Introduction to Wood: Structural Gravity Framing Design

January 14, 2025

Presented by

Anthony Harvey, WoodWorks

Erin Kinder, WoodWorks

Ivy Residences at Health Village / Photo Charlan Brock Architects

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Course Description

This presentation will provide an introductory review of structural wood design for vertical (gravity) loads, including bending, shear, deflection, vibration, tension, compression, and connections. Referenced codes and standards, design properties, design examples and detailing best practices will be covered.

Learning Objectives

1. Review wood's role and allowable uses as a structural gravity framing material under current building codes.
2. Discuss design considerations specific to wood wall, floor and roof framing that resists gravity forces in non-residential and multi-family buildings.
3. Identify code-compliant connection design processes for dowel-type fasteners in wood members.
4. Explore the variety of options for wood as a gravity force-resisting system and discuss how to efficiently utilize and design each.

Outline

- Design Basis & Notation
- Bending Design
- Shear Design
- Deflection
- Compression
- Bearing
- Other Axial
- Connections

Outline

- **Design Basis & Notation**
- Bending Design
- Shear Design
- Deflection
- Compression
- Bearing
- Other Axial
- Connections

Structural Wood Design

Structural building design loads:

» Gravity

» Lateral

Gravity loads:

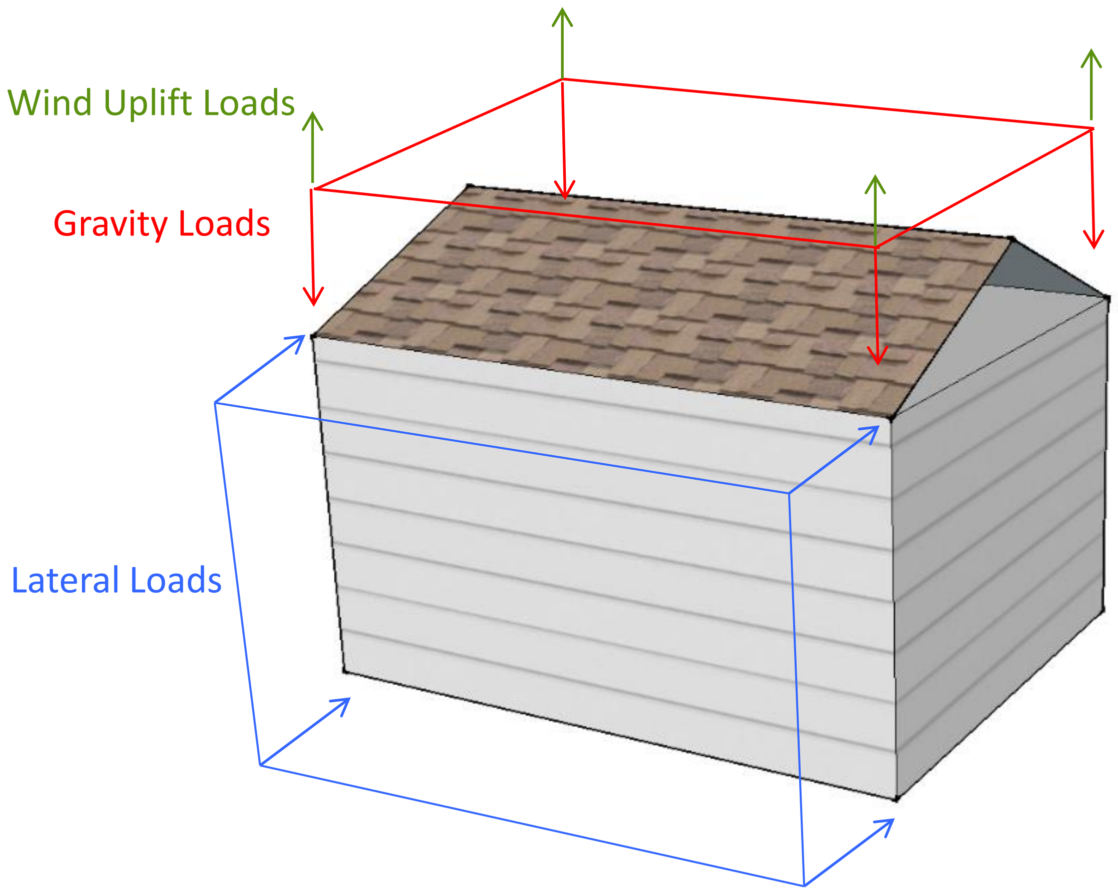
» Dead

» Live

» Snow

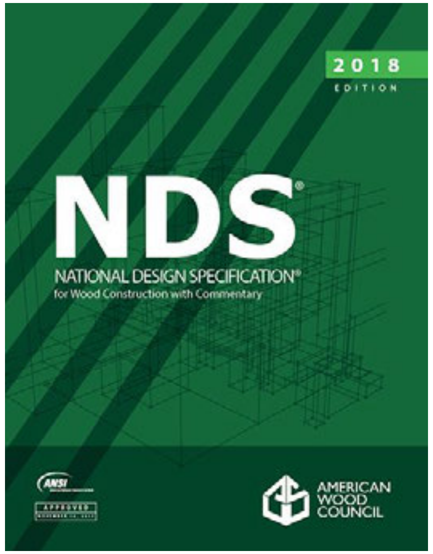
» Rain

» Ice

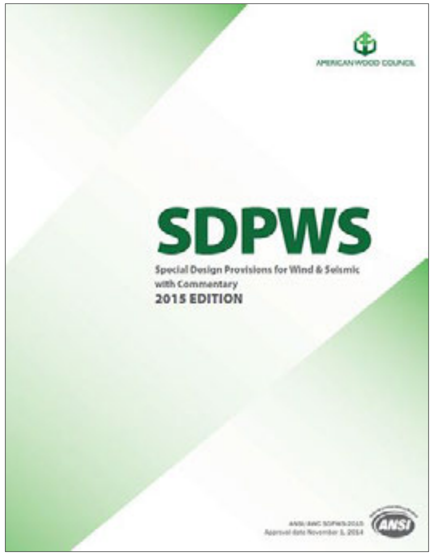


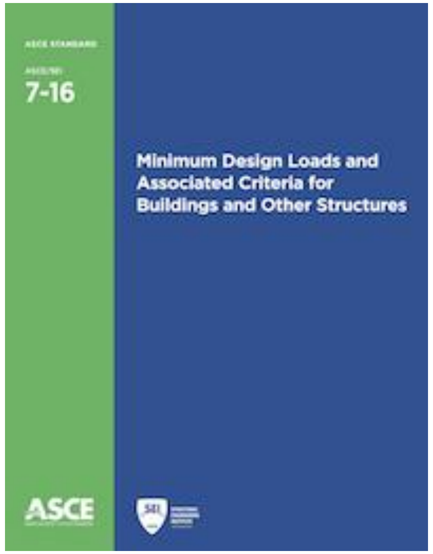
2018 IBC

2018 NDS



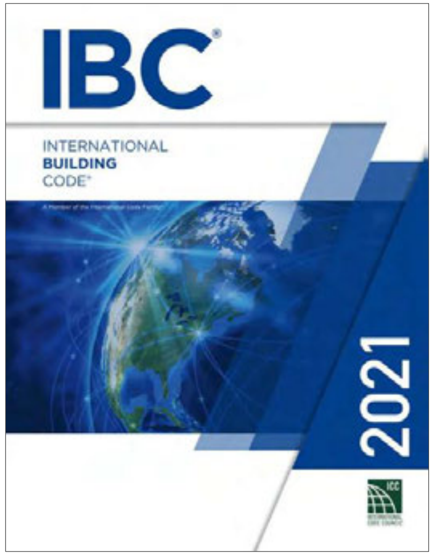
2015 SDPWS



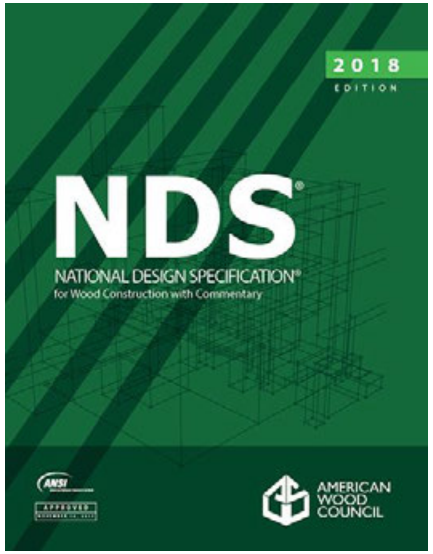


ASCE 7-16
(2016)

2021 IBC



2018 NDS



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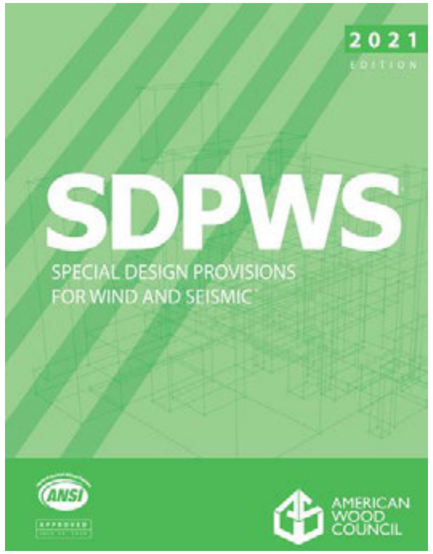
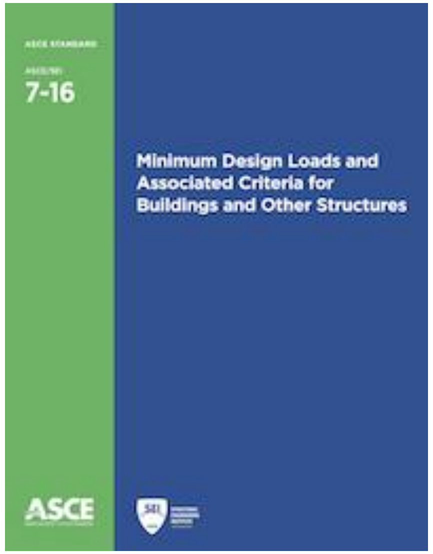
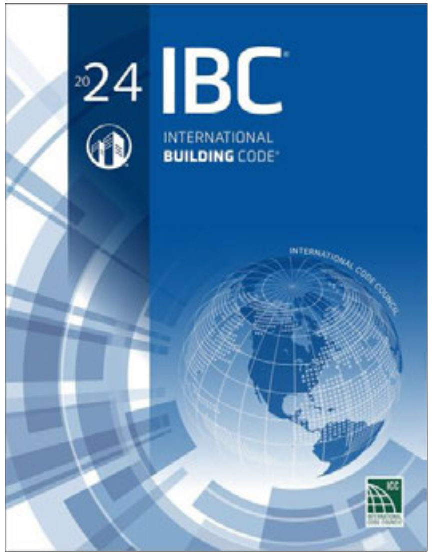


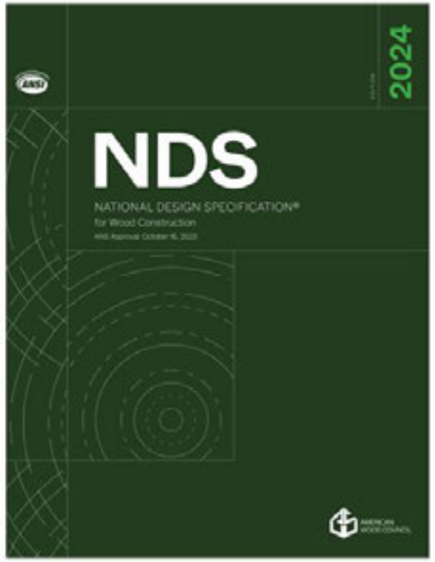


ASCE 7-16
(2016)

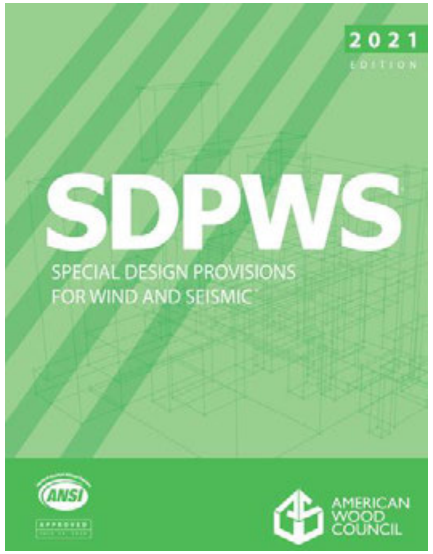
2024 IBC

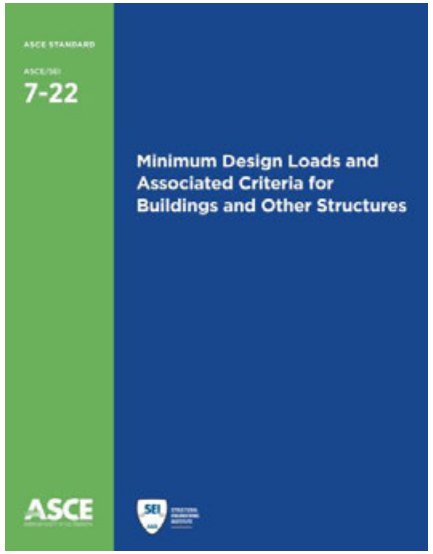


2024 NDS



2021 SDPWS





ASCE 7-22
(2022)

Structural Wood Design

ASD vs. LRFD

- NDS Section 1.4:
  - Designs shall be made according to the provisions for Allowable Stress Design (ASD) or Load and Resistance Factor Design (LRFD)

ASD

- Allowable Stress Design
- Based on allowable stresses and nominal (unfactored) loads

LRFD

- Load and Resistance Factor Design
- Based on nominal strengths and factored loads

Structural Wood Design

Nomenclature:

- **Demand:** Load, stresses, etc. applied to a member or structure
- **Capacity:** Resistance a member, connection, or system is capable of withstanding before a limit state is reached
- **Limit State:** Defined point at which a member, connection, or system can no longer perform its intended function
  - Service limit state
  - Strength limit state
- **ASD (Allowable Stress Design):** Design methodology comparing unfactored loads to scaled down capacities
- **LRFD (Load and Resistance Factor Design):** Design methodology comparing scaled up loads to scaled down capacities

$$\text{Demand} \leq \text{Capacity}$$

Structural Wood Design

ASD Notation:

Demand $$f_t \leq F'_t$$ Adjusted Capacity

Stress type

Structural Wood Design

LRFD Notation:

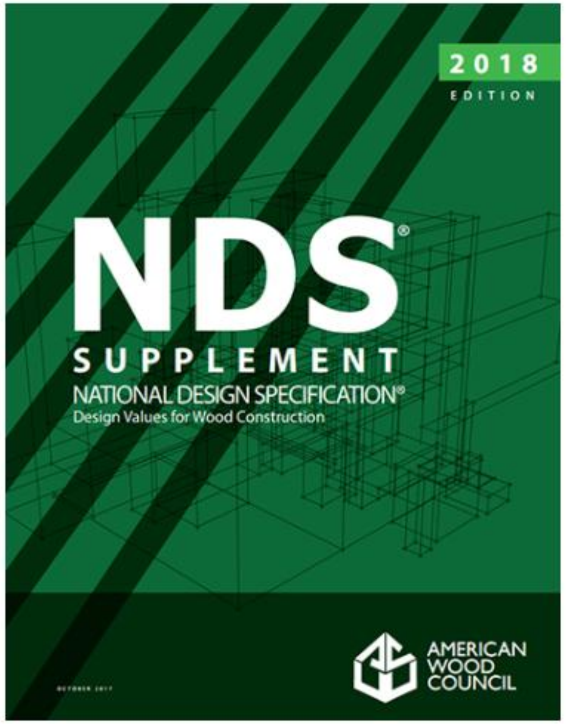
Demand $$T_u \leq \phi T_n$$ Adjusted Capacity

Stress type

Structural Wood Design: Capacity

Reference Design Values:

» Mechanical properties associated with commercial grades of wood



Reference Design Values	
F_b	Bending
F_t	Tension parallel to grain
F_v	Shear parallel to grain
$F_{c\perp}$	Compression perpendicular to grain
F_c	Compression parallel to grain
E, E_{min}	Modulus of elasticity

Structural Wood Design: Capacity

Reference Design Values:

Species

AWC NDS Supplement, Table 4A

Species and commercial grade	Size classification	Design values in pounds per square inch (psi)							Specific Gravity[4]	Grading Rules Agency
		Bending	Tension parallel to grain	Shear parallel to grain	Compression perpendicular to grain	Compression parallel to grain	Modulus of Elasticity			
		F_b	F_t	F_v	$F_{c\perp}$	F_c	E	E_{min}	G	
DOUGLAS FIR-LARCH										
Select Structural	2" & wider	1,500	1,000	180	625	1,700	1,900,000	690,000	0.50	WCLIB WWPA
No. 1 & Btr		1,200	800	180	625	1,550	1,800,000	660,000		
No. 1		1,000	675	180	625	1,500	1,700,000	620,000		
No. 2		900	575	180	625	1,350	1,600,000	580,000		
No. 3		525	325	180	625	775	1,400,000	510,000		
Stud	2" & wider	700	450	180	625	850	1,400,000	510,000		
Construction	2" - 4" wide	1,000	650	180	625	1,650	1,500,000	550,000		
Standard		575	375	180	625	1,400	1,400,000	510,000		
Utility		275	175	180	625	900	1,300,000	470,000		

AWC NDS Supplement, 2018

Grades

Structural Wood Design: Capacity

Adjustment Factors:

Table 4.3.1 Applicability of Adjustment Factors for Sawn Lumber

		ASD only	ASD and LRFD										LRFD only		
		Load Duration Factor	Wet Service Factor	Temperature Factor	Beam Stability Factor	Size Factor	Flat Use Factor	Incising Factor	Repetitive Member Factor	Column Stability Factor	Buckling Stiffness Factor	Bearing Area Factor	Format Conversion Factor	Resistance Factor	Time Effect Factor
													K_F	ϕ	
$F_b' = F_b$	x	C_D	C_M	C_t	C_L	C_F	C_{fu}	C_i	C_r	-	-	-	2.54	0.85	λ
$F_t' = F_t$	x	C_D	C_M	C_t	-	C_F	-	C_i	-	-	-	-	2.70	0.80	λ
$F_v' = F_v$	x	C_D	C_M	C_t	-	-	-	C_i	-	-	-	-	2.88	0.75	λ
$F_c' = F_c$	x	C_D	C_M	C_t	-	C_F	-	C_i	-	C_P	-	-	2.40	0.90	λ
$F_{c\perp}' = F_{c\perp}$	x	-	C_M	C_t	-	-	-	C_i	-	-	-	C_b	1.67	0.90	-
$E' = E$	x	-	C_M	C_t	-	-	-	C_i	-	-	-	-	-	-	-
$E_{min}' = E_{min}$	x	-	C_M	C_t	-	-	-	C_i	-	-	C_T	-	1.76	0.85	-

AWC NDS, 2018

Structural Wood Design: Capacity

Adjustment Factors:

Table 4.3.1 Applicability of Adjustment Factors for Sawn Lumber

		ASD only	ASD and LRFD										LRFD only		
		Load Duration Factor	Wet Service Factor	Temperature Factor	Beam Stability Factor	Size Factor	Flat Use Factor	Incising Factor	Repetitive Member Factor	Column Stability Factor	Buckling Stiffness Factor	Bearing Area Factor	Format Conversion Factor K_F	Resistance Factor ϕ	Time Effect Factor
$E' = E$	x	-	C_M	C_t	-	-	-	C_i	-	-	-	-	-	-	-
$E_{min}' = E_{min}$	x	-	C_M	C_t	-	-	-	C_i	-	-	C_T	-	1.76	0.85	-

AWC NDS, 2018

Structural Wood Design: Capacity

Adjusted Design Values:

» $F'_t = F_t * (adjustment\ factors)$

Table 4.3.1 Applicability of Adjustment Factors for Sawn Lumber

		ASD only	ASD and LRFD										LRFD only		
		Load Duration Factor	Wet Service Factor	Temperature Factor	Beam Stability Factor	Size Factor	Flat Use Factor	Incising Factor	Repetitive Member Factor	Column Stability Factor	Buckling Stiffness Factor	Bearing Area Factor	Format Conversion Factor K_F	Resistance Factor ϕ	Time Effect Factor
$F_t' = F_t$	x	C_D	C_M	C_t	-	C_F	-	C_i	-	-	-	-	2.70	0.80	λ

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ASD

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

LRFD

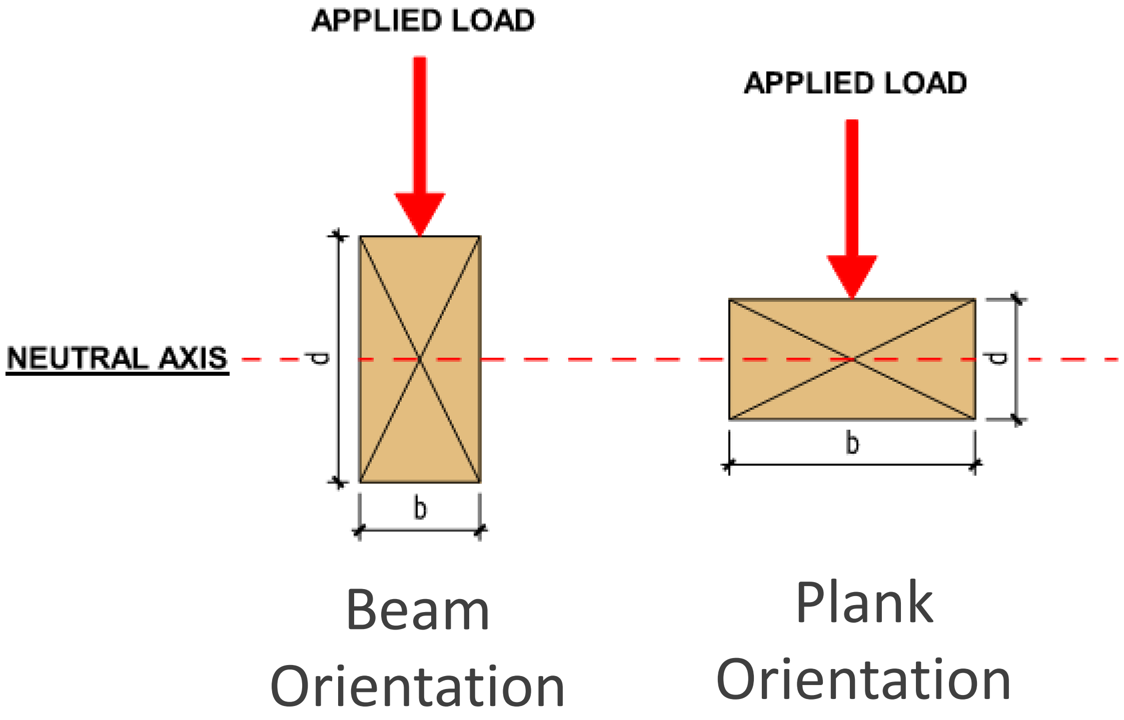
$$F'_t = F_t * C_M * C_t * C_F * C_i * K_F * \emptyset * \lambda$$

$$\rightarrow \emptyset T_n = F'_t * A$$

Wood Design: Member Properties

Section properties:

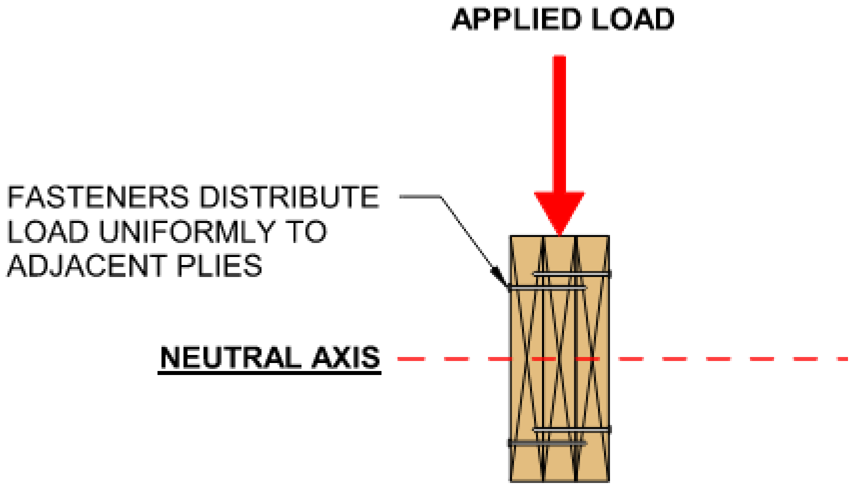
- Cross Sectional Area:
  - $A = b * d$
  - Shear, compression, tension
- Moment of Inertia:
  - $I = \frac{b * d^3}{12}$
  - Bending, deflection, vibration
- Elastic Section Modulus:
  - $S = \frac{I}{c} = \frac{b * d^2}{6}$
  - Bending



Wood Design: Member Properties

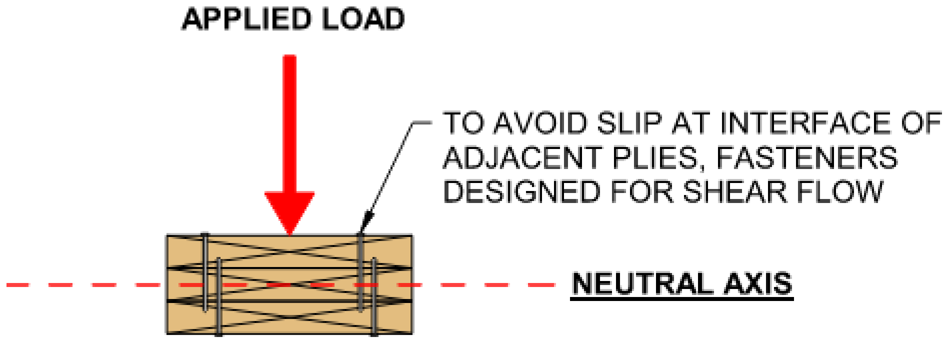
Multi-ply members:

» Ply interfaces **parallel** to direction of load



» Ply interfaces **perpendicular** to direction of load

» Shear flow: $q = \frac{V*Q}{I}, Q = \frac{b*h^2}{8}$



Outline

» Design Basis & Notation
» **Bending Design**
» Shear Design
» Deflection
» Compression
» Bearing
» Other Axial
» Connections

Wood Design: Bending

3.3.1 Strength in Bending

The actual bending stress or moment shall not exceed the adjusted bending design value.

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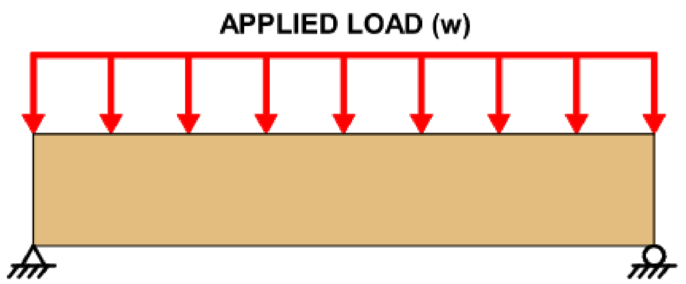
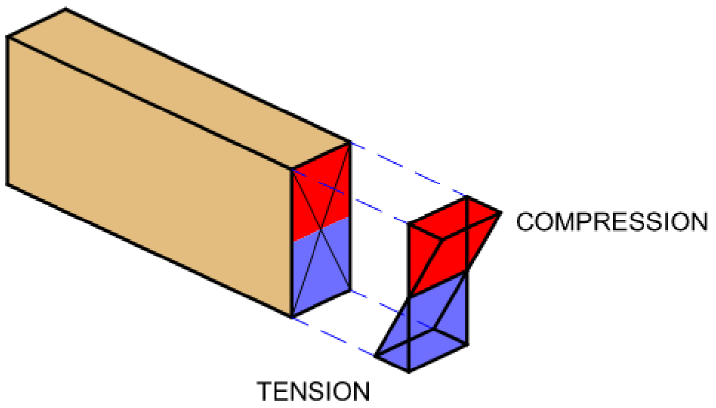
- Bending design check:
  - $f_b \leq F'_b$

Wood Design: Bending

Actual bending stress:

- Actual bending stress
  - $f_b = \frac{M*c}{I} = \frac{M}{S}$ (NDS Equation 3.3-1)
- For rectangular members
  - $f_b = \frac{M}{S} = \frac{6*M}{b*d^2}$ (NDS Equation 3.3-2)

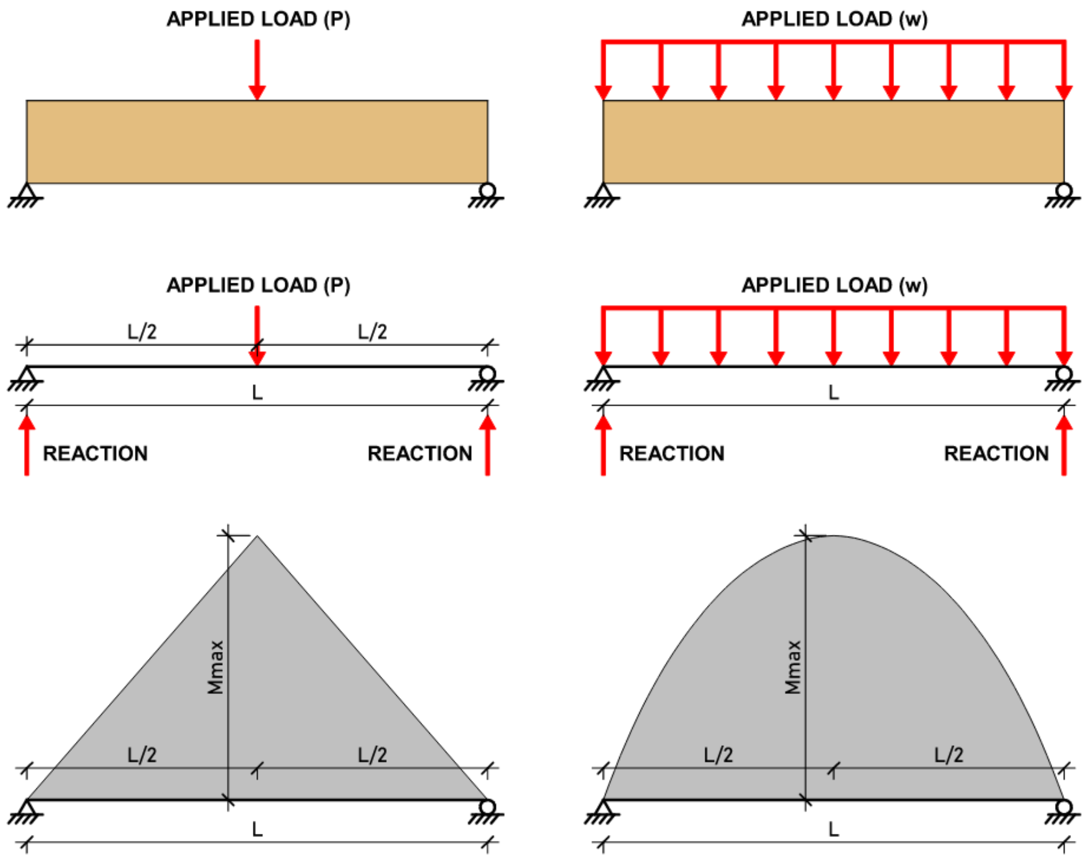




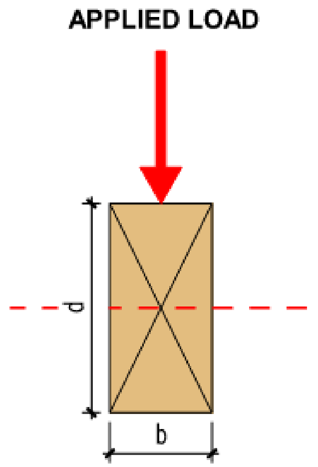
Wood Design: Bending

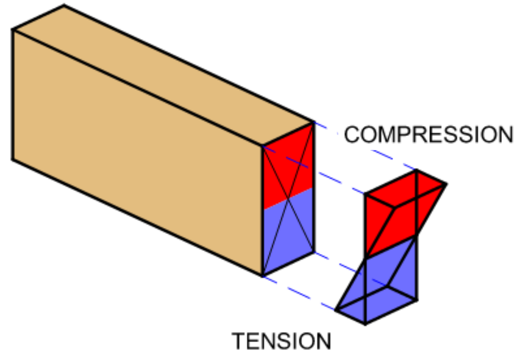
Maximum moments, simply supported beam:

- Uniform loading
  - $M = \frac{w*L^2}{8}$
- Concentrated mid-span load
  - $M = \frac{P*L}{4}$



Wood Design: Bending





Beam stability factor, C_L (NDS Section 3.3.3):

- $C_L = 1.0$ if:
  - Depth of member ≤ breadth *(d ≤ b)*
  - Sawn lumber laterally supported per NDS Section 4.4.1
  - Compression edge supported throughout length
- Otherwise:
  - $C_L = \frac{1+(F_{bE}/F_b^*)}{1.9} - \sqrt{\left[\frac{1+(F_{bE}/F_b^*)}{1.9}\right]^2 - \frac{F_{bE}/F_b^*}{0.95}}$ (NDS Equation 3.3-6)
    - F_b^*= reference bending design value (not including C_{fu}, C_v, C_{vL})
    - $F_{bE} = \frac{1.20*E'_{min}}{{R_B}^2}$
    - $R_B = \sqrt{\frac{l_e*d}{b^2}}$
    - l_e = effective span length
  - Check slenderness ratio $R_B \leq 50$ (NDS Section 3.3.3.7)

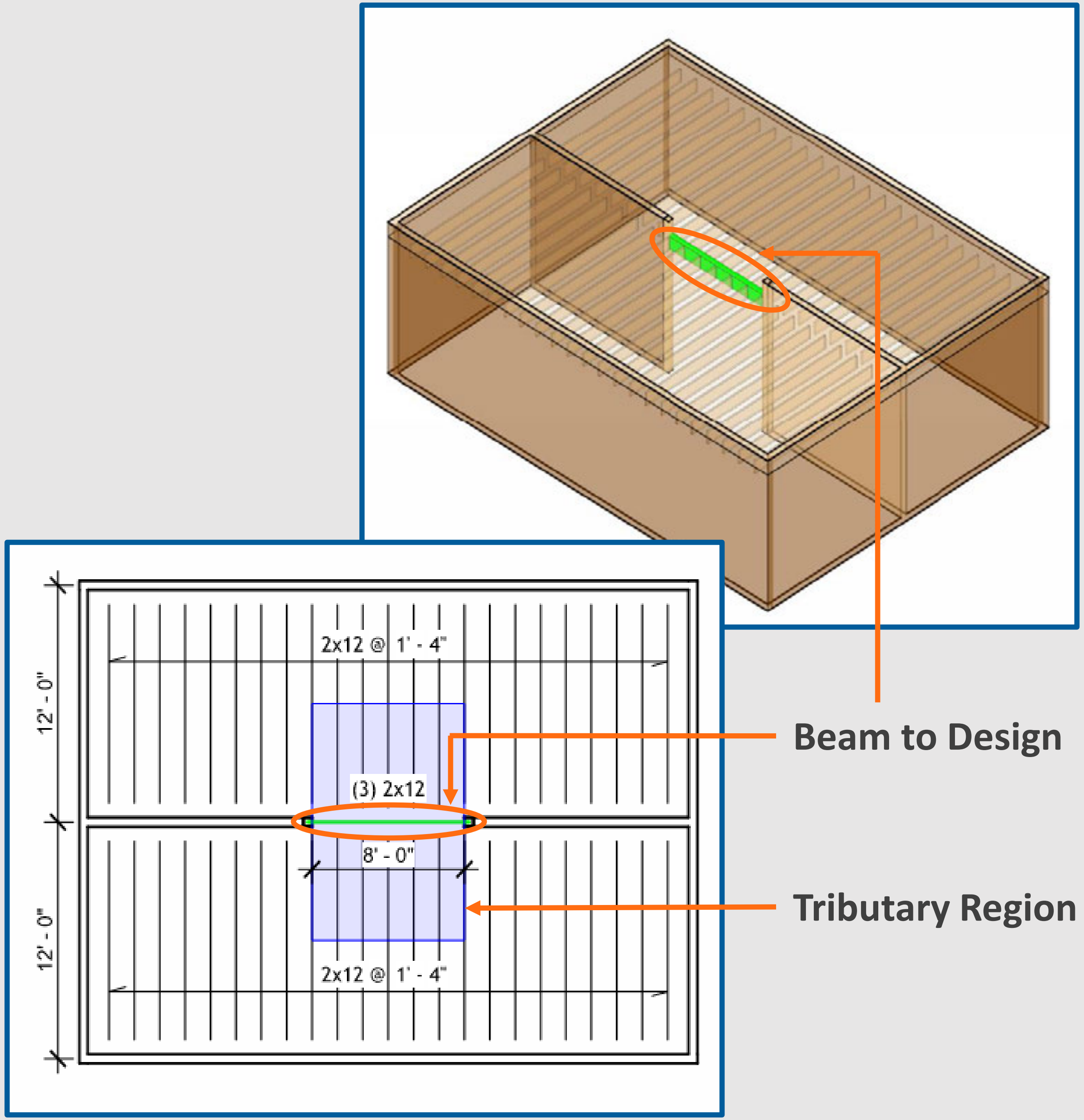
Design Example: Bending

Loading:

- » Loads:
  - » Live load = 50 psf
  - » Dead load = 30 psf
  - » Total Load = 50 + 30 = 80 psf

Framing:

- » (3) 2x12 beam
- » Douglas-Fir Larch #2



Design Example: Bending

Bending stress for (3) 2x12 beam:

» Elastic section modulus:

  » $S = \frac{b*d^2}{6} = \frac{(4.5in)*(11.25in)^2}{6} = 94.9\ in^3$

» Span = 8 ft

» Tributary width = 12 ft

  » Uniform load w = 80 psf * 12 ft = 960 lb/ft

» Maximum moment:

  » $M = \frac{w*L^2}{8} = \frac{960\frac{lb}{ft}*(8ft)^2}{8} = 7{,}680\ lb*ft$

» Bending stress:

  » $f_b = \frac{M}{S} = \frac{(7{,}680\ lb*ft)(\frac{12in}{1ft})}{94.9in^3} = 971\ psi$

Design Example: Bending

Douglas-Fir Larch #2 capacity:

- » $F_b = 900\ psi$ (NDS Supplement)
- » $F'_b = F_b * C_D * C_M * C_t * \ C_L * C_F * \ C_{fu} * C_i * \ C_r$
  - » $C_D = C_M = C_t = \ C_L = C_F = \ C_{fu} = C_i = 1.0, C_r = 1.15$
- » $F'_b = 900\ psi * 1.15 = 1{,}035\ psi$

AWC NDS Supplement, Table 4A

Species and commercial grade	Size classification	Design values in pounds per square inch (psi)							Specific Gravity[4]	Grading Rules Agency
		Bending	Tension parallel to grain	Shear parallel to grain	Compression perpendicular to grain	Compression parallel to grain	Modulus of Elasticity			
		F_b	F_t	F_v	$F_{c\perp}$	F_c	E	E_{min}	G	
DOUGLAS FIR-LARCH										
Select Structural	2" & wider	1,500	1,000	180	625	1,700	1,900,000	690,000	0.50	WCLIB WWPA
No. 1 & Btr		1,200	800	180	625	1,550	1,800,000	660,000		
No. 1		1,000	675	180	625	1,500	1,700,000	620,000		
No. 2		900	575	180	625	1,350	1,600,000	580,000		
No. 3		525	325	180	625	775	1,400,000	510,000		
Stud	2" & wider	700	450	180	625	850	1,400,000	510,000		
Construction	2" - 4" wide	1,000	650	180	625	1,650	1,500,000	550,000		
Standard		575	375	180	625	1,400	1,400,000	510,000		
Utility		275	175	180	625	900	1,300,000	470,000		

AWC NDS Supplement, 2018

Design Example: Bending

Design Check:

- Demand: $f_b = 971\,psi$
- Capacity: $F'_b = 1{,}035\,psi$

- $f_b < F'_b \rightarrow$ OK for bending

Outline

- » Design Basis & Notation
- » Bending Design
- » **Shear Design**
- » Deflection
- » Compression
- » Bearing
- » Other Axial
- » Connections

Wood Design: Shear

> 3.4.1.1 The actual shear stress parallel to grain or shear force at any cross section of the bending member shall not exceed the adjusted shear design value. A check of the strength of wood bending members in shear perpendicular to grain is not required.

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- Shear design check:
  - $f_v \leq F'_v$

Adjusted Capacity

Demand

Wood Design: Shear

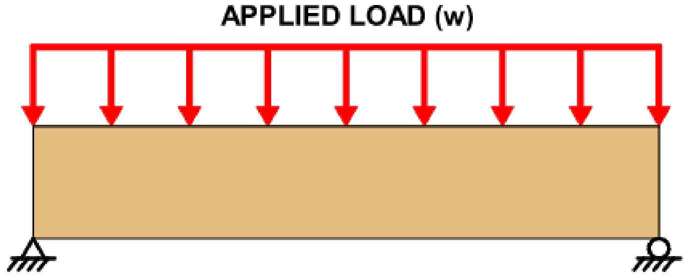
Shear stress:

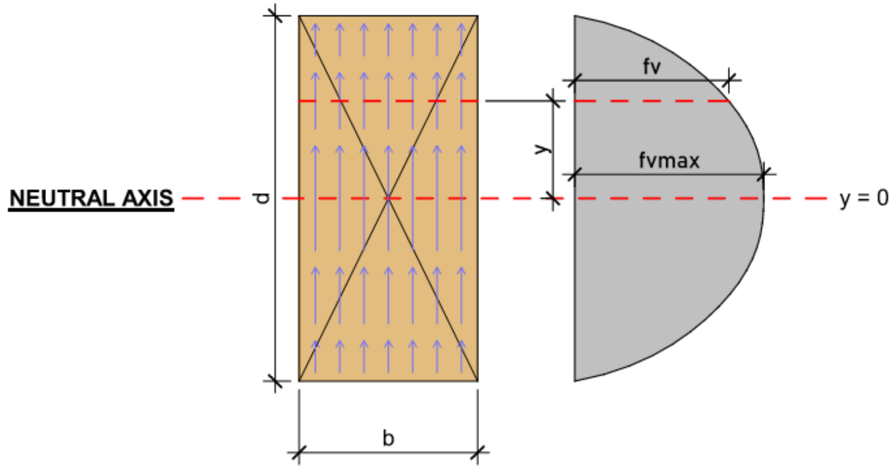
» Actual shear stress

» $f_v = \frac{V*Q}{I*b}$ (NDS Equation 3.4-1)

» For rectangular members

» $f_v = \frac{3*V}{2*b*d}$ (NDS Equation 3.4-2)





Wood Design: Shear

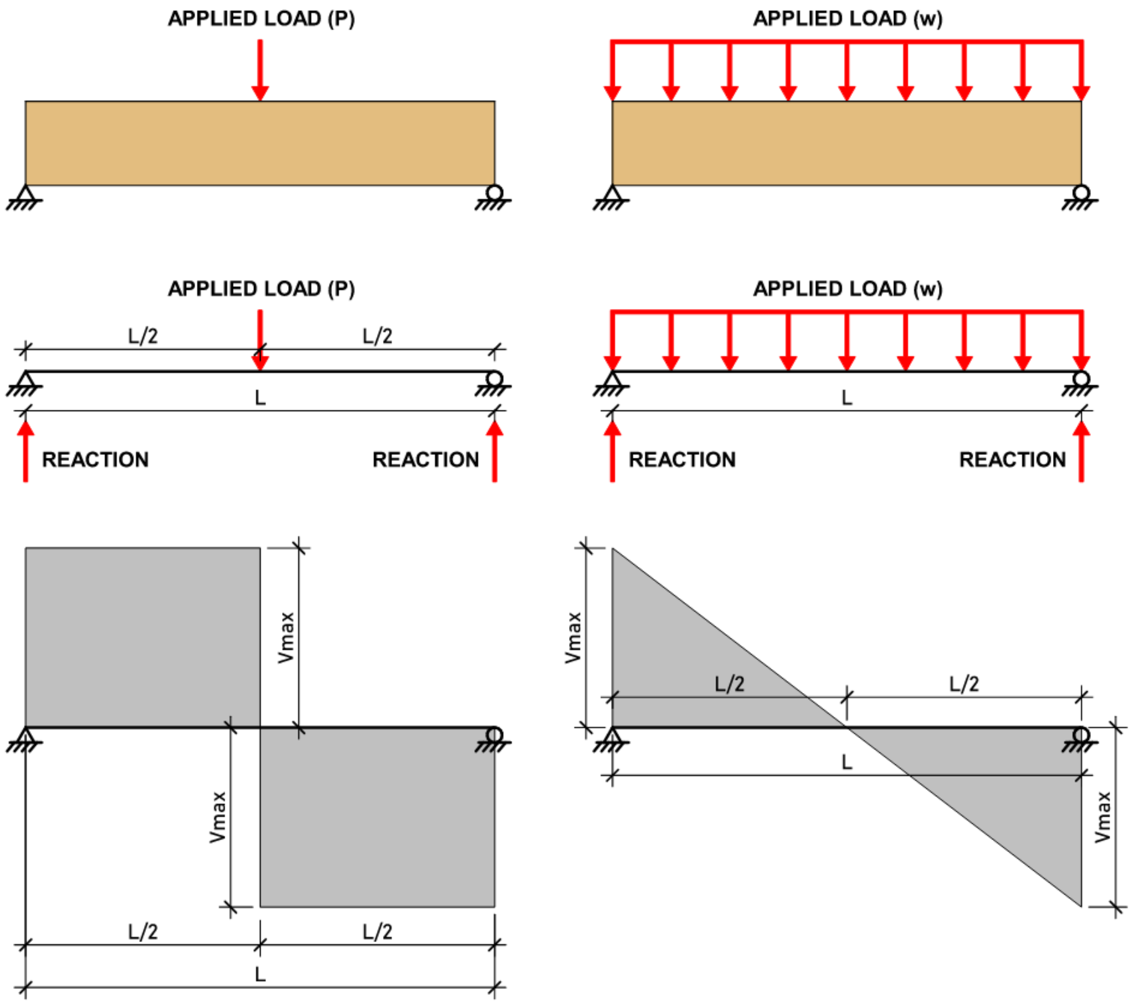
Maximum shear, simply supported beam:

» Uniform loading

  » $V = \frac{w*L}{2}$

» Concentrated mid-span load

  » $V = \frac{P}{2}$



Wood Design: Shear

Shear at supports:

- NDS Section 3.4.3.1
  - Uniform loads within “d” of support permitted to be neglected
  - Concentrated loads within “d” of support permitted to be reduced

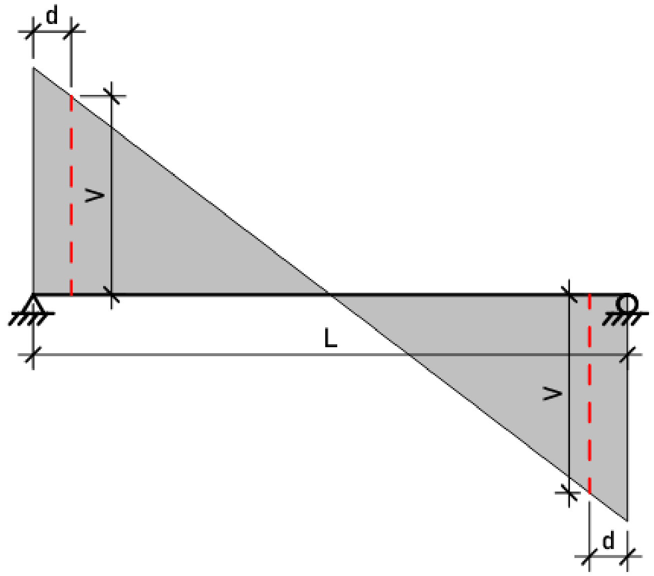
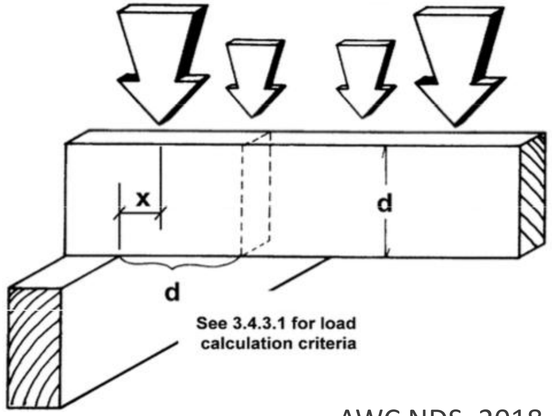


Figure 3C Shear at Supports



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Wood Design: Shear of Notched Member

Adjusted design shear in notched members:

- Notched tension face:
  - $V_r' = \left(\frac{2}{3} * F_v' * b * d_n\right) * (\frac{d_n}{d})^2$ (NDS Equation 3.4-3)

- Notched compression face:
  - $V_r' = \frac{2}{3} * F_v' * b * \left[d - \left(\frac{d-d_n}{d_n}\right) * e\right]$ (NDS Equation 3.4-5)

    - F_v' = adjusted shear design value
    - d = depth of unnotched member
    - d_n = depth of member remaining at notch
    - e = distance notch extends from support

Design Example: Shear

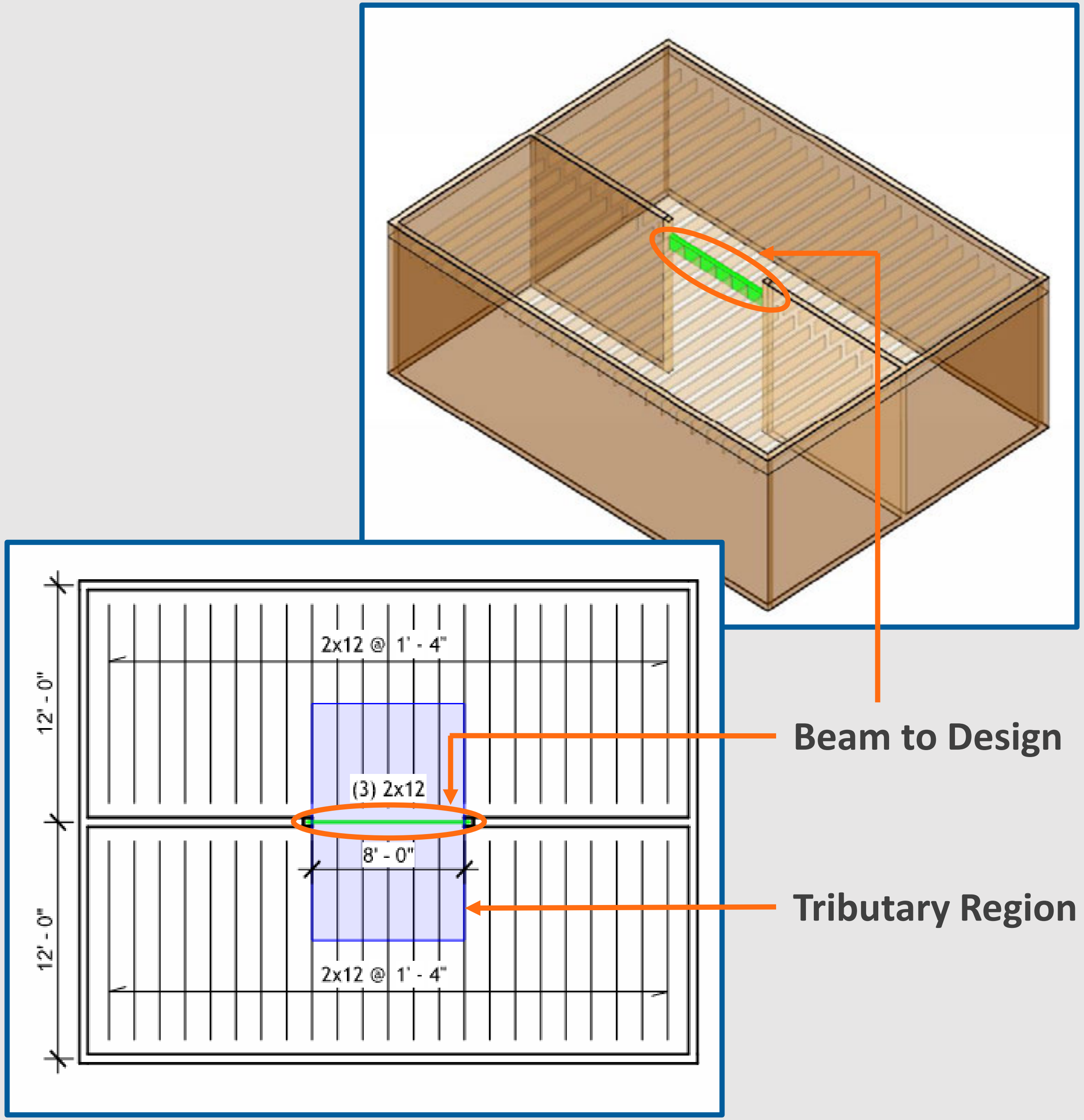
Loading:

» Loads:
  » Live load = 50 psf
  » Dead load = 30 psf
  » Total Load = 50 + 30 = 80 psf

Framing:

» (3) 2x12 beam

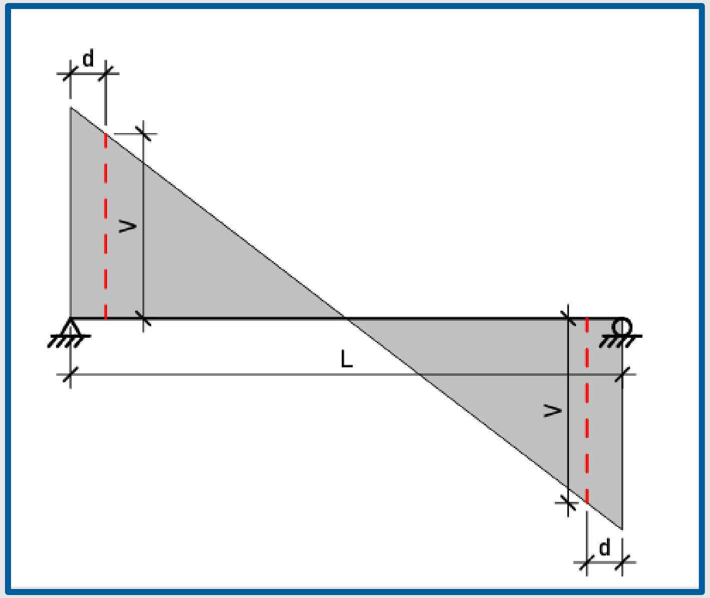
» Douglas-Fir Larch #2



Design Example: Shear

Shear stress for (3) 2x12 beam:

- Uniform load w = 960 lb/ft
- Maximum shear:
  - $V = \frac{w*(L-2*d)}{2} = \frac{960\frac{lb}{ft}*(8ft-2*\frac{11.25in}{12in/ft})}{2} = 2{,}940\ lb$
- Shear stress:
  - $f_v = \frac{3*V}{2*A} = \frac{3*2{,}940\ lb}{2*(4.5in*11.25in)} = 87\ psi$



Design Example: Shear

Douglas-Fir Larch #2 capacity:

» $F_v = 180\ psi$ (NDS Supplement)

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

  » $C_D = C_M = C_t = C_i = 1.0$

» $F'_v = 180\ psi$

AWC NDS Supplement, Table 4A

Species and commercial grade	Size classification	Design values in pounds per square inch (psi)							Specific Gravity[4]	Grading Rules Agency
		Bending	Tension parallel to grain	Shear parallel to grain	Compression perpendicular to grain	Compression parallel to grain	Modulus of Elasticity			
		F_b	F_t	F_v	$F_{c\perp}$	F_c	E	E_{min}	G	
DOUGLAS FIR-LARCH										
Select Structural	2" & wider	1,500	1,000	180	625	1,700	1,900,000	690,000	0.50	WCLIB WWPA
No. 1 & Btr		1,200	800	180	625	1,550	1,800,000	660,000		
No. 1		1,000	675	180	625	1,500	1,700,000	620,000		
No. 2		900	575	180	625	1,350	1,600,000	580,000		
No. 3		525	325	180	625	775	1,400,000	510,000		
Stud	2" & wider	700	450	180	625	850	1,400,000	510,000		
Construction	2" - 4" wide	1,000	650	180	625	1,650	1,500,000	550,000		
Standard		575	375	180	625	1,400	1,400,000	510,000		
Utility		275	175	180	625	900	1,300,000	470,000		

AWC NDS Supplement, 2018

Design Example: Shear

Design Check:

- Demand: $f_v = 87\ psi$
- Capacity: $F'_v = 180\ psi$

- $f_v < F'_v \rightarrow$ OK for shear

Outline

- Design Basis & Notation
- Bending Design
- Shear Design
- **Deflection**
- Compression
- Bearing
- Other Axial
- Connections

Wood Design: Deflection

3.5.1 Deflection Calculations

If deflection is a factor in design, it shall be calculated by standard methods of engineering mechanics considering bending deflections and, when applicable, shear deflections. Consideration for shear deflection is required when the reference modulus of elasticity has not been adjusted to include the effects of shear deflection (see Appendix F).

AWC NDS, 2018

Wood Design: Deflection

Deflection limits: IBC Section 1604.3.1

TABLE 1604.3
DEFLECTION LIMITS[a, b, c, h, i]

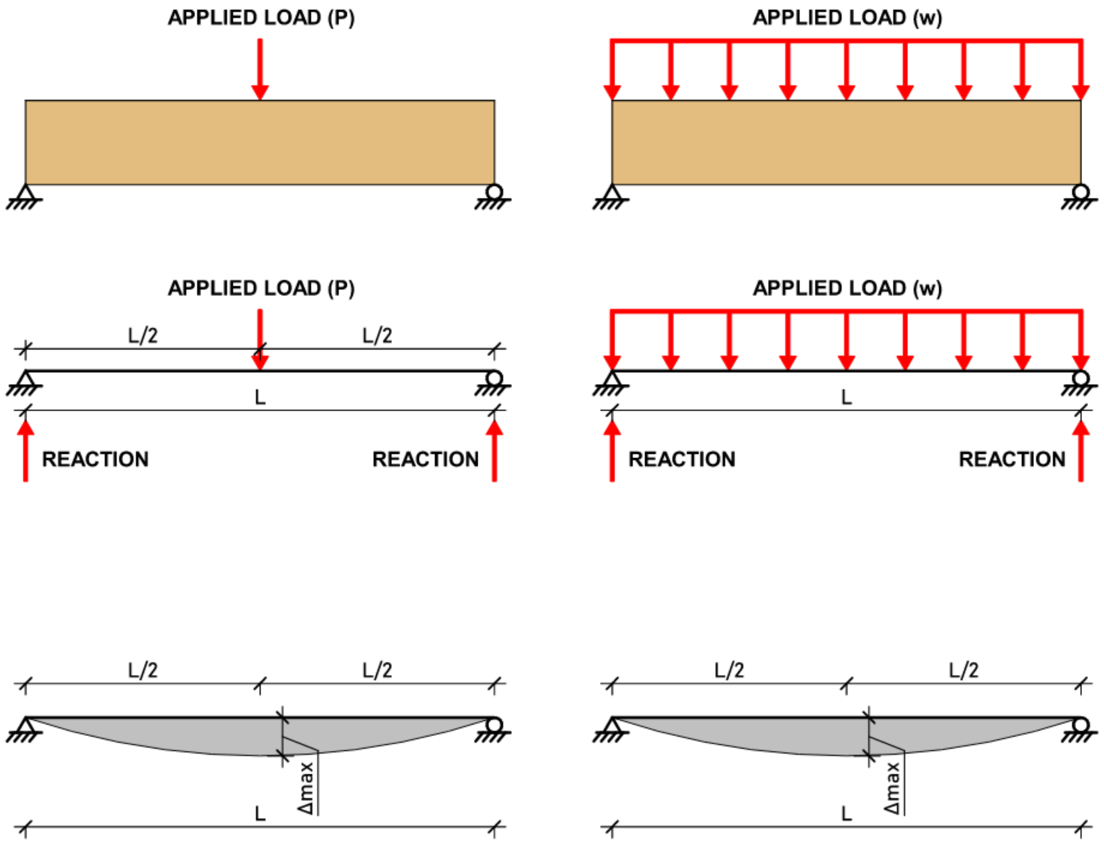
CONSTRUCTION	L or L_r	S or W[f]	$D + L$[d, g]
Roof members:[e]			
Supporting plaster or stucco ceiling	$l/360$	$l/360$	$l/240$
Supporting nonplaster ceiling	$l/240$	$l/240$	$l/180$
Not supporting ceiling	$l/180$	$l/180$	$l/120$
Floor members	$l/360$	—	$l/240$
Exterior walls:			
With plaster or stucco finishes	—	$l/360$	—
With other brittle finishes	—	$l/240$	—
With flexible finishes	—	$l/120$	—
Interior partitions:[b]			
With plaster or stucco finishes	$l/360$	—	—
With other brittle finishes	$l/240$	—	—
With flexible finishes	$l/120$	—	—
Farm buildings	—	—	$l/180$
Greenhouses	—	—	$l/120$

International Building Code, 2021

Wood Design: Deflection

Maximum deflection, simply supported beam:

- Uniform loading
  - $$\Delta = \frac{5 * w * L^4}{384 * E * I}$$
- Concentrated mid-span load
  - $$\Delta = \frac{P * L^3}{48 * E * I}$$



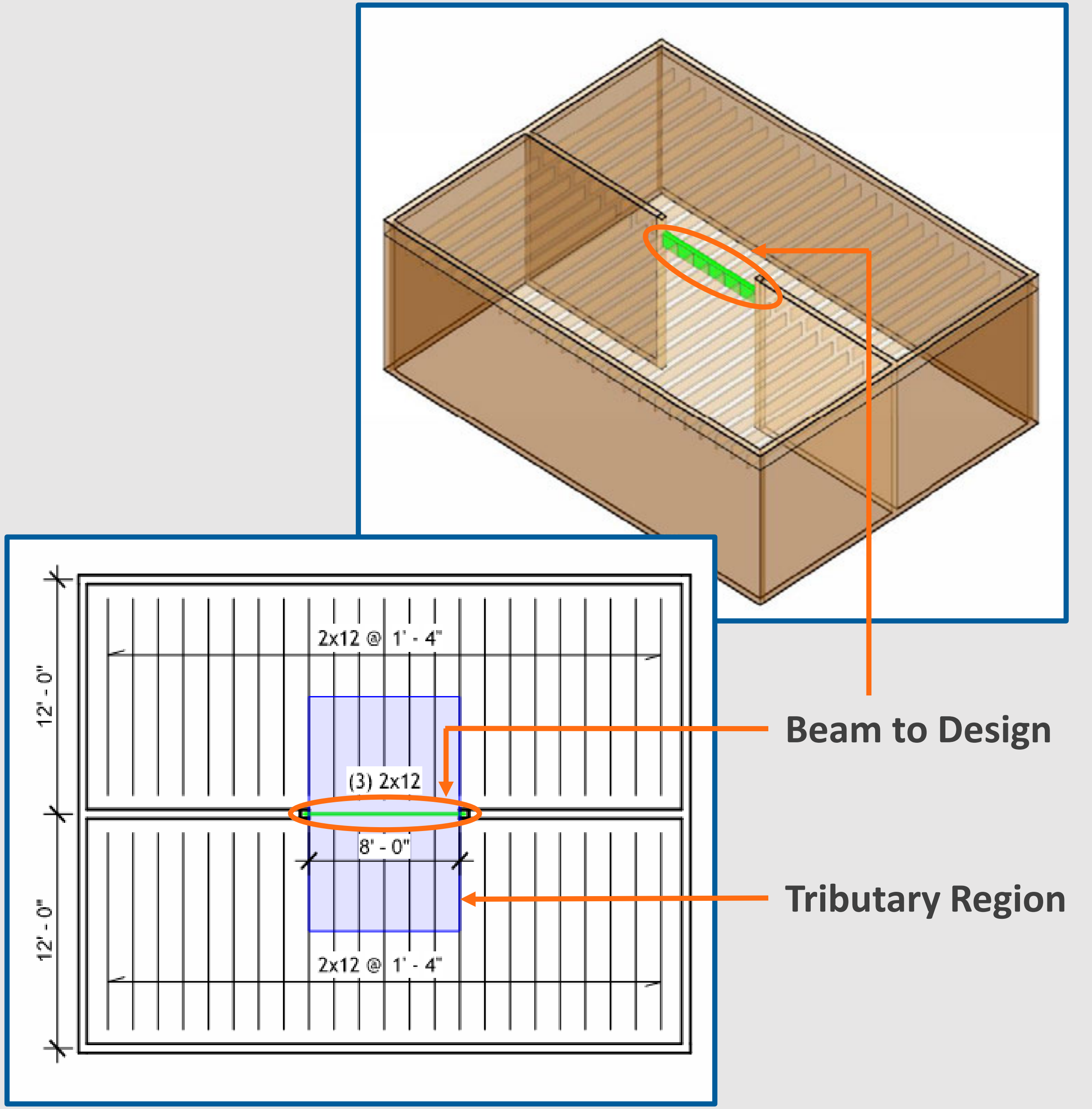
Design Example: Deflection

Loading:

- Loads:
  - Live load = 50 psf
  - Dead load = 30 psf
  - Total Load = 50 + 30 = 80 psf

Framing:

- (3) 2x12 beam
- Douglas-Fir Larch #2



Design Example: Deflection

Deflections for (3) 2x12 beam:

» Uniform load w_{D+L} = 960 lb/ft

» Uniform live load w_{LL} = 50 psf * 12 ft = 600 lb/ft

Douglas-Fir Larch #2:

» $E = 1{,}600{,}000\ psi$ (NDS Supplement)

AWC NDS Supplement, Table 4A

Species and commercial grade	Size classification	Design values in pounds per square inch (psi)							Specific Gravity[4]	Grading Rules Agency
		Bending F_b	Tension parallel to grain F_t	Shear parallel to grain F_v	Compression perpendicular to grain $F_{c\perp}$	Compression parallel to grain F_c	Modulus of Elasticity E	Modulus of Elasticity E_{min}	G	
DOUGLAS FIR-LARCH										
Select Structural	2" & wider	1,500	1,000	180	625	1,700	1,900,000	690,000	0.50	WCLIB WWPA
No. 1 & Btr		1,200	800	180	625	1,550	1,800,000	660,000		
No. 1		1,000	675	180	625	1,500	1,700,000	620,000		
No. 2		900	575	180	625	1,350	1,600,000	580,000		
No. 3		525	325	180	625	775	1,400,000	510,000		
Stud	2" & wider	700	450	180	625	850	1,400,000	510,000		
Construction	2" - 4" wide	1,000	650	180	625	1,650	1,500,000	550,000		
Standard		575	375	180	625	1,400	1,400,000	510,000		
Utility		275	175	180	625	900	1,300,000	470,000		

AWC NDS Supplement, 2018

Design Example: Deflection

Deflections for (3) 2x12 beam:

- Moment of Inertia:
  - $I = \frac{b*d^3}{12} = \frac{4.5in*(11.25in)^3}{12} = 534\ in^4$
- Maximum (dead + live) deflection:
  - $\Delta_{D+L} = \frac{5*w*L^4}{384*E*I} = \frac{5*960\frac{lb}{ft}*\left(\frac{1ft}{12in}\right)*[8ft*\left(\frac{12in}{1ft}\right)]^4}{384*1{,}600{,}000\ psi*534\ in^4} = 0.10\ in$
- Maximum live load deflection:
  - $\Delta_{LL} = \frac{5*w*L^4}{384*E*I} = \frac{5*600\frac{lb}{ft}*\left(\frac{1ft}{12in}\right)*[8ft*\left(\frac{12in}{1ft}\right)]^4}{384*1{,}600{,}000\ psi*534\ in^4} = 0.06\ in$

Design Example: Deflection

Maximum allowable deflections:

- $\Delta_{D+L,max} = \frac{L}{240} = \frac{8ft * \frac{12in}{1ft}}{240} = 0.40\ in$
- $\Delta_{LL,max} = \frac{L}{360} = \frac{8ft * \frac{12in}{1ft}}{360} = 0.27\ in$

TABLE 1604.3
DEFLECTION LIMITS[a, b, c, h, i]

CONSTRUCTION	*L* or *L_r*	*S* or *W*[f]	*D* + *L*[d, g]
Roof members:[e]			
Supporting plaster or stucco ceiling	*l*/360	*l*/360	*l*/240
Supporting nonplaster ceiling	*l*/240	*l*/240	*l*/180
Not supporting ceiling	*l*/180	*l*/180	*l*/120
Floor members	*l*/360	—	*l*/240
Exterior walls:			
With plaster or stucco finishes	—	*l*/360	—
With other brittle finishes	—	*l*/240	—
With flexible finishes	—	*l*/120	—
Interior partitions:[b]			
With plaster or stucco finishes	*l*/360	—	—
With other brittle finishes	*l*/240	—	—
With flexible finishes	*l*/120	—	—
Farm buildings	—	—	*l*/180
Greenhouses	—	—	*l*/120

International Building Code, 2021

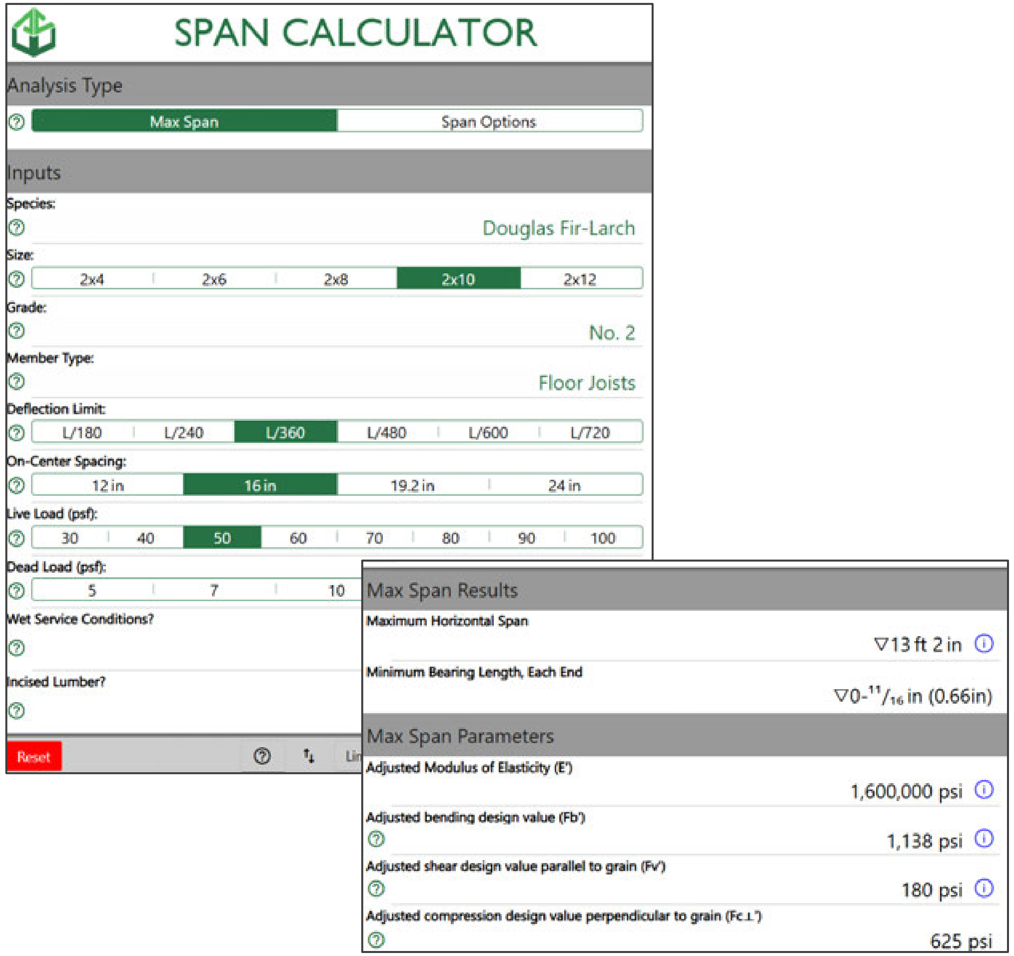
Design Example: Deflection

Design Checks:

- Dead + Live:
  - Maximum deflection: $\Delta_{D+L} = 0.10\ in$
  - Maximum allowable: $\Delta_{D+L,max} = 0.40\ in$
  - $\Delta_{D+L} < \Delta_{D+L,max}$ → OK for dead + live deflection

- Live:
  - Maximum deflection: $\Delta_{LL} = 0.06\ in$
  - Maximum allowable: $\Delta_{LL,max} = 0.27\ in$
  - $\Delta_{LL} < \Delta_{LL,max}$ → OK for live deflection

Beam Design Aids



AWC Span Calculator:
https://awc.org/calculators/span-options-calculator-for-wood-joists-and-rafters/

American Wood Council Span Tables:
https://awc.org/codes-and-standards/span-tables/

Outline

- Design Basis & Notation
- Bending Design
- Shear Design
- Deflection
- **Compression**
- Bearing
- Other Axial
- Connections

Wood Design: Compression

3.6.3 Strength in Compression Parallel to Grain

The actual compression stress or force parallel to grain shall not exceed the adjusted compression design value. Calculations of f_c shall be based on the net section area (see 3.1.2) where the reduced section occurs in the critical part of the column length that is most subject to potential buckling. Where the reduced section does not occur in the critical part of the column length that is most subject to potential buckling, calculations of f_c shall be based on gross section area. In addition, f_c based on net section area shall not exceed the reference compression design value parallel to grain multiplied by all applicable adjustment factors except the column stability factor, C_P.

AWC NDS, 2018

- Compression design check:
  - $f_c \leq F'_c$

Adjusted Capacity (F'_c)

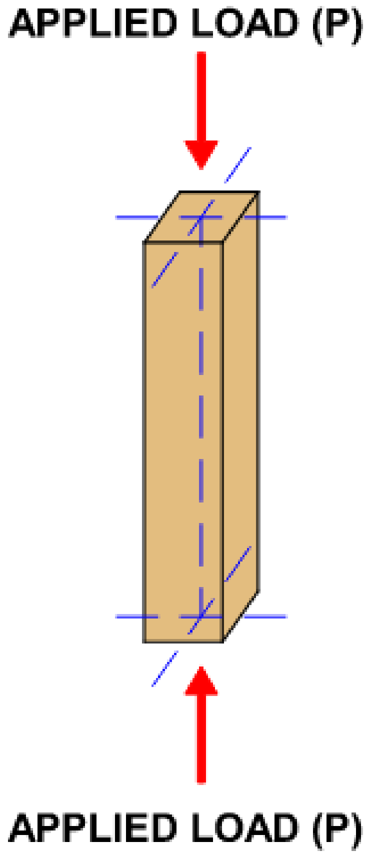
Demand (f_c)

Wood Design: Compression

Actual compression stress:

» $f_c = \frac{P}{A}$

» Note: f_c for eccentrically loaded columns will be non-uniform



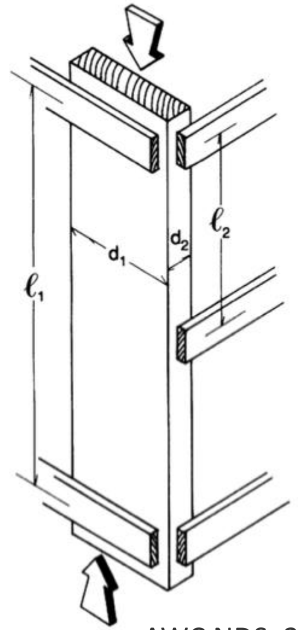
Wood Design: Compression

Column stability factor, C_P (NDS Section 3.7):

- Member supported for full length: $C_P = 1.0$
- Member not supported for full length
  - $C_P = \frac{1+(F_{cE}/F_c^*)}{2*c} - \sqrt{[\frac{1+(F_{cE}/F_c^*)}{2*c}]^2 - \frac{F_{cE}/F_c^*}{c}}$

    (NDS Equation 3.7-1)
    - F_c^* = reference compression design value parallel to grain (excluding C_P adjustment factor)
    - $F_{cE} = \frac{0.822*E'_{min}}{(l_e/d)^2}$
    - c varies for sawn lumber, timber poles, glulam, etc.
    - l_e = effective column length
  - Check slenderness ratio ${}^{l_e}/_{d} \leq 50$ (NDS Section 3.7.1.4)

Figure 3F Simple Solid Column



AWC NDS, 2018

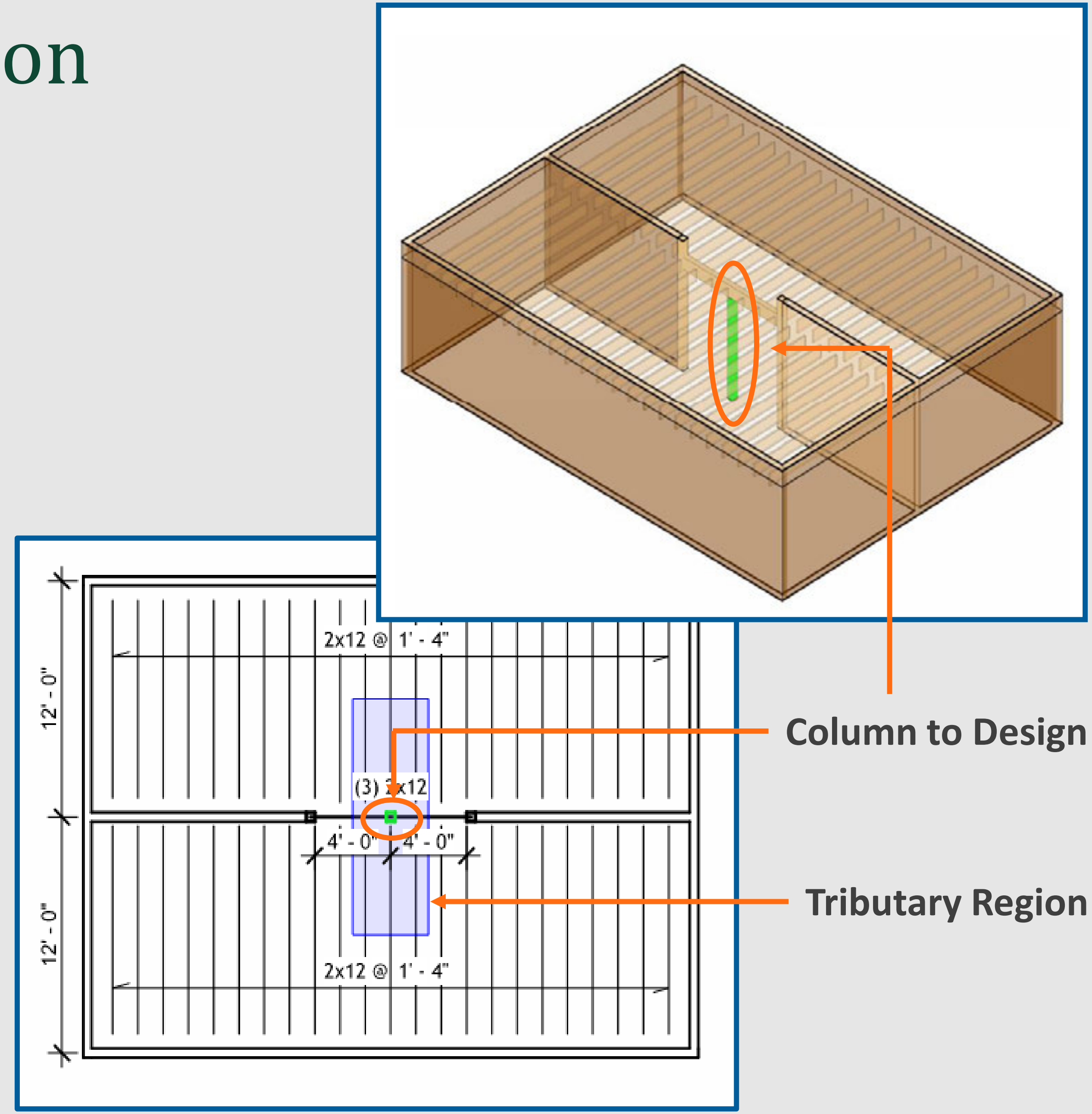
Design Example: Compression

Loading:

- » Loads:
  - » Live load = 50 psf
  - » Dead load = 30 psf
  - » Total Load = 50 + 30 = 80 psf

Framing:

- » 6x6 column – 10’-0” height
- » Douglas-Fir Larch #2



Design Example: Compression

Axial stress on column:

- Tributary area = 12 ft * 4 ft = 48 ft^2
- Compression load = 80 psf * 48 ft^2 = 3,840 lb
- Compression stress:
  - $f_c = \frac{P}{A} = \frac{3{,}840\ lb}{5.5\ in * 5.5\ in} = 127\ psi$

Design Example: Compression

Douglas-Fir Larch #2 capacity:

- $F_c = 700\ psi$ (NDS Supplement)
- Must determine column stability factor, C_P
  - $E_{min} = 470{,}000\ psi$
- $C_D = C_M = C_t = C_F = C_i = 1.0$

AWC NDS Supplement, Table 4D

Species and commercial Grade	Size classification	Design values in pounds per square inch (psi)							Specific Gravity[4]	Grading Rules Agency
		Bending	Tension parallel to grain	Shear parallel to grain	Compression perpendicular to grain	Compression parallel to grain	Modulus of Elasticity			
		F_b	F_t	F_v	$F_{c\perp}$	F_c	E	E_{min}	G	
DOUGLAS FIR-LARCH										
Dense Select Structural	Beams and Stringers	1,900	1,100	170	730	1,300	1,700,000	620,000	0.50	WCLIB
Select Structural		1,600	950	170	625	1,100	1,600,000	580,000		
Dense No. 1		1,550	775	170	730	1,100	1,700,000	620,000		
No. 1		1,350	675	170	625	925	1,600,000	580,000		
No. 2		875	425	170	625	600	1,300,000	470,000		
Dense Select Structural	Posts and Timbers	1,750	1,150	170	730	1,350	1,700,000	620,000		
Select Structural		1,500	1,000	170	625	1,150	1,600,000	580,000		
Dense No. 1		1,400	950	170	730	1,200	1,700,000	620,000		
No. 1		1,200	825	170	625	1,000	1,600,000	580,000		
No. 2		750	475	170	625	700	1,300,000	470,000		

AWC NDS Supplement, 2018

Design Example: Compression

Column stability factor:

- $C_P = \frac{1+(F_{cE}/F_c^*)}{2*c} - \sqrt{[\frac{1+(F_{cE}/F_c^*)}{2*c}]^2 - \frac{F_{cE}/F_c^*}{c}}$
  - $F_c^* = F_c * C_D * C_M * C_t * C_F * C_i = 700\ psi$
  - $F_{cE} = \frac{0.822 * E'_{min}}{(l_e/d)^2}$
    - $E'_{min} = E_{min} * C_M * C_t * C_i * C_T = 470{,}000\ psi$
    - $l_e = 10\text{ft} * \frac{12 in}{1 ft} = 120\ in$ (assume pinned end connections)
    - $F_{cE} = \frac{0.822 * E'_{min}}{(l_e/d)^2} = \frac{0.822 * 470{,}000\ psi}{(120 in/5.5 in)^2} = 812\ psi$
  - c = 0.8 for sawn lumber per NDS Section 3.7.1.5
  - $C_P = \frac{1+(812/700)}{2*0.8} - \sqrt{[\frac{1+(812/700)}{2*0.8}]^2 - \frac{812/700}{0.8}} = 0.74$

c = 0.8 for sawn lumber

c = 0.85 for round timber poles and piles

c = 0.9 for structural glued laminated timber, structural composite lumber, and cross-laminated timber

AWC NDS, 2018

Design Example: Compression

Column capacity:

- $F'_c = F_c * \ C_D * \ C_M * \ C_t * C_F * \ C_i * C_P$
  - $C_D = C_M = C_t = C_F = \ C_i = 1.0$
  - $C_P = 0.74$
  - $F'_c = 700\, psi * \ 0.74 = 518\, psi$

Design Check:

- Demand: $f_c = 127\, psi$
- Capacity: $F'_c = 518\, psi$
- $f_c < F'_c$ → OK for compression

- $\frac{l_e}{d} = (10\text{ft} * \frac{12in}{1ft})/5.5in = 21.8 \ < 50$ → OK

Outline

» Design Basis & Notation
» Bending Design
» Shear Design
» Deflection
» Compression
» **Bearing**
» Other Axial
» Connections

Wood Design: Bearing

3.10.1 Bearing Parallel to Grain

3.10.1.1 The actual compressive bearing stress parallel to grain shall be based on the net bearing area and shall not exceed the reference compression design value parallel to grain multiplied by all applicable adjustment factors except the column stability factor, C_P.

AWC NDS, 2018

3.10.2 Bearing Perpendicular to Grain

The actual compression stress perpendicular to grain shall be based on the net bearing area and shall not exceed the adjusted compression design value perpendicular to grain, $f_{c\perp} \leq F_{c\perp}'$. When calculating bearing area at the ends of bending members, no allowance shall be made for the fact that as the member bends, pressure upon the inner edge of the bearing is greater than at the member end.

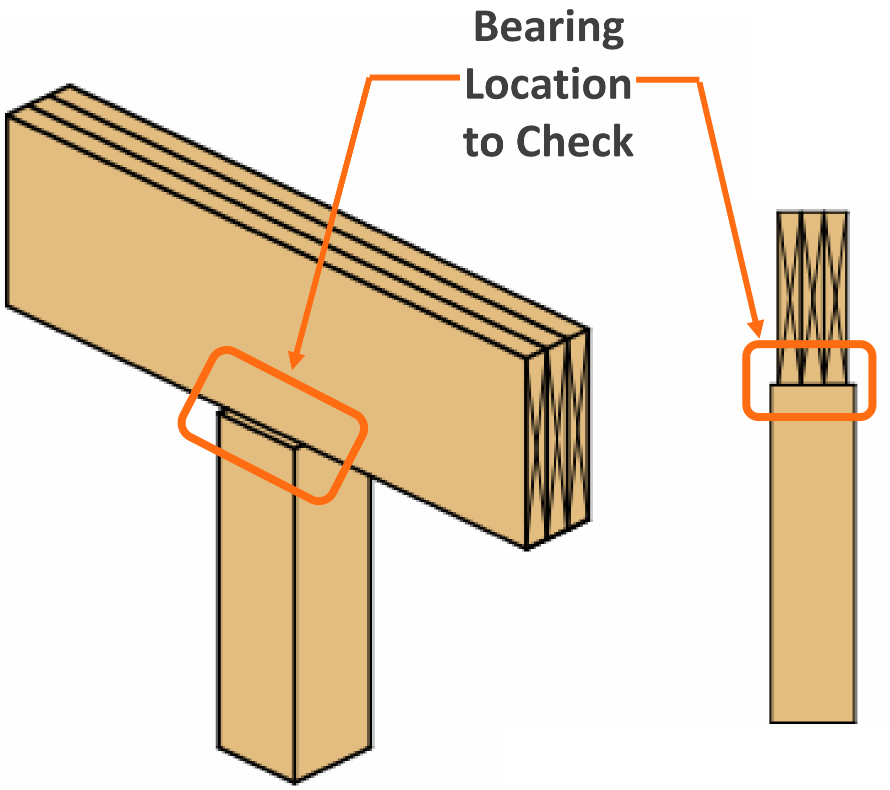
AWC NDS, 2018

- Bearing design checks:
  - Parallel to grain:
    - $f_c \leq F'_c$ (excluding C_P)
      - f_c: Demand
      - F'_c: Adjusted Capacity
  - Perpendicular to grain:
    - $f_{c\perp} \leq F'_{c\perp}$
      - $f_{c\perp}$: Demand
      - $F'_{c\perp}$: Adjusted Capacity

Wood Design: Bearing

Actual bearing stress:

» $f_c = f_{c\perp} = \frac{P}{A_{brg}}$



Wood Design: Bearing

Bearing area factor, C_b (NDS Section 3.10.4):

- Permitted for:
  - Bearings less than 6" in length AND
  - No closer than 3" to end of member

- $C_b = \frac{l_b + 0.375}{l_b}$ (NDS Equation 3.10-2)
  - l_b = bearing length parallel to grain

Table 3.10.4 Bearing Area Factors, C_b

ℓ_b	0.5"	1"	1.5"	2"	3"	4"	6" or more
C_b	1.75	1.38	1.25	1.19	1.13	1.10	1.00

AWC NDS, 2018

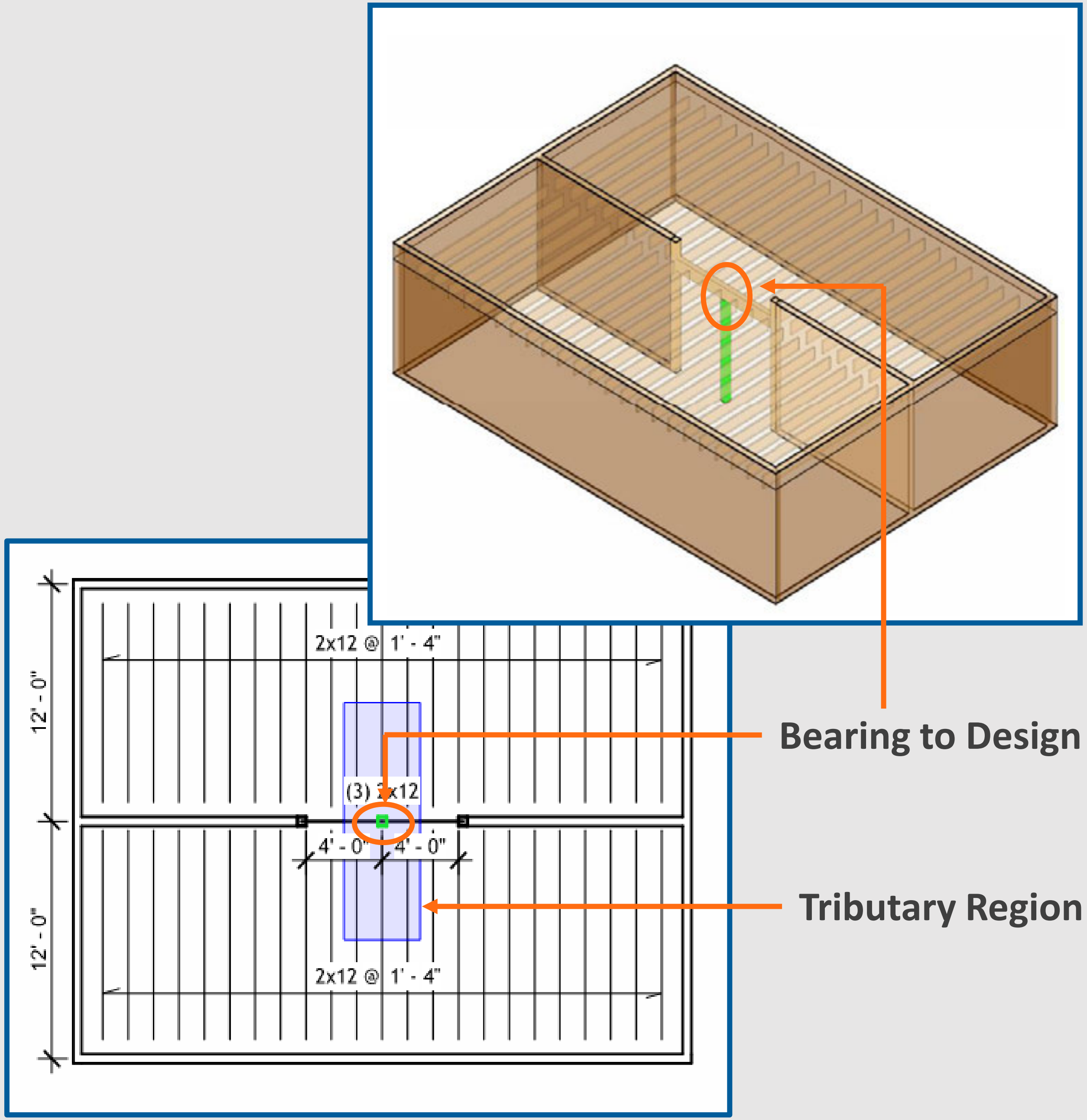
Design Example: Bearing

Loading:

- Loads:
  - Live load = 50 psf
  - Dead load = 30 psf
  - Total Load = 50 + 30 = 80 psf

Framing:

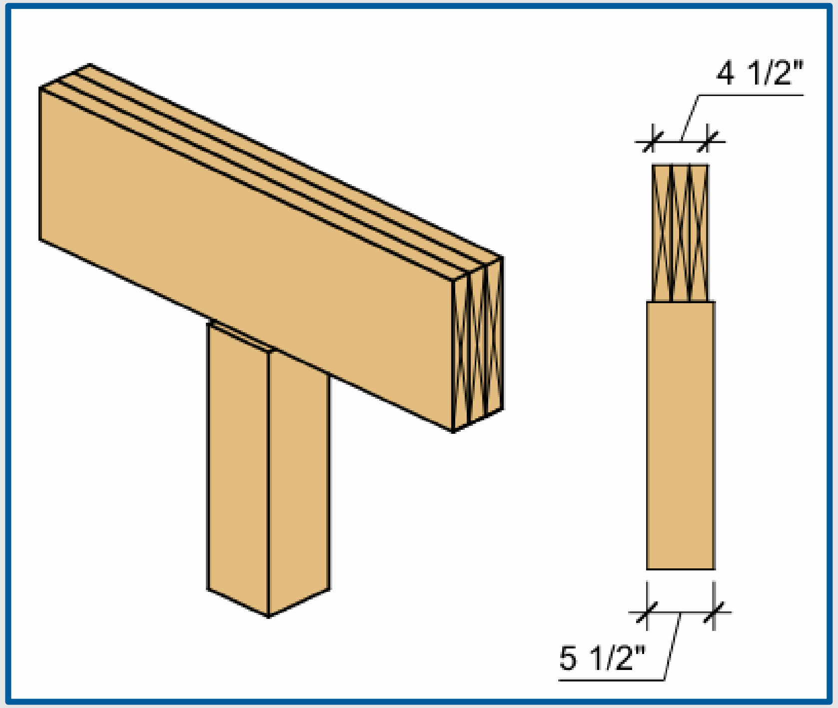
- (3) 2x12 beam
- 6x6 column
- Douglas-Fir Larch #2



Design Example: Bearing

- Bearing area:
  - Bearing length = length along column = 5.5 inches
  - Bearing width = minimum of:
    - Column width = 5.5 inches
    - Beam width = (3) * 1.5 inches = 4.5 inches
  - $A_{brg} = 5.5\ in * 4.5\ in = 24.75\ in^2$

- Bearing stress:
  - $f_{c,brg} = f_{c,brg\perp} = \frac{3{,}840\ lb}{24.75 in^2} = 155\ psi$



Design Example: Bearing

Douglas-Fir Larch #2 capacity:

» Beam: $F_{c\perp} = 625\ psi$ (NDS Supplement, Table 4A)

» Column $F_c = 700\ psi$ (NDS Supplement, Table 4D)

AWC NDS Supplement, Table 4A

Species and commercial grade	Size classification	Design values in pounds per square inch (psi)							Specific Gravity[4]	Grading Rules Agency
		Bending	Tension parallel to grain	Shear parallel to grain	Compression perpendicular to grain	Compression parallel to grain	Modulus of Elasticity			
		F_b	F_t	F_v	$F_{c\perp}$	F_c	E	E_{min}	G	
DOUGLAS FIR-LARCH										
Select Structural	2" & wider	1,500	1,000	180	625	1,700	1,900,000	690,000	0.50	WCLIB WWPA
No. 1 & Btr		1,200	800	180	625	1,550	1,800,000	660,000		
No. 1		1,000	675	180	625	1,500	1,700,000	620,000		
No. 2		900	575	180	625	1,350	1,600,000	580,000		
No. 3		525	325	180	625	775	1,400,000	510,000		
Stud	2" & wider	700	450	180	625	850	1,400,000	510,000		
Construction	2" - 4" wide	1,000	650	180	625	1,650	1,500,000	550,000		
Standard		575	375	180	625	1,400	1,400,000	510,000		
Utility		275	175	180	625	900	1,300,000	470,000		

AWC NDS Supplement, 2018

Design Example: Bearing

Bearing area factor:

- $C_b = \frac{l_b + 0.375}{l_b} = \frac{5.5 + 0.375}{5.5} = 1.068$

Bearing capacity:

- $F'_{c\perp} = F_{c\perp} * C_M * C_t * C_i * C_b$
  - $C_M = C_t = C_i = 1.0$
  - $F'_{c\perp} = 625\ psi * 1.068 = 668\ psi$

Design Example: Bearing

Design Check:

- Demand: $f_{c\perp} = 155\ psi$
- Capacity: $F'_{c\perp} = 668\ psi$

- $f_{c,brg\perp} < F'_{c\perp} \rightarrow$ OK for bearing

Outline

- » Design Basis & Notation
- » Bending Design
- » Shear Design
- » Deflection
- » Compression
- » Bearing
- » **Other Axial**
- » Connections

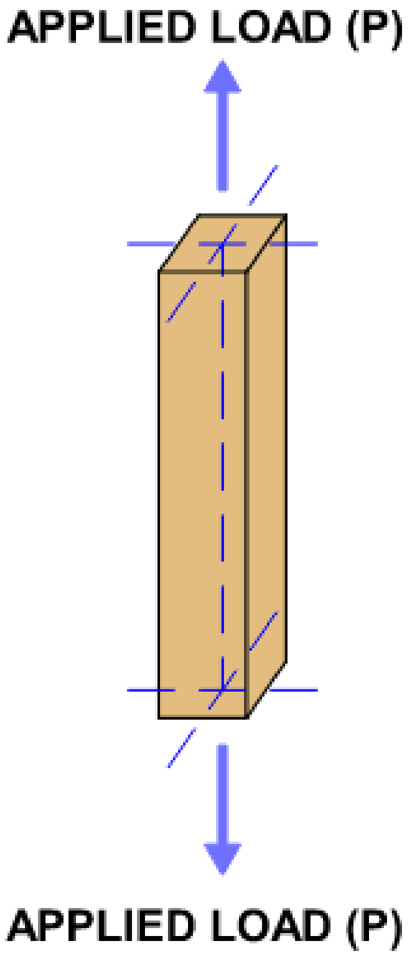
Wood Design: Other Axial

Tension (NDS Section 3.8)

- Tension design check:
  - $f_t \leq F'_t$

    f_t — Demand; F'_t — Adjusted Capacity

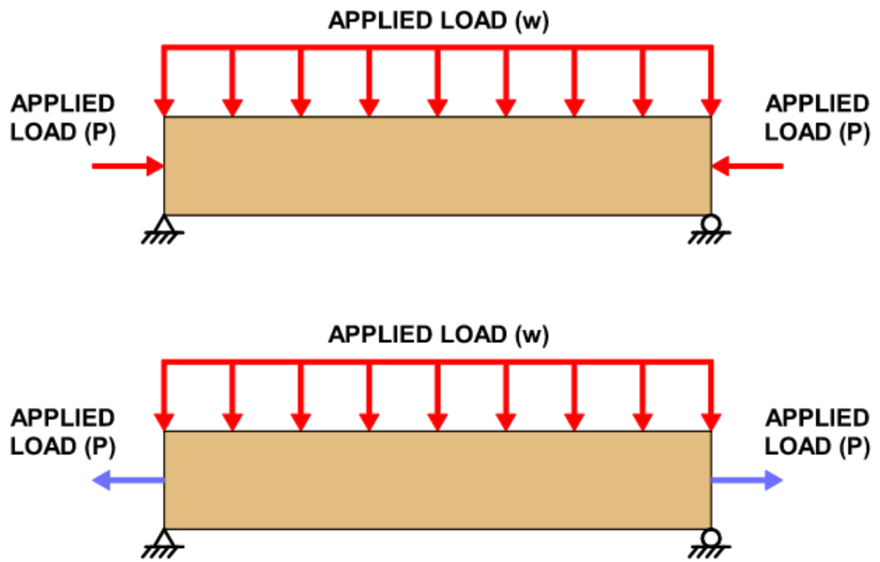
- Actual tension stress:
  - $f_t = \frac{P}{A}$



Wood Design: Combined Bending + Axial

Combined Bending and Axial (NDS Section 3.9)

- Bending + Tension design checks:
  - $\frac{f_t}{F_t'} + \frac{f_b}{F_b^*} \leq 1.0$ (NDS Equation 3.9-1)
  - $\frac{f_b - f_t}{F_b^{**}} \leq 1.0$ (NDS Equation 3.9-2)



- Bending + Compression design checks:
  - $[\frac{f_c}{F_c'}]^2 + \frac{f_{b1}}{F_{b1}' * [1 - (f_c/F_{cE1})]} + \frac{f_{b2}}{F_{b2}' * [1 - (f_c/F_{cE2}) - (f_{b1}/F_{bE})^2]} \leq 1.0$

    (NDS Equation 3.9-3)
  - $\frac{f_c}{F_{cE2}} + (\frac{f_{b1}}{F_{bE}})^2 < 1.0$ (NDS Equation 3.9-4)

Outline

» Design Basis & Notation
» Bending Design
» Shear Design
» Deflection
» Compression
» Bearing
» Other Axial
» **Connections**

Wood Design: Connections

Mechanical connections (NDS Chapter 11)

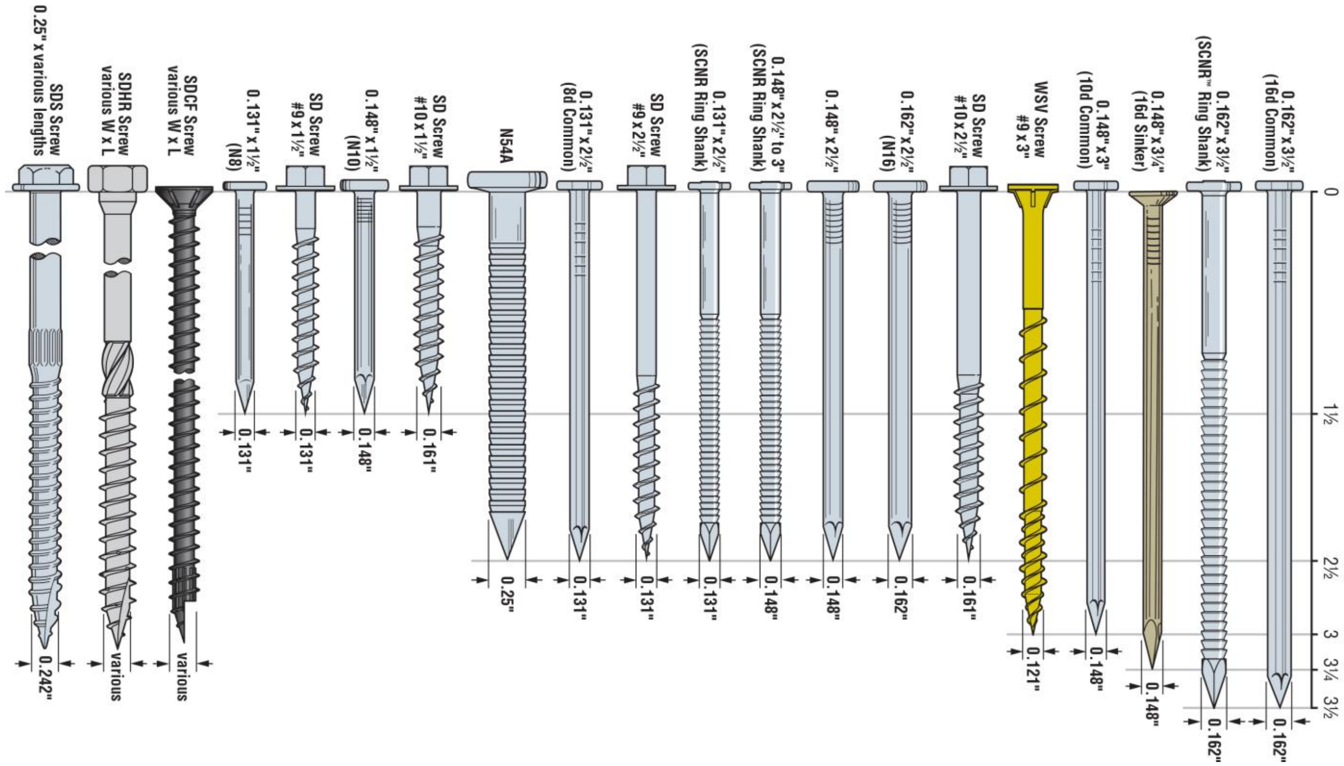
- Dowel-type fasteners
  - Bolts
  - Lag screws
  - Wood screws
  - Nails
  - Spikes
  - Drift bolts
  - Drift pins
  - Other dowel-type fasteners
- Connectors:
  - Split ring connectors
  - Shear plate connectors
  - Timber rivets
  - Spike grids
  - Other fasteners

iStock, ozgurdonmaz, 174679319

Wood Design: Connections

Dowel-type fasteners (NDS Chapter 12):

- Withdrawal / Pull-through (NDS Section 12.2)
- Lateral (NDS Section 12.3)



Simpson Strong-Tie

Wood Design: Connections

Withdrawal design values:

Fastener Size

Table 12.2B Cut Thread or Rolled Thread Wood Screw Reference Withdrawal Design Values, W[1]

Tabulated withdrawal design values, W, are in pounds per inch of thread penetration into side grain of wood member (see 12.2.2.1).

Specific Gravity, G[2]	Wood Screw Number										
	6	7	8	9	10	12	14	16	18	20	24
0.73	209	229	249	268	288	327	367	406	446	485	564
0.71	198	216	235	254	272	310	347	384	421	459	533
0.68	181	199	216	233	250	284	318	352	387	421	489
0.67	176	193	209	226	243	276	309	342	375	409	475
0.58	132	144	157	169	182	207	232	256	281	306	356
0.55	119	130	141	152	163	186	208	231	253	275	320
0.51	102	112	121	131	141	160	179	198	217	237	275
0.50	98	107	117	126	135	154	172	191	209	228	264
0.49	94	103	112	121	130	147	165	183	201	219	254
0.47	87	95	103	111	119	136	152	168	185	201	234
0.46	83	91	99	107	114	130	146	161	177	193	224
0.44	76	83	90	97	105	119	133	148	162	176	205
0.43	73	79	86	93	100	114	127	141	155	168	196
0.42	69	76	82	89	95	108	121	134	147	161	187
0.41	66	72	78	85	91	103	116	128	141	153	178
0.40	63	69	75	81	86	98	110	122	134	146	169
0.39	60	65	71	77	82	93	105	116	127	138	161
0.38	57	62	67	73	78	89	99	110	121	131	153
0.37	54	59	64	69	74	84	94	104	114	125	145
0.36	51	56	60	65	70	80	89	99	108	118	137
0.35	48	53	57	62	66	75	84	93	102	111	130
0.31	38	41	45	48	52	59	66	73	80	87	102

Wood Specific Gravity

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Wood Design: Connections

Withdrawal design values:

Table 12.2B Cut Thread or Rolled Thread Wood Screw Reference Withdrawal Design Values, W[1]

Tabulated withdrawal design values, W, are in pounds per inch of thread penetration into side grain of wood member (see 12.2.2.1).

Specific Gravity, G[2]	Wood Screw Number										
	6	7	8	9	10	12	14	16	18	20	24
0.73	209	229	249	268	288	327	367	406	446	485	564
0.71	198	216	235	254	272	310	347	384	421	459	533
0.68	181	199	216	233	250	284	318	352	387	421	489
0.67	176	193	209	226	243	276	309	342	375	409	475
0.58	132	144	157	169	182	207	232	256	281	306	356
0.55	119	130	141	152	163	186	208	231	253	275	320
0.51	102	112	121	131	141	160	179	198	217	237	275
0.50	98	107	117	126	135	154	172	191	209	228	264
0.49	94	103	112	121	130	147	165	183	201	219	254
0.47	87	95	103	111	119	136	152	168	185	201	234
0.46	83	91	99	107	114	130	146	161	177	193	224
0.44	76	83	90	97	105	119	133	148	162	176	205
0.43	73	79	86	93	100	114	127	141	155	168	196
0.42	69	76	82	89	95	108	121	134	147	161	187
0.41	66	72	78	85	91	103	116	128	141	153	178
0.40	63	69	75	81	86	98	110	122	134	146	169
0.39	60	65	71	77	82	93	105	116	127	138	161
0.38	57	62	67	73	78	89	99	110	121	131	153
0.37	54	59	64	69	74	84	94	104	114	125	145
0.36	51	56	60	65	70	80	89	99	108	118	137
0.35	48	53	57	62	66	75	84	93	102	111	130
0.31	38	41	45	48	52	59	66	73	80	87	102

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Wood Design: Connections

Lateral design values:

Table 12.3.1A Yield Limit Equations

Yield Mode	Single Shear		Double Shear	
I_m	$Z = \frac{D \ell_m F_{em}}{R_d}$	(12.3-1)	$Z = \frac{D \ell_m F_{em}}{R_d}$	(12.3-7)
I_s	$Z = \frac{D \ell_s F_{es}}{R_d}$	(12.3-2)	$Z = \frac{2 D \ell_s F_{es}}{R_d}$	(12.3-8)
II	$Z = \frac{k_1 D \ell_s F_{es}}{R_d}$	(12.3-3)		
III_m	$Z = \frac{k_2 D \ell_m F_{em}}{(1+2R_e) R_d}$	(12.3-4)		
III_s	$Z = \frac{k_3 D \ell_s F_{em}}{(2+R_e) R_d}$	(12.3-5)	$Z = \frac{2 k_3 D \ell_s F_{em}}{(2+R_e) R_d}$	(12.3-9)
IV	$Z = \frac{D^2}{R_d} \sqrt{\frac{2 F_{em} F_{yb}}{3(1+R_e)}}$	(12.3-6)	$Z = \frac{2 D^2}{R_d} \sqrt{\frac{2 F_{em} F_{yb}}{3(1+R_e)}}$	(12.3-10)

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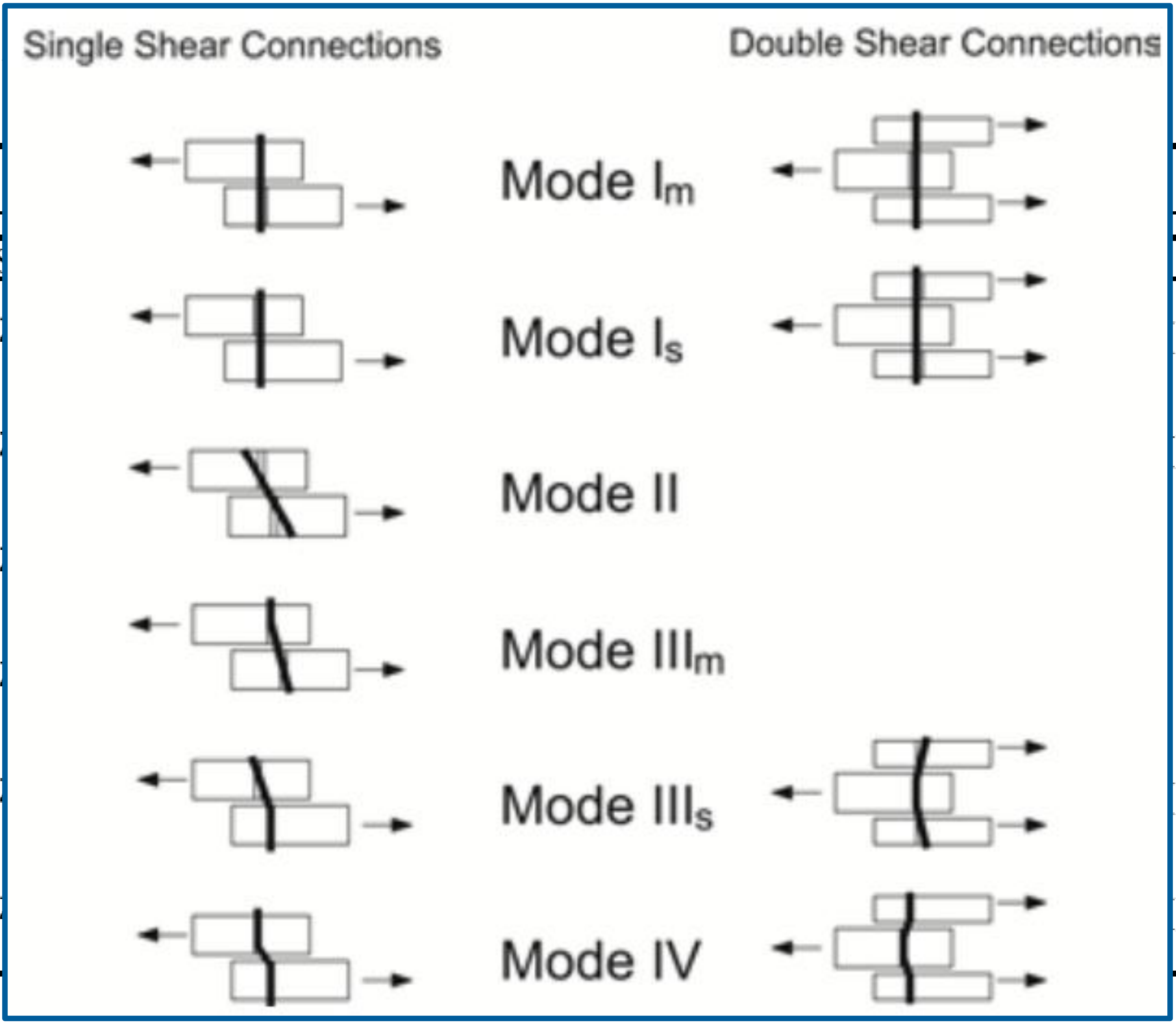
Wood Design: Connections

Lateral design

Table 12.3.1A

Yield Mode	S	
I_m		(12.3-7)
I_s		(12.3-8)
II		
III_m		
III_s		(12.3-9)
IV		(12.3-10)



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AWC TR12, Figure 2-1

Wood Design: Connections

Lateral design values:

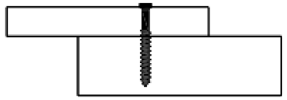
Fastener Size

Wood Specific Gravity

Wood Member Thickness

Table 12L **WOOD SCREWS: Reference Lateral Design Values, Z, for Single Shear (two member) Connections[1,2,3]**

for sawn lumber or SCL with both members of identical specific gravity (tabulated lateral design values are calculated based on an assumed length of wood screw penetration, p, into the main member equal to 10D)



Side Member Thickness t_s in.	Wood Screw Diameter D in.	Wood Screw Number	G=0.67 Red Oak lbs.	G=0.55 Mixed Maple Southern Pine lbs.	G=0.5 Douglas Fir-Larch lbs.	G=0.49 Douglas Fir-Larch(N) lbs.	G=0.46 Douglas Fir(S) Hem-Fir(N) lbs.	G=0.43 Hem-Fir lbs.	G=0.42 Spruce-Pine-Fir lbs.	G=0.37 Redwood lbs.	G=0.36 Eastern Softwoods Spruce-Pine-Fir(S) Western Cedars Western Woods lbs.	G=0.35 Northern Species lbs.
1/2	0.138	6	88	67	59	57	53	49	47	41	40	38
	0.151	7	96	74	65	63	59	54	52	45	44	42
	0.164	8	107	82	73	71	66	61	59	51	50	48
	0.177	9	121	94	83	81	76	70	68	59	58	56
	0.190	10	130	101	90	87	82	75	73	64	63	60
	0.216	12	156	123	110	107	100	93	91	79	78	75
	0.242	14	168	133	120	117	110	102	99	87	86	83
5/8	0.138	6	94	76	66	64	59	53	52	44	43	41
	0.151	7	104	83	72	70	64	58	56	48	47	45
	0.164	8	120	92	80	77	72	65	63	54	53	51
	0.177	9	136	103	91	88	81	74	72	62	61	58
	0.190	10	146	111	97	94	88	80	78	67	65	63
	0.216	12	173	133	117	114	106	97	95	82	80	77
	0.242	14	184	142	126	123	115	106	103	89	87	84
3/4	0.138	6	94	79	72	71	65	58	57	47	46	44
	0.151	7	104	87	80	77	71	64	62	52	50	48
	0.164	8	120	101	88	85	78	71	69	58	56	54
	0.177	9	142	114	99	96	88	80	78	66	64	61

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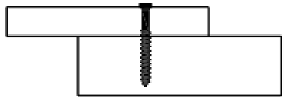
Wood Design: Connections

Lateral design values:

Table 12L **WOOD SCREWS: Reference Lateral Design Values, Z, for Single Shear (two member) Connections[1,2,3]**

for sawn lumber or SCL with both members of identical specific gravity (tabulated lateral design values are calculated based on an assumed length of wood screw penetration, p, into the main member equal to 10D)



Side Member Thickness t_s in.	Wood Screw Diameter D in.	Wood Screw Number	G=0.67 Red Oak lbs.	G=0.55 Mixed Maple Southern Pine lbs.	G=0.5 Douglas Fir-Larch lbs.	G=0.49 Douglas Fir-Larch(N) lbs.	G=0.46 Douglas Fir(S) Hem-Fir(N) lbs.	G=0.43 Hem-Fir lbs.	G=0.42 Spruce-Pine-Fir lbs.	G=0.37 Redwood lbs.	G=0.36 Eastern Softwoods Spruce-Pine-Fir(S) Western Cedars Western Woods lbs.	G=0.35 Northern Species lbs.
1/2	0.138	6	88	67	59	57	53	49	47	41	40	38
	0.151	7	96	74	65	63	59	54	52	45	44	42
	0.164	8	107	82	73	71	66	61	59	51	50	48
	0.177	9	121	94	83	81	76	70	68	59	58	56
	0.190	10	130	101	90	87	82	75	73	64	63	60
	0.216	12	156	123	110	107	100	93	91	79	78	75
	0.242	14	168	133	120	117	110	102	99	87	86	83
5/8	0.138	6	94	76	66	64	59	53	52	44	43	41
	0.151	7	104	83	72	70	64	58	56	48	47	45
	0.164	8	120	92	80	77	72	65	63	54	53	51
	0.177	9	136	103	91	88	81	74	72	62	61	58
	0.190	10	146	111	97	94	88	80	78	67	65	63
	0.216	12	173	133	117	114	106	97	95	82	80	77
	0.242	14	184	142	126	123	115	106	103	89	87	84
3/4	0.138	6	94	79	72	71	65	58	57	47	46	44
	0.151	7	104	87	80	77	71	64	62	52	50	48
	0.164	8	120	101	88	85	78	71	69	58	56	54
	0.177	9	142	114	99	96	88	80	78	66	64	61

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Wood Design: Connections

Adjustment Factors:

Table 11.3.1 Applicability of Adjustment Factors for Connections

		ASD Only	ASD and LRFD										LRFD Only		
		Load Duration Factor[1]	Wet Service Factor	Temperature Factor	Group Action Factor	Geometry Factor[3]	Penetration Depth Factor[3]	End Grain Factor[3]	Metal Side Plate Factor[3]	Diaphragm Factor[3]	Toe-Nail Factor[3]	Format Conversion Factor K_F	Resistance Factor ϕ	Time Effect Factor
Lateral Loads														
Dowel-type Fasteners (e.g. bolts, lag screws, wood screws, nails, spikes, drift bolts, & drift pins)	$Z' = Z$ x	C_D	C_M	C_t	C_g	C_Δ	-	C_{eg}	-	C_{di}	C_{tn}	3.32	0.65	λ
Split Ring and Shear Plate Connectors	$P' = P$ x	C_D	C_M	C_t	C_g	C_Δ	C_d	-	C_{st}	-	-	3.32	0.65	λ
	$Q' = Q$ x	C_D	C_M	C_t	C_g	C_Δ	C_d	-	-	-	-	3.32	0.65	λ
Timber Rivets	$P' = P$ x	C_D	C_M	C_t	-	-	-	-	C_{st}[4]	-	-	3.32	0.65	λ
	$Q' = Q$ x	C_D	C_M	C_t	-	C_Δ[5]	-	-	C_{st}[4]	-	-	3.32	0.65	λ
Spike Grids	$Z' = Z$ x	C_D	C_M	C_t	-	C_Δ	-	-	-	-	-	3.32	0.65	λ
Withdrawal Loads														
Nails, spikes, lag screws, wood screws, & drift pins	$W' = W$ x	C_D	C_M[2]	C_t	-	-	-	C_{eg}	-	-	C_{tn}	3.32	0.65	λ
Pull-Through														
Fasteners with Round Heads	$W'_H = W_H$ x	C_D	C_M	C_t	-	-	-	-	-	-	-	3.32	0.65	λ

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Wood Design: Connections

Adjustment Factors:

Table 11.3.1 Applicability of Adjustment Factors for Connections

		ASD Only	ASD and LRFD									LRFD Only		
		Load Duration Factor [1]	Wet Service Factor	Temperature Factor	Group Action Factor	Geometry Factor [3]	Penetration Depth Factor [3]	End Grain Factor [3]	Metal Side Plate Factor [3]	Diaphragm Factor [3]	Toe-Nail Factor [3]	Format Conversion Factor	Resistance Factor	Time Effect Factor
												K_F	ϕ	
Withdrawal Loads														
Nails, spikes, lag screws, wood screws, & drift pins	$W' = W$ x	C_D	C_M[2]	C_t	-	-	-	C_{eg}	-	-	C_{tn}	3.32	0.65	λ
Pull-Through														
Fasteners with Round Heads	$W'_H = W_H$ x	C_D	C_M	C_t	-	-	-	-	-	-	-	3.32	0.65	λ

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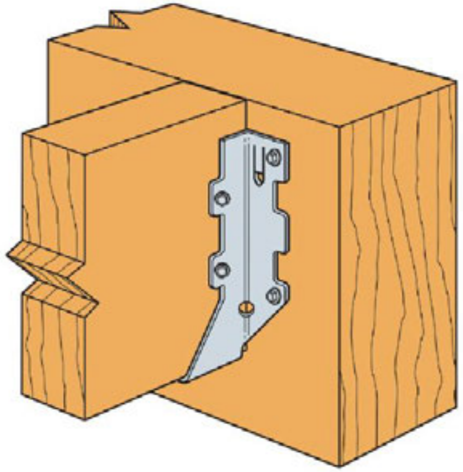
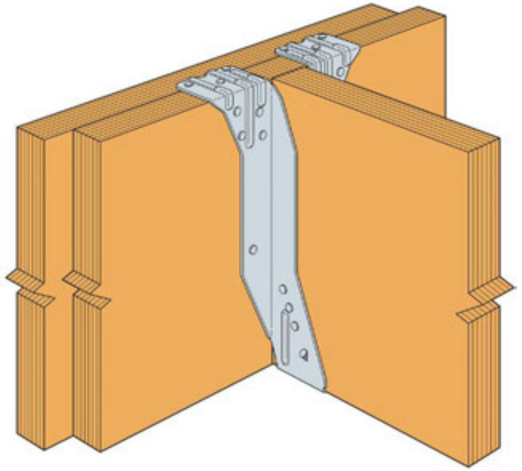
Wood Design: Connections

Prefabricated Hardware

- Capacity based on testing
- See manufacturer literature



Simpson LUS Hanger



Simpson BA Hanger

MiTek JUS
Joist Hanger

MiTek FSC Framing Clip

Outline

» Design Basis & Notation
» Bending Design
» Shear Design
» Deflection
» Compression
» Bearing
» Other Axial
» Connections

QUESTIONS?

This concludes The American Institute of Architects Continuing Education Systems Course

Anthony Harvey, PE

WoodWorks

anthony.harvey@woodworks.org

Erin Kinder, PE, SE, LEED AP

WoodWorks

erin.kinder@woodworks.org

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