1/8 in. per ft. of depth. Minus 3/16 in., or minus 1/16 in. per ft. of depth, whichever is larger.

Length – Up to 20 ft., plus or minus 1/16 in. Over 20 ft., plus or minus 1/16 in. per 20 feet of length or fraction thereof.

Jobsite evaluation of glulam dimensions must take into account both the size tolerances permitted at the time of manufacture as listed above, and possible changes that may have occurred in a member due to changes in moisture content after leaving the manufacturing facility.

ENGINEERED WOOD SYSTEMS

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Shrinkage and Swelling Characteristics of Wood

Figure 1 illustrates the nature of shrinkage and swelling characteristics in individual pieces of lumber in terms of grain orientation, and how grain orientation may be expected to vary in a typical glulam layup. Dimensional changes are largest in the "tangential" direction, but the net change in a typical glulam member results from a composite behavior, or net effect of changes in the respective laminations making up the member.

As shown in Figure 2, grain orientation of laminations within a typical glulam member will be random in nature. Differential changes in dimensions across the width of individual laminations may result from both grain orientation differences and variability in the moisture content of individual laminations.

Table 1 lists factors that may be applied to initial dimensions (width or depth) when attempting to estimate net dimensional changes due to moisture content variations. The factors in Table 1 are based on a one percent net change in moisture content in either the tangential or radial direction. Assumptions on net changes in moisture content to be expected must take environmental considerations into account.

FIGURE 1

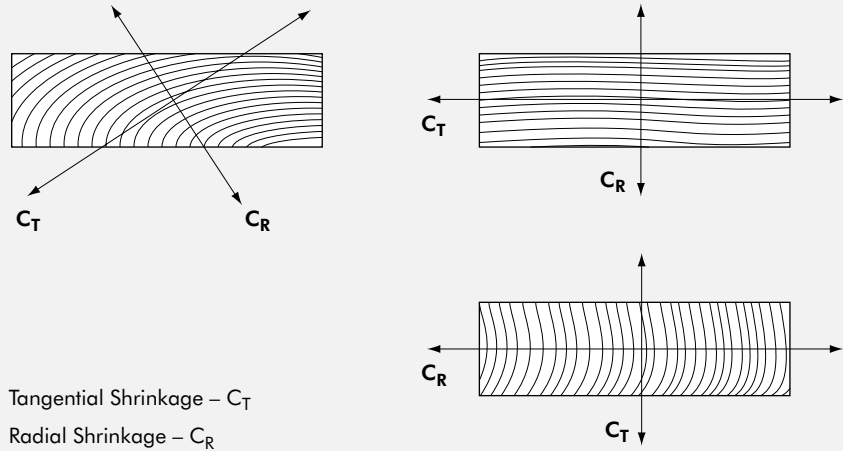**SHRINKAGE CHARACTERISTICS OF LUMBER AS RELATED TO GRAIN ORIENTATION**

Tangential Shrinkage – C_T

Radial Shrinkage – C_R

FIGURE 2

RANDOM GRAIN ORIENTATION OF LAMINATIONS IN A GLULAM
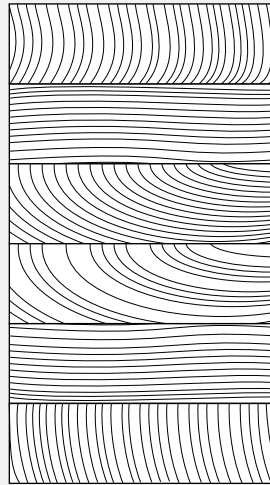
TABLE 1

DIMENSIONAL CHANGE COEFFICIENTS (C_C)*

	C_T	C_R
Douglas-fir	0.0035	0.0018
Southern pine	0.0030	0.0021
Spruce-pine-fir	0.0024	0.0013

*Per 1% change in member moisture content. Values shown for southern pine and SPF are weighted to account for sub-species variations within the species group. All values shown are averages and represent mean trends in anticipated dimensional changes.

C_R = Coefficient to be used for estimating dimensional changes in a member "radial" to the growth ring grain orientation (see Figure 1).

C_T = Coefficient to be used for estimating dimensional changes in a member "tangential" to the growth ring grain orientation (see Figure 1).

C_C = The selected dimensional change coefficient for Tangential or Radial shrinkage or swelling, or a weighted value based on the combined effects of mixed grain orientation (see Figures 1 and 2).

FIGURE 3

SHRINKAGE EFFECT OF TANGENTIAL AND RADIAL CHANGES ON LAMINATION DIMENSIONS
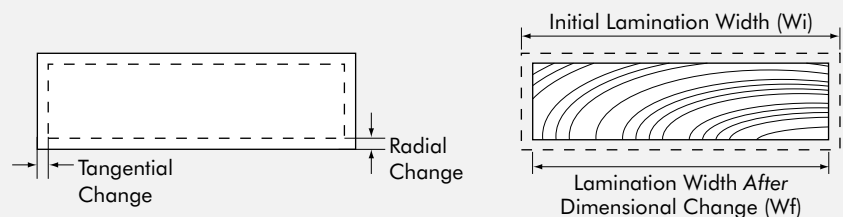

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Figure 3 illustrates how the width of a lamination might change if the grain orientation of the lamination was essentially "flat."

For this grain orientation, the average tangential change may be estimated using the equation shown below.

$$Wf = Wi + D$$

Total Change (D) = (Wi) [C_C(Mf – Mi)]

Where: Mi = Initial Moisture Content
       Mf = Final Moisture Content

Tables 2 and 3 tabulate examples of average tangential and radial changes for Douglas-fir, assuming a "flat" grain orientation of the laminations, that might be expected for the changes in moisture content noted in the respective tables using the mean trend coefficients in Table 1.

Best estimates for the moisture content to be expected once a member is in place and stabilized with its surrounding environment can be determined from Table 4 which lists "equilibrium moisture content" values for various combinations of temperature and relative humidity (RH). These values may be used to estimate glulam moisture content levels to be expected one to two seasons after installation – Summer to Fall or Winter, Spring to Summer or Fall. Members installed in arid climates may reach equilibrium moisture content levels sooner than in humid climates.

The average moisture content of glulam members may be measured with insulated needle probe type moisture detectors. For this purpose, measurements should be made at depths approximately equal to 1/4 the width of the member.

TABLE 2

TOTAL WIDTH CHANGES FOR DOUGLAS-FIR GLULAM FOR INDICATED M.C. RANGES

| C_T = 0.0035 | From 15% to 8% | | From 11% to 15% | |
| Initial Width | Total Change | Final Width | Total Change | Final Width |
Wi (in)	D (in)	Wf (in)	D (in)	Wf (in)
3.125	–0.077	3.048	+0.044	3.169
5.125	–0.126	4.999	+0.072	5.197
6.75	–0.165	6.585	+0.095	6.845
8.75	–0.214	8.536	+0.123	8.873

TABLE 3

TOTAL DEPTH CHANGES FOR DOUGLAS-FIR GLULAM FOR INDICATED M.C. RANGES

| C_R = 0.0018 | From 15% to 8% | | From 11% to 15% | |
| Initial Depth | Total Change | Final Depth | Total Change | Final Depth |
D_i (in)	D (in)	D_f (in)	D (in)	D_f (in)
12	–0.151	11.849	+0.168	12.168
19.5	–0.246	19.254	+0.273	19.773
24	–0.302	23.698	+0.336	24.336
30	–0.378	29.622	+0.420	30.423

TABLE 4

MOISTURE CONTENT OF WOOD IN EQUILIBRIUM WITH STATED DRY-BULB TEMPERATURE & RH*

| Temp | Relative Humidity (%) | | | | | | | | |
°F	15	25	35	45	55	65	75	85	95
30	3.7	5.5	7.1	8.7	10.4	12.4	14.9	18.5	24.3
50	3.6	5.5	7.1	8.7	10.3	12.3	14.8	18.4	24.3
70	3.5	5.4	6.9	8.5	10.1	12.0	14.4	17.9	23.9
90	3.4	5.1	6.7	8.1	9.7	11.5	13.9	17.3	23.3
110	3.2	4.9	6.3	7.7	9.2	11.0	13.2	16.6	22.4
130	2.9	4.5	5.9	7.2	8.7	10.3	12.5	15.8	21.5
150	2.6	4.1	5.5	6.7	8.1	9.7	11.8	14.9	23.1

*Excerpt from USDA *Wood Handbook: Wood as an Engineering Material, 1987.*

Example Calculations Illustrating Dimensional Changes in Glulam

Case 1: Assume a Douglas-fir glulam beam, manufactured to a net cross-sectional dimension of 8-3/4" x 24", with an average moisture content of the member at the time of manufacture of 15%, is shipped to Montana for installation in a new ski resort hotel. What dimensional changes would be expected in both the width and depth of the member after it reaches an equilibrium condition.

• The relatively low combination of temperature and relative humidity at the building location in Montana indicates an Equilibrium Moisture Content (EMC) level of approximately 8% would be expected. This would result in a net decrease in M.C. of 7%. Assume that an inspection of the member indicates that most of the laminations have a characteristic "flat" grain. In this case, width change estimates based on the Tangential Shrinkage Factor (C_T) will provide the best estimate of dimensional change.

Total Width Change (D)

$= 8.75 \, [C_T(M_f - M_i)]$

$= 8.75 \, [0.0035 \, (-7)] = -0.214$ in.

Thus, the new width after reaching equilibrium moisture conditions $= 8.75 - 0.214 = 8.54$ in. or approximately 8-1/2".

Note: It would appear from this calculation that the width tolerance of "minus 1/16 in." as permitted under ANSI A190.1 has been exceeded. However, the dimensional change was due instead to moisture loss in the member after installation.

• The best dimensional change coefficient value to use to estimate expected depth changes in this case is the Radial Shrinkage Factor (C_R).

Total Depth Change (D)

$= 24 \, [C_R(M_f - M_i)]$

$= 24 \, [0.0018 \, (-7)] = -0.302$ in.

Thus, the new depth after reaching equilibrium moisture conditions $= 24 - 0.302 = 23.70$ in. or approximately 23-3/4".

Note: It would appear from this calculation that the depth tolerance of "minus 3/16 in." as permitted under ANSI A190.1 for a member with a depth of 24" has been exceeded. However, the dimensional change was due instead to a reduction in the member's moisture content.

In summary, for this example, *minus* dimensional changes may vary as shown in the summary table below.

CASE 1

COMPARISON OF DIMENSIONAL MEASUREMENTS

	As Specified	Per ANSI A190.1 Tolerances	Jobsite Dimensions After Moisture Change
Width	8-3/4"	8-11/16"	8-1/2"
Depth	24"	23-13/16"	23-3/4"

Case 2: Assume a southern pine glulam having a net cross-sectional dimension of 8-1/2" x 24-3/4", with an average moisture content of the member of 12% at time of manufacture, is shipped to Florida and stored at the jobsite for a prolonged period of time. Assume that jobsite conditions during the storage period produce an EMC of 17% in the member. What dimensional changes could be expected assuming the member has increased in average M.C. from 12% to 17%?

• In this example, a moisture content increase of 5% has occurred. Predominately "flat" grained lumber is once again assumed indicating that the use of C_T for the member width change, and C_R for the member depth change will provide the best overall estimates for dimensional changes.

Total Width Change (D)
$= 8.5[C_T(M_f - M_i)]$
$= 8.5[0.0030(+5)] = +0.128$ in.

Thus, the new width after reaching equilibrium moisture conditions = 8.5 + 0.128 = 8.628 in. or approximately 8-5/8 in.

Note: It would appear from this calculation that the width tolerance of "plus 1/16 in." as permitted under ANSI A190.1 has been exceeded. However, the dimensional change was due instead to member moisture absorption at the jobsite.

• The net change in depth for this member is best estimated using the C_R factor

Total Depth Change (D)
$= 24.75[C_R(M_f - M_i)]$
$= 24.75[0.0021(+5)] = +0.26$ in.

Thus, the new depth after reaching equilibrium moisture condition = 24.75 + 0.26 = 25.01 in. or approximately 25 in.

Note: It would appear from this calculation that the depth tolerance of approximately "plus 1/4 in." as permitted under ANSI A190.1 for a member with a depth of 24-3/4" has been equaled due to the member moisture absorption at the jobsite.

In summary for this example, *plus* dimensional tolerances may vary as shown in the table below.

Summary

All wood products are subjected to changes in dimension due to changes in moisture content. The changes for a glulam member are typically relatively small due to the low average moisture content of glulam at the time of manufacture. However, it is important to note that, as shown by the examples in this Technical Note, the dimensional changes in a glulam member due to moisture variations that may occur during the shipping, storage and installation cycle may exceed the dimensional tolerances that are permitted at the time of manufacture and such changes should not be inferred as meaning that the members were not manufactured in accordance with the provisions of ANSI A190.1.

Also, it is important to provide for possible dimensional changes due to moisture cycling when detailing structural connections for glued laminated timber framing. Refer to EWS Technical Note T300, *Glulam Connection Details* for further information on this topic.

Changes in moisture content may also lead to checking in glulam. Refer to EWS Technical Note R465, *Checking in Glued Laminated Timber,* for further information on this topic.

CASE 2

COMPARISON OF DIMENSIONAL MEASUREMENTS

	As Specified	Per ANSI A190.1 Tolerances	Jobsite Dimensions After Moisture Change
Width	8-1/2"	8-9/16"	8-5/8"
Depth	24-3/4"	25"	25"

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