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TECHNICAL NOTE

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 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. Therefore, 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 trademarks are manufactured in accordance with provisions of ANSI A190.1, *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 inch.

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

Length – Up to 20 foot, plus or minus 1/16 inch, over 20 foot, plus or minus 1/16 inch per 20 feet of length or fraction thereof.

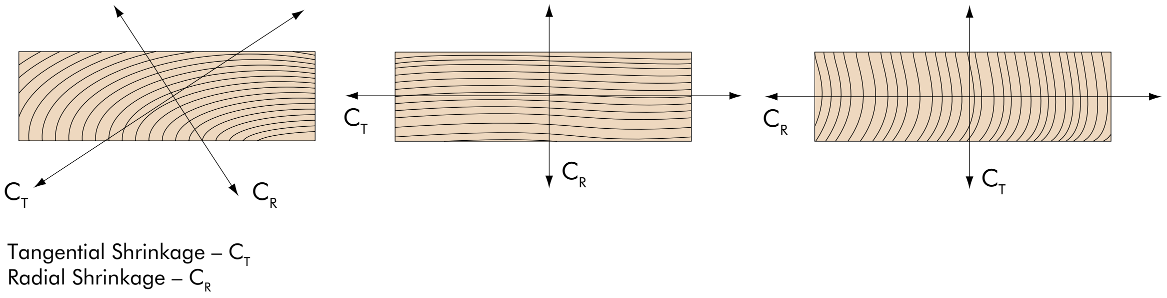
Jobsite evaluation of glulam dimensions must take into account both the size tolerances permitted at the time of manufacture as listed above and possible changes that may have occurred in a member due to changes in moisture content after leaving the manufacturing facility.

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.

FIGURE 1

SHRINKAGE CHARACTERISTICS OF LUMBER AS RELATED TO GRAIN ORIENTATION



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

DIMENSIONAL CHANGE COEFFICIENTS[a]

Wood species	C_T[b]	C_R[c]
Douglas-fir	0.0035	0.0018
Southern pine	0.0030	0.0021
Spruce-pine-fir	0.0024	0.0013

a. Values shown are for the dimensional change per 1% change in member moisture content. For southern pine and SPF, values shown 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.

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

FIGURE 2

RANDOM GRAIN ORIENTATION OF LAMINATIONS IN A GLULAM

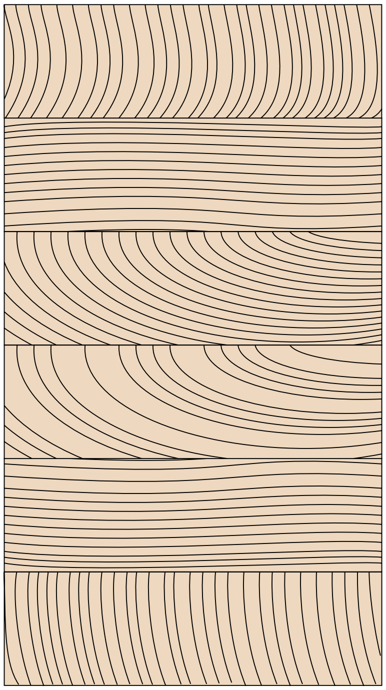
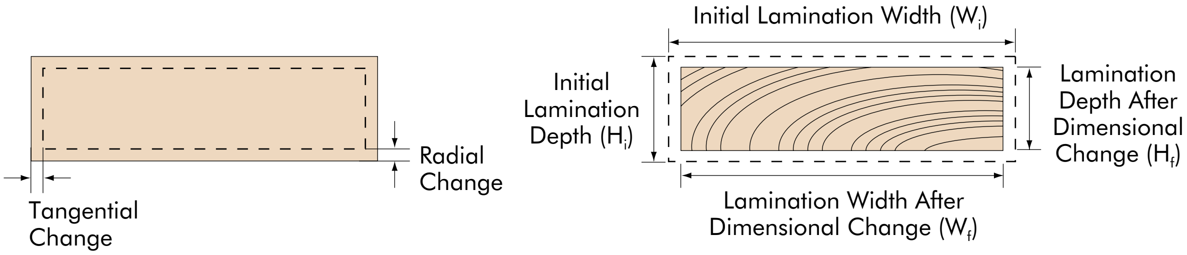


Table 1 lists factors that may be applied to initial dimensions (width or depth) when attempting to estimate net dimensional changes due to moisture content variations. The factors in Table 1 are based on a one percent net change in moisture content in either the tangential or radial direction. Assumptions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

Figure 3 illustrates how the width of a lamination might change if the grain orientation of the lamination was essentially "flat" (the width for all laminations is in the tangential orientation). For this grain orientation, the average tangential change may be estimated using Equation 1.

FIGURE 3

SHRINKAGE EFFECT OF TANGENTIAL AND RADIAL CHANGES ON LAMINATION DIMENSIONS



$$D_f = D_i + \Delta D \qquad [1]$$

where

D_f = final dimension (in.) = W_f for width or H_f for depth

D_i = initial dimension (in.) = W_i for width or H_i for depth

ΔD =total dimensional change = $(D_i)\ [C\ (M_f - M_i)]$, (in.) = ΔW for width or ΔH for depth

C = dimensional change coefficient as provided in Table 1

M_f = final moisture content (%)

M_i = initial 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 provided in Table 1.

Note that when the orientation of the lamination is mixed or the wood species is unknown, some design standards, such as CSA O86, *Engineering Design in Wood*, in Canada, have recommended the dimensional change (ΔD) in Equation 1 be estimated using a generic dimensional change coefficient (C) of 0.002.

TABLE 2

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

	From 15% to 8%		From 11% to 15%	
$C_T = 0.0035$ Initial Width	Total Change	Final Width	Total Change	Final Width
W_i in.	ΔW in.	W_f in.	ΔW in.	W_f 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

	From 15% to 8%		From 11% to 15%	
$C_R = 0.0018$ Initial Width	Total Change	Final Width	Total Change	Final Width
H_i in.	ΔH in.	H_f in.	ΔH in.	H_f in.
12	–0.151	11.849	+0.086	12.086
19.5	–0.246	19.254	+0.140	19.640
24	–0.302	23.698	+0.173	24.173
30	–0.378	29.622	+0.216	30.216

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.

TABLE 4

MOISTURE CONTENT OF WOOD (%) IN EQUILIBRIUM WITH STATED DRY-BULB TEMPERATURE & RH[a]

Temp (°F)	Relative Humidity (%)								
	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	20.4

a. Excerpt from *USDA Wood Handbook: Wood as an Engineering Material*, 2010.

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

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. What dimensional changes would be expected in both the width and depth of the member after it reaches an equilibrium condition?

1. 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

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

$$= 8.75\ [0.0035\ (-7)] = -0.214 \text{ in.}$$

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

2. 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

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

$$= 24\ [0.0018\ (-7)] = -0.302 \text{ in.}$$

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

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[a]	Jobsite Dimensions After Moisture Change
Width	8-3/4"	8-1/2"
Depth	24"	23-3/4"

a. The specified dimension does not include the dimensional tolerance permitted at the time of manufacture in accordance with ANSI A190.1.

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%?

1. In this example, a moisture content increase of 5% has occurred. Predominately "flat" grained lumber is once again assumed, indicating that the use of CT 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

$$\Delta W = 8.5[C_T(M_f - M_i)]$$

$$= 8.5[0.0030(+5)] = +0.128 \text{ in.}$$

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

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

Total Depth Change

$$\Delta H = 24.75[C_R(M_f - M_i)]$$

$$= 24.75[0.0021(+5)] = +0.26 \text{ in.}$$

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

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

CASE 2

COMPARISON OF DIMENSIONAL MEASUREMENTS

	As Specified[a]	Jobsite Dimensions After Moisture Change
Width	8-1/2"	8-5/8"
Depth	24-3/4"	25"

a. The specified dimension does not include the dimensional tolerance permitted at the time of manufacture in accordance with ANSI A190.1.

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 shipping, storage and installation may exceed the dimensional tolerances that are permitted at the time of manufacture and such changes should not be inferred as 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 *APA Construction Guide: Glulam Connection Details*, Form T300, for further information on this topic.

Changes in moisture content may also lead to checking in glulam. Refer to *APA Technical Note: Evaluation of Check Size in Glued Laminated Timber Beams*, Form R465, for further information on this topic.

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