

---

# Determining Allowable Design Values for Wood

Course No: S02-004

Credit: 2 PDH

---

Richard Nolan, P.E.

---



Continuing Education and Development, Inc.  
9 Greyridge Farm Court  
Stony Point, NY 10980

P: (877) 322-5800

F: (877) 322-4774

[info@cedengineering.com](mailto:info@cedengineering.com)

---

# Determining Allowable Design Values for Wood

Using Methods from the  
NATIONAL DESIGN SPECIFICATION  
FOR WOOD CONSTRUCTION

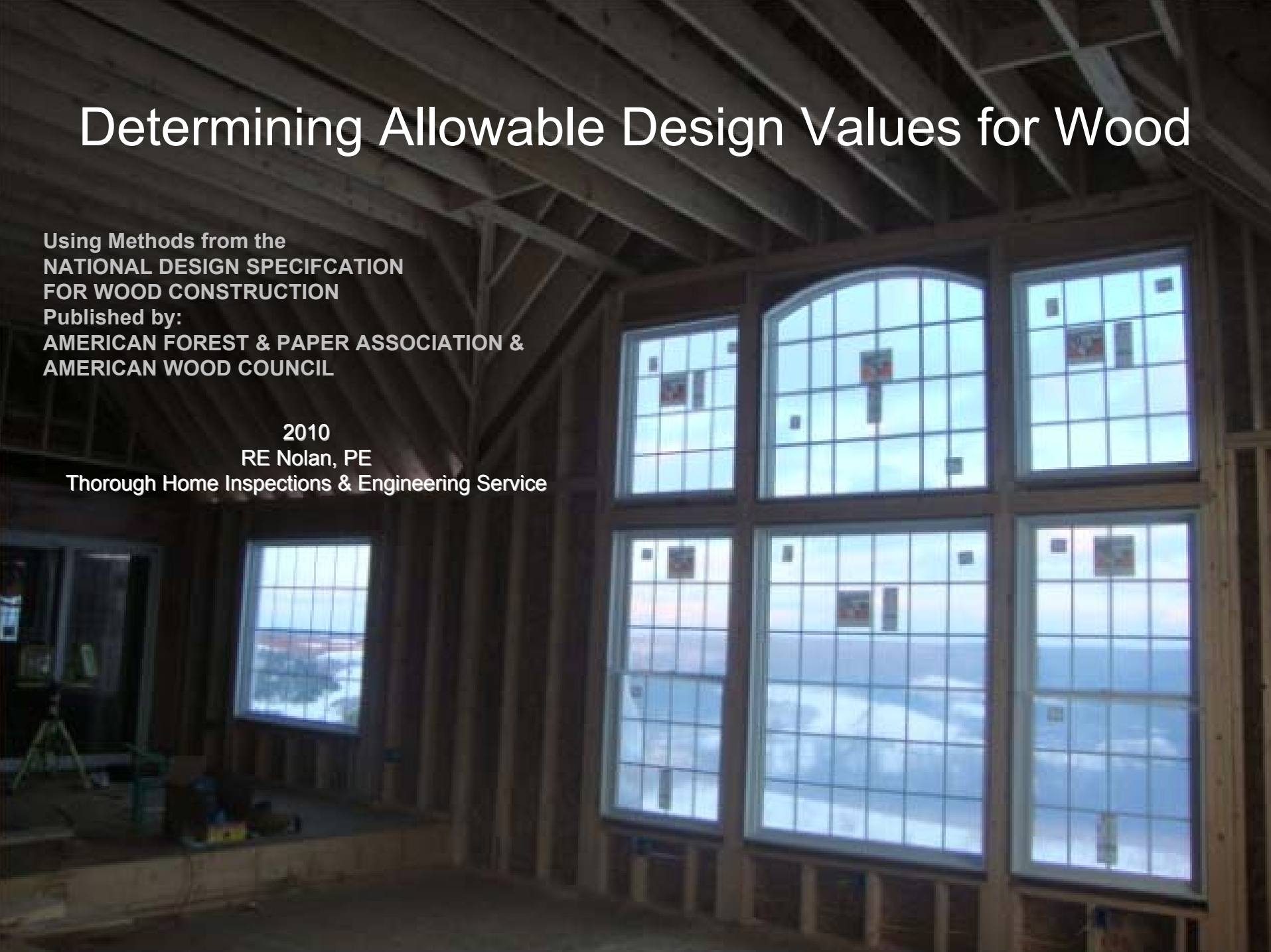
Published by:

AMERICAN FOREST & PAPER ASSOCIATION &  
AMERICAN WOOD COUNCIL

2010

RE Nolan, PE

Thorough Home Inspections & Engineering Service



# I. Introduction

Wood is the most popular building material for residential homes and other smaller buildings. There are many types of wood products on the market used in the construction industry today. Some of the engineered wood products include I-joists, laminated veneer and glued laminated timber. However, the most familiar and well used is still sawn lumber. This course will provide the methodology for determining the allowable design values to use when designing sawn lumber components, such as beams, headers, trusses, floor joists, decking, etc. However, much of the same methodology and adjustment factors are also applicable to the other types of engineered lumber.

This course teaches the methodology used by the National Design Specification (NDS) for Wood Construction published by the American Forest & Paper Association and the American Wood Council. It is recommended, but not essential, that the student obtain a copy of this nationally recognized standard. Owning a copy of the NDS will not only increase the understanding of the course material but also be an invaluable source of information for anyone designing wood structures. The NDS contains reference design values for all types of sawn lumber and other engineered wood products. The copy of the NDS can be purchased from [www.amc.org](http://www.amc.org).

# Lumber Types

- Sawn Lumber
  - Graded
  - Standard Sizes
  - Same visual appearance
  - Spans 6-32'
- Glued Laminated Timber
- I-Joists
- Laminated Veneer
- Etc.



Sawn Lumber



Laminated Veneer



I-Joist



Glued Laminated Timber

# II. Reference Vs. Allowed Design Values

There are a few readily available sources which tabulate reference design values for all types and grades of sawn lumber. Reference (a) and (b) are two good sources of sawn lumber design values. However, it is not appropriate to use the reference design values without first adjusting them for the size of the lumber, service condition, type of loading, and the way the lumber is to be supported. Once the reference design values have been adjusted for these factors, the wood member may be safely designed to handle the applied loads.

The reference design values found in various references are referred to in this course as either reference, tabulated or baseline design values. Once the reference design values have been adjusted for all factors, it is termed the 'allowable' design value. The allowable design value is the value that should be used when sizing/designing wood structural components. This course teaches the methodology for adjusting the reference design values for all significant factors in order to arrive at the allowable design value.

## Remember:

- Reference values are baseline values that you start with.
- These values need to be adjusted (downward or upward) to account for different conditions which are discussed herein.

## Reference:

- a) Nation Design Specification (NDS) for Wood Construction, American Forest & Paper Association and American Wood Council, [www.amc.org](http://www.amc.org)
- b) Timber Construction Manual, American Institute of Timber Construction, [www.aitc-glulam.org](http://www.aitc-glulam.org)

# III. Types of Design Values

Below is a list of the design values which are typically needed to design wood components. The actual design values that will be used when designing a structural wood component will depend on what the wood component is being designed to do. For example, if a beam is being designed, the design values used will typically be bending, shear and compression perpendicular to the grain and modulus (to calculate deflection). Design values for a column would be compression parallel to the grain and modulus. For a chord in a truss under tension, the tension design value would be needed. The next slide will illustrate the definitions of the terms “perpendicular to the grain” and “parallel to the grain”.

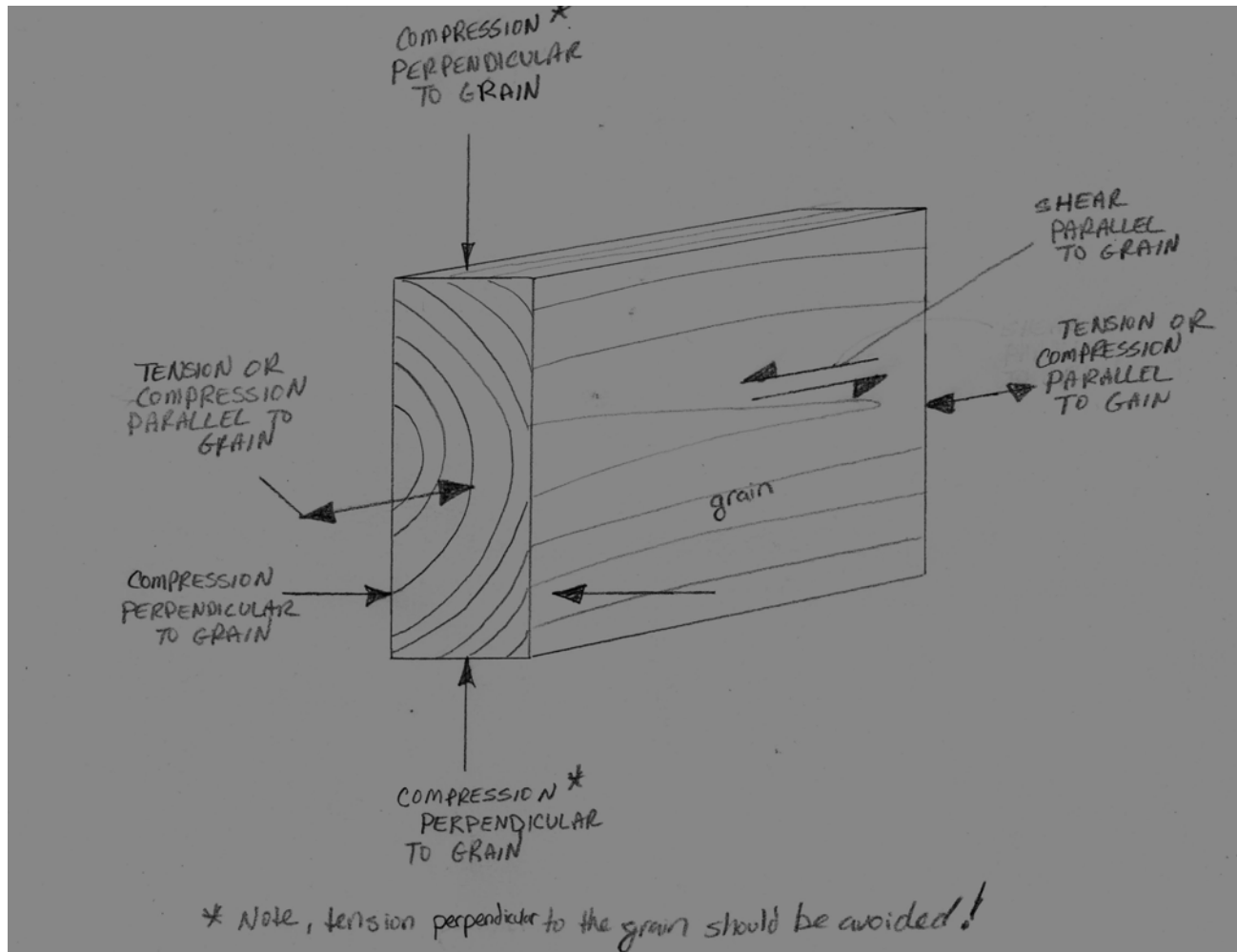
- $F_b$  Bending (typical beam bending)
- $F_t$  Tensions (hanging something from timber, truss member under tension)
- $F_v$  Shear parallel to grain (Beam design)
- $F_{c\perp}$  Compression perpendicular to grain (Beam bearing)
- $F_c$  Compression parallel to grain (header support, truss chord in compression, studs in a wall)
- $E$  modulus of Elasticity (used for displacement calculations or column buckling calculations)

Remember:

$F$  = Reference (Baseline) Design Value

$F'$  = Allowable Design Value after all Adjustments have been made

# IV. Wood Grain



This slide illustrates what is meant by 'parallel' and 'perpendicular' to the grain.

# V. Factors that Affect Reference Design Values

Below is a list of the significant adjustment factors that are applied to the reference design values. Not all of the adjustment factors are used on every type of design value. For example, the bending reference design value is adjusted for all the factors below except for the column stability factor ( $C_P$ ) and the buckling stiffness factor ( $C_T$ ). The following slides will explain and show you how to determine each adjustment.

- Temperature,  $C_t$
- Moisture Content,  $C_M$
- Load duration,  $C_D$
- Beam Stability Factor,  $C_L$
- Size Factor,  $C_F$
- Repetitive Factor,  $C_r$
- Incising Factor,  $C_i$
- Column Stability Factor,  $C_P$
- Buckling Stiffness Factor,  $C_T$
- Bearing Area Factor,  $C_b$

Below is a sample of how to adjust the reference bending value by the factors listed above to arrive at the allowable bending value that would be used to design wood in bending. Note that not all of the factors are used to adjust the bending design value. This formula will be discussed later in further detail.

$$F'_b = F_b C_D C_F C_L C_M C_t C_{fu} C_r C_i$$



# Load Duration Factor ( $C_D$ )

Most reference design values may be increased or decreased to account for the duration of load; that is how long the load acts on a structural wood component in aggregate. Reference design values may be increased for loads acting less than 10 years and decreased for loads acting more than 10 years. Different combination of loads and load duration factors may be used in order to determine the most limiting case.

Frequently Used Load Durations Factors $C_D$ <sup>1</sup>		
Load Duration	$C_D$	Typical Design Loads
Permanent (>10 yrs)	0.9	Dead Load
Ten Years (Normal)	1.0	Occupancy Live Load
Two Months	1.15	Snow Load
Seven Days	1.25	Construction Load (Roof Included)
Ten Minutes	1.6	Wind/Earthquake Load
Impact <sup>2</sup>	2.0	Impact Load

Notes:

1) Load durations factors shall neither apply to the modulus of elasticity  $E$ , nor to compression perpendicular to grain design values,  $F_{C\perp}$ , based on a deformation limit.

2) The impact load duration factor shall neither apply to structural members pressure-treated with water-borne preservatives to the heavy retentions required for 'marine' exposed conditions, nor to structural members pressure-treated with fire retardant chemicals. Also, the impact load duration factor shall not apply to connections.

# Moisture (Wet) Service Factor ( $C_M$ )

The strength of wood increases with a reduction in the moisture content. Reference design values for sawn lumber assume maximum moisture content of 19%. Wood with a moisture content of 19% or less is considered dry. Kiln dried or seasoned wood would be considered dry as long as it hasn't been exposed to weather long enough to cause re-saturation. If there is a reasonable chance that wood will be subject to conditions favorable to increase its moisture content, then the reference design values should be reduced by the factor  $C_M$  as shown in the table below. Examples of situations where wood is susceptible to increase in moisture content would be freshly cut 'green' wood, wood used to construct scaffolding that is exposed to weather, wood used as decking, floor joists suspended over ground susceptible to splashing, wood not protected from weather, wood near potentially leaky locations, etc. If the wood is dry then  $C_M = 1.0$

Moisture Content Factors $C_M^{a,b,e}$								
Strength Property	Fb	Ft	Fc	$F_c^\perp$	Fv	E	Frt	Fg
<b>Sawn Lumber, Visual or Machine Graded</b> <b>Wet conditions of use MC &gt; 19%</b> <b>Dimension lumber (including Southern Pine)</b>	0.85 <sup>a</sup>	1.00	0.80 <sup>b</sup>	0.67	0.97	0.90	--	-- <sup>d</sup>
<b>5 in. X 5 in. and larger</b>	1.00	1.00	0.91	0.67	1.00	1.00	--	-- <sup>d</sup>
<b>Decking</b> <b>Wet conditions if use all</b> <b>Species except Southern Pine<sup>c</sup></b>	0.85	--	--	0.67	--	0.90	--	--

Notes:

a) When  $(F_b)(C_F)$  for dimension lumber of all species  $\leq 1150$  psi,  $C_M = 1.0$ .

b) When  $(F_c)(C_F)$  for dimension lumber of all species except Southern Pine  $\leq 750$  psi,  $C_M = 1.0$ ; when  $F_c$  for visually graded Southern Pine  $\leq 750$  psi,  $C_M = 1.0$ .

c) For Southern Pine, use Reference design values for wet service conditions

# Effect of Size ( $C_F$ )

- Two types of size factors:
  - Flat use (i.e., plank)  $C_{fu}$
  - Adjustment in reference design value related to the depth of the Sawn lumber,  $C_F$
- Design values are affected by size: thickness and width (or depth)
- For sawn lumber used as a plank (laid flat wise),  $C_{fu}$  applies
- Many Southern pine design values are sorted by width and thickness so  $C_F$  need not apply
- Machine graded lumber design values already account for  $C_F$
- The factor is greater than 1.0 for wood less than 12" nominal in depth and less than 1.0 for wood greater than 12" in depth

The typical use of the size factor for sawn lumber is to adjust the reference design value for the depth of the piece. Sawn lumber smaller than 12" depth gets an increase in the reference design values. Use the table on slide 12 to determine the adjustment factor.

# Size Factor $C_F$

Some more notes regarding the size factor:

- Most Southern Pine has Size Factor included in the baseline design values with the exceptions of those listed on slide 13
- Mechanically Graded Lumber, already included
- Included for visually Graded Timbers (5" X 5" and larger) up to 12" in depth. Beyond 12" in depth,  $C_F = (12/d)^{1/9}$
- For decking, except redwood, bending design values are based on 4" thickness. When 2" or 3" thick decking is used, the bending design values,  $F_b$ , for all species except redwood shall be multiplied by the following size factors:  $C_F = 1.10$  for 2" thick and  $C_F = 1.04$  for 3" thick.

# SIZE FACTORS, $C_F$

SIZE FACTORS, $C_F$ - for Sawn Lumber not including Southern Pine					
		$F_b$		$F_t$	$F_c$
Grades	Width/Depth	Thickness			
		2" & 3"	4"		
Select Structural, No.1 & Btr. No. 1, No. 2, No. 3	2",3"&4"	1.5	1.5	1.5	1.15
	5"	1.4	1.4	1.4	1.1
	6"	1.3	1.3	1.3	1.1
	8"	1.2	1.3	1.2	1.05
	10"	1.1	1.2	1.1	1.0
	12"	1.0	1.1	1.0	1.0
	14" & Wider	0.9	1.0	0.9	0.9
Stud	2", 3" & 4"	1.1	1.1	1.1	1.05
	5" & 6"	1.0	1.0	1.0	1.0
Construction & Standard	2", 3, & 4"	1.0	1.0	1.0	1.0
Utility	4"	1.0	1.0	1.0	1.0
	2" & 3"	0.4	--	0.4	0.6

# SIZE FACTORS, $C_F$ -continued, Southern Pine

Appropriate size adjustments factors have already been incorporated in the reference design values for most thicknesses of Southern Pine and Mixed Southern Pine dimension lumber (i.e.,  $C_F = 1.0$ ). For dimension lumber 4" thick, 8" and wider (all grades except Dense Structural 86, Dense Structural 72 and Dense Structural 65), reference bending design values,  $F_b$ , shall be permitted to be multiplied by the size factor  $C_F = 1.1$ . For dimension lumber wider than 12" (all grades except Dense Structural 86, Dense Structural 72 and Dense Structural 65), reference bending, tension and compression parallel to grain design values for 12" wide lumber shall be multiplied by the size factor,  $C_F=0.9$ . When the depth,  $d$ , of Dense Structural 86, Dense Structural 72 or Dense Structural 65 dimension lumber exceeds 12", the reference bending design value,  $F_b$ , shall be multiplied by the following size factor:

$$C_F = \left( \frac{12}{d} \right)^{1/9}$$

# Flat Use Factor ( $C_{fu}$ )

If a sawn lumber is to be used as a plank (i.e., loaded on the wide face) the reference design values must be adjusted by the flat use factor as shown in the tables below. First correct for the size factor, then adjust for the flat use factor. The flat use factor is not applicable to decking since it is already accounted for in baseline values.

Flat Use Factor, $C_{fu}$ for Visually and Machine Graded Sawn Lumber (including Southern Pine)		
Width (depth)	Thickness (breadth)	
	2" & 3"	4"
2" & 3"	1.0	--
4"	1.1	1.0
5"	1.1	1.05
6"	1.15	1.05
8"	1.15	1.05
10" & Wider	1.2	1.1

Size Factor for 5" x 5" and Larger Timbers			
Grade	$F_b$	$E$ & $E_{min}$	Other Properties
Select Structural	0.86	1.00	1.00
No. 1	0.76	0.90	1.00
No. 2	1.00	1.00	1.00

# Temperature Factor, $C_t$

The temperature factor is not applicable for wood used under 100°F and occasionally heated up to 150°F. Wood increases in strength when cooled and decreases when heated. Prolonged temperatures above 150°F may result in permanent loss of strength. For sustained elevated temperatures up to 150°F, the temperature factor must be applied.

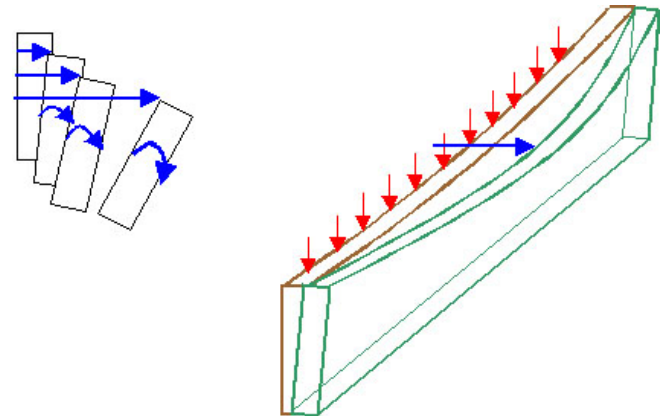
TEMPERATURE FACTORS, $C_t$				
Design Values	In Service Moisture Conditions	$C_t$ $T \leq 100^\circ\text{F}$	$C_t$ $100^\circ\text{F} < T \leq 125^\circ\text{F}$	$C_t$ $125^\circ\text{F} < T \leq 150^\circ\text{F}$
$F_t, E$	Wet or Dry	1.0	0.9	0.9
$F_b, F_v, F_c$ and $F_{c\perp}$	Dry	1.0	0.8	0.7
$F_b, F_v, F_c$ and $F_{c\perp}$	Wet	1.0	0.7	0.5



# Beam Stability Factor, $C_L$

The stability of the beam refers to ability of the beam not to twist, warp, rotate or otherwise displace under load. For example, if a long, deep beam was supported only at the ends with no provision to restrain the beam against rotation or other lateral displacement, the beam could buckle, shift, rotate or laterally move such that the beam might fail or the load would fall off. One sure way for the beam stability factor to be equal to 1.0 is to fix both ends against rotation and fix both the tension and compression flange along its entire length against lateral displacement. This extreme beam fixation cannot always be achieved. For beam with certain dimensions and spans with unrestrained lateral sections, the reference bending design value needs to be adjusted lower. The bullets below along with the table on the next slide, list all of the conditions in which the beam stability factor is equal to 1.0. If the beam does not meet these conditions, the beam stability factor is less than 1.0. The calculation of the beam stability factor (if it is less than 1.0) is beyond the scope of this course but can be determined using the methodology discussed in the NDSWC.

- $C_L$  is used to prevent buckling of compression or tension side
- $C_L$  is applied to bending stress only
- If depth of beam is equal or less than the width then  $C_L$  is 1.0 (e.g., planks)
- If the beam is supported at the ends against rotation and along the entire compression flange against lateral displacement,  $C_L$  is 1.0
- $C_L$  is accumulative with  $C_F$  for sawn lumber
- $C_L$  can be taken as 1.0 if the rules indicated on Table on the next slide are followed



# Beam Stability Factor, $C_L$ -continued

## APPROXIMATE LATERAL STABILITY RULES FOR SAWN BEAMS

Depth-Breadth Ratio	Rule
2:1 or less	No lateral bracing is required
3:1 to 4:1	The ends shall be held in position, as by full-depth solid blocking, bridging, hangers, nailing or bolting to other framing members, or other acceptable means
5:1	One edge shall be held in line for its entire length
6:1	Bridging, full-depth solid blocking, or cross bracing shall be installed at intervals not exceeding 8-ft unless both edges are held in line or unless the compression edge of the member is supported throughout its length to prevent lateral displacement, by adequate sheathing or subflooring, and the ends at points of bearing have lateral stability to prevent rotation
7:1	Both edges shall be held in line for their entire length

# Beam Stability Factor, $C_L$ -continued

- If conditions of the table on the previous slide are not met,  $C_L$  is less than 1.0. Determining the value of  $C_L$  for unsupported lengths and different loading combinations is beyond the scope of this lecture.

# Repetitive Member Factor, $C_r$

The reference bending design value may be increased for repetitive members as described below:

- Must have at least 3 members not spaced more than 24" apart
- Members must be used as joists, truss chords, rafters, studs, planks and decking or similar members in contact
- Members must be joined by floor, roof or other load distributing elements capable of supporting the design load
- Not used with decking since it is already considered
- Factor is 1.15



# Column Stability Factor, $C_p$

The column stability factor is used when designing columns and is applied to the reference compression parallel to the grain design value. If the column is supported throughout its length to prevent lateral displacement in all directions, then  $C_p = 1.0$ . Otherwise,  $C_p$  is a function of the column's dimensions, design value in compression and modulus of elasticity, and is determined by methods beyond the scope of this course.

# Buckling Stiffness Factor, $C_T$

The buckling stiffness factor is only used with 2" X 4" (or smaller) sawn compression chords in wood trusses sheathed with 3/8 in. or thicker plywood when they are subject to combined bending and compressions loads and used under dry conditions. The plywood must be applied with good nailing practice. The buckling stiffness factor is applied to the modulus of elasticity used in column stability calculations for the sawn 2 X 4 or smaller compression chords. The determination of the buckling stiffness factor is beyond scope of this course. However, the buckling stiffness factor is never less than 1.0, therefore it would be conservative to use 1.0.

# Bearing Area Factor, $C_b$

For bearing less than 6" in length and not nearer than 3" to the end of the member (e.g., intermediate support), the maximum design load per square inch is obtained by multiplying the reference design value in compression perpendicular to grain by the bearing area factor,  $C_b$  via the following equation:



Where:

$l_b$  = the length in bearing parallel to the grain of the wood (in.)

Can also use table below

$$C_b = \frac{l_b + 0.375}{l_b}$$

BEARING AREA FACTOR, $C_b$							
Length of Bearing, in.	½	4	1 ½	2	3	4	6 or more
$C_b$	1.75	1.38	1.25	1.19	1.13	1.10	1.00

# Incising Factor

Incising factor accounts for notches cut into wood which help in the application of preservative chemicals. Not all pressure treated wood is incised. The incising factor is applicable if the wood is incised parallel to grain a maximum depth of 0.4", a maximum length of 3/8" and for a density of incisions up to 1100/ft<sup>2</sup>. If these limits are exceeded, the incising factor shall be determined by test or by calculation using reduced section properties.

Incising Factors, $C_i$	
Design Value	$C_i$
$E, E_{min}$	0.95
$F_b, F_t, F_c, F_v$	0.80
$F_{c\perp}$	1.00



# Other Adjustment Factors

The preceding discussion covers the adjustment factors usually applicable to sawn lumber design. For special cases, such as poles and piles, other adjustment factors may be necessary.

# VI. Adjusting the Reference Design Values

The next series of slides show how to adjust each design value (e.g., bending, shear, compression, tension & modulus) for the factors discussed above.

# APPLICATION OF ADJUSTMENT FACTORS TO BENDING STRESS

$$F'_b = F_b C_D C_F C_L C_M C_t C_{fu} C_r C_i$$

# APPLICATION OF ADJUSTMENT FACTORS TO TENSION PARALLEL TO GRAIN

$$F'_t = F_t C_D C_M C_t C_F C_i$$

# APPLICATION OF ADJUSTMENT FACTORS TO COMPRESSION PARALLEL TO GRAIN

$$F'_c = F_c C_D C_P C_M C_F C_t C_i$$

# APPLICATION OF ADJUSTMENT FACTORS TO COMPRESSION PERPENDICULAR TO GRAIN

$$F'_{c\perp} = F_{c\perp} C_M C_t C_i C_b$$

# APPLICATION OF ADJUSTMENT FACTORS TO SHEAR PARALLEL TO GRAIN

$$F'_v = F_v C_D C_M C_t C_i$$

# APPLICATION OF ADJUSTMENT FACTORS TO MODULUS OF ELASTICITY

$$E' = EC_M C_t C_i$$



# VII. Examples

- Example 1: Determination of Allowable Bending Design Value for a Beam
- Example 2: Sizing a 6-foot Header
- Example 3: Determining Number of Header Supports

# Example 1 – Determination of Allowable Bending Design Value for a Beam

A 2" X 10" X 10' Spruce Pine Fir is to be used as a beam for a uniformly distributed load. The beam is laterally supported along its length and at each end. It is used in dry conditions and normal temperatures to support a snow load. Determine the allowable design value in terms of  $F'_b$  (example  $F'_b = 1.10F_b$ ).

Start with:  $F'_b = F_b C_D C_F C_L C_M C_t C_{fu} C_r C_i$

For bending, the following adjustment factors apply to sawn lumber:

$C_D$	The beam is designed to support a snow load, which is considered to act less than 2 months in aggregate, use chart on slide 8.	1.15
$C_F$	From the table on slide 12 (for a beam with 10" width and 2" in thickness).	1.1
$C_L$	Since beam is laterally supported along its length and at each end, $C_L = 1.0$	1.0
$C_M$	It is indicated that the beam is used in dry conditions, such that there is no reduction due to moisture	1.0
$C_i$	The beam is not pressure-treated and, therefore, is not incised so the Incising Factor is 1.0	1.0
$C_t$	It is indicated that the beam is used under normal temperatures	1.0
$C_r$	No increase via the Repetitive Factor applies since there is only one beam	1.0
$C_{fu}$	The beam is not used in the flat-wise orientation (not used as a plank)	1.0

$$F'_b = 1.265F_b$$

You can get an increase in the baseline allowable stress of almost 27% under these conditions.

# Example 2 – Sizing a 6-foot Header

Plans were submitted which show two, 2" X 12" headers over a bay window. The header spans 6 feet. Above the header is a roof in a snow area, attic storage, and a 2<sup>nd</sup> floor. The ends of the header are nailed to the adjacent studs to prevent rotation. Second floor joists are nailed along the top of the header so that it is laterally supported along the compression flange. The loading which includes beam weight was determined to be 1,500 PLF which results in a maximum bending stress at the center of the header of 1,286 psi. Determine if the beam is sized correctly. Determine the number of 2" X 6" header supports necessary at either side of the beam. Use the baseline design values for Spruce-Pine-Fir (SPF) #2 taken from Reference (a).

The baseline design value for bending stress for SPF #2 is 875 psi, allowable shear is 135 psi, the allowable bearing perpendicular to the grain is 425 psi, the allowable compression parallel to the grain is 1,150 psi and the allowable deflection is  $\text{del}/360$ . The modulus is 1,400,000 psi.



# Example 2 – continued, Bending

Acceptability in bending will be checked first, start with:  $F'_b = F_b C_D C_F C_L C_M C_t C_{fu} C_r C_i$

$C_D$	The beam is designed to support a snow load, which is considered to act less than 2 months in aggregate, use chart on slide 8.	1.15
$C_F$	From the table on slide 12 (for a beam with 12" width and 2" in thickness).	1.0
$C_L$	Since beam is laterally supported along its length and at each end, $CL = 1.0$ .	1.0
$C_M$	It is indicated that the beam is used in wet conditions, such that there is no reduction due to moisture	1.0
$C_r$	No increase via the Repetitive Factor applies to header beams and is therefore equal to 1.0	1.0
$C_t$	It is indicated that the beam is used under normal temperatures	1.0
$C_i$	The beam is not pressure-treated and, therefore, is not incised so the Incising Factor is 1.0	1.0
$C_{fu}$	The beam is not used in the flat-wise orientation (not used as a plank)	1.0

$$F'_b = 1.15 F_b$$

$$F'_b = 1.15(875 \text{ psi}) = 1006 \text{ psi}$$

Since the actual bending of stress of 1,286 psi is more than the adjusted allowable (1,006 psi) the beam is not acceptable in bending so another 2" X 12" must be added. Adding another 2" x 12" for a total of (3) 2" x 12" header beam lowers the bending stress to 860 psi which is lower than the allowed 1,006 psi and, therefore, acceptable so far as we have determined. Next the shear stress in the beam will be calculated. Alternatively, a higher grade of Select Structural could be tried.

# Example 2 – continued, Shear

The allowable shear parallel to the grain is:  $F'_v = F_v C_D C_M C_t C_i$

$C_D$	The beam is designed to support a snow load, which is considered to act less than 2 months in aggregate, use chart on slide 8.	1.15
$C_M$	It is assumed that the beam is used in dry conditions, such that there is no reduction due to moisture	1.0
$C_t$	It is indicated that the beam is used under normal temperatures	1.0
$C_i$	The beam is not pressure-treated and, therefore, is not incised so the Incising Factor is 1.0	1.0

$$F'_v = 1.15 F_v = 1.15(135 \text{ psi}) = 155 \text{ psi}$$

# Example 2 – continued, Shear

The total load on the header is the applied load multiplied by its length, 1,500 PLF X 6 ft = 9,000 lb. Each side of the beam must react 4,500 lb; since the header is made up of three beams, each beam end reacts 4500 lb./3 = 1,500 lb. Therefore, 1,500 lbs. is used as the shear load. The usual way to determine shear stress for a rectangular beam is:

$$f_v = \frac{3V}{2bd}$$

Where V, is the vertical shear force (1,500 lbf), b is the width of the beam (1.5") and d is the depth of the beam (11.25").

Therefore, the shear stress is  $(3*1500)/(2*1.5*11.25) = 133$  psi. Since 133 psi shear stress in the header parallel to the grain is less than the allowable shear stress of 155 psi, which was calculated on the previous slide, the header beam is acceptable for use so far as we have determined.

# Example 2 – continued, Compression

The header beam experiences compressive stresses at the ends where it is supported by 2" X 6" lumber. As determined earlier, each side of the individual beams that make up the header must react 1,500 lb.

$$\text{USE: } F'_{c\perp} = F_{c\perp} C_M C_t C_i C_b$$

The header will be used in a dry location under normal temperatures so there is no adjustment for  $C_M$  or  $C_t$ . Also, the header is not pressure-treated so there is no incising so that  $C_i$  is equal to 1.0. Finally, since the end bearing is being checked,  $C_b$  does not apply and is equal to 1.0. Therefore there is no adjustment to the baseline design value of compression perpendicular to the grain of 425 psi. The required bearing area is calculated below based on the header reaction load and allowable compressive stress.

$$A = \frac{1500lb}{425psi} = 3.53in^2 \quad \text{Required bearing area.}$$

Since the width of the header beam (one of the three beams) is fixed at 1.5 in, the required seat length will be  $3.53in^2 / 1.5in = 2.35$  in. Since the 2" X 6" header supports are 1.5 in. wide, two will be required. The total bearing area will then be 1.5 in X 3 in (width of 2 supports) =  $4.5 in^2$ . And the compressive stress in the end of the header will be  $1500 lb. / 4.5 in^2 = 333$  psi which of course is less than the 425 psi allowed. This calculation is used in conjunction with Example 3 to determine the number of header supports required.

# Example 2 – continued, Deflection

The formula to calculate deflection is:  $\delta = \frac{5WL^4}{384EI}$

Where: W=1,500 PLF, L = 6', E = 1,400,000 psi, I = 178 in<sup>4</sup> (for one 2" x 12")

Determine Modulus:  $E' = EC_M C_t C_i$

Since the header is used in a dry location under normal temperatures and since it is not incised, there is no adjustment to the modulus of elasticity. Calculation of the deflection yields 0.18 inches at the center. This results in an L/del (6' \* 12 / 0.18) of 400 which is greater than the required 360 and the header is now considered acceptable for use.



## Example 3, Determining Number of Header Supports

Start with the compression parallel to grain formula:  $F'_c = F_c C_D C_P C_M C_F C_t C_i$

Note that this section only checks that the compression parallel to the grain in the header support is acceptable (i.e., below the adjusted reference compression design value). The ability of the header support not to buckle under the load (column analysis) has not been carried out and should be performed in a separate calculation not addressed here.

$C_D$	The header supports will support a snow load, which is considered to act less than 2 months in aggregate, use chart on slide 8.	1.15
$C_F$	From the table on slide 12 (for a wood with 6" width and 2" in thickness).	1.3
$C_P$	For this problem, the header support columns are assumed to be on both edges against lateral displacement in all directions so that, $CL = 1.0$ .	1.0
$C_M$	It is assumed that the supports are used in dry conditions, such that there is no reduction due to moisture	1.0
$C_t$	It is indicated that the beam is used under normal temperatures	1.0
$C_i$	The beam is not pressure-treated and, therefore, is not incised so the Incising Factor is 1.0	1.0

$$F'_c = (1.15)(1.3)(1.0)(1.0)(1.0)(1.0)1,150 \text{ psi} = 1719 \text{ psi}$$

As determined in a previous slide, each side of the beam must react 1,500 lb. The seat area of the header beam is the thickness of the header (1.5 in.) times the seat length (2 – 2" x 6"), 1.5 in X 3.0 in = 4.50 in<sup>2</sup>. Therefore, the compression stress at the end of the header where it rests on the support is 1,500 lb / 4.50 in<sup>2</sup> = 333 psi. Since 333 psi compression on the end grain is less than the allowable 1719 psi, the supports are acceptable for use. This calculation confirms that two header supports are sufficient to support the header beam.

# VIII. Summary

- The necessary types of design values needed to design structural wood components were presented (e.g.,  $F_b$ ,  $F_c$ ,  $F_{c\perp}$ ,  $F_v$ ,  $F_t$ ,  $E$ )
- The significant Adjustment Factors needed to adjust the reference design values were presented (e.g.,  $C_D$ ,  $C_M$ ,  $C_t$ ,  $C_C$ ,  $C_F$ ,  $C_r$ ,  $C_i$ ,  $C_P$ ,  $C_T$ ,  $C_b$ )
- How to determine all the value of the adjustment factors were presented except those for  $C_T$ ,  $C_P$ , and  $C_L$  which were beyond the scope of the course.
- Circumstances when  $C_T$ ,  $C_P$  and  $C_L$  are equal to unity were explained
- How to determine  $C_T$ ,  $C_P$  and  $C_L$  when they do not equal 1.0 can be found in reference (a) or (b).
- Reference Design Values need to be adjusted by all the applicable adjustment factors in order to obtain the correct allowable design values
- Example problems were provided which utilized the information learned

Reference:

- a) Nation Design Specification (NDS) for Wood Construction, American Forest & Paper Association and American Wood Council, [www.amc.org](http://www.amc.org)
- b) Timber Construction Manual, American Institute of Timber Construction, [www.aitc-glulam.org](http://www.aitc-glulam.org)