KM3

AMERICAN WOOD COUNCIL

Connection Design with the NDS and Technical Report 12

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American Wood Council

This webinar is presented on behalf of NCSEA National Council of Structural Engineers Associations

Slide 1

KM3 If you have time, I suggest increase the font sizes throughout the presentation. Maybe this is something that you can have Kim do. Also, check some of slides graphics as they may have the graphics cut off at the bottom of the slides.
Kam-Biron, Michelle, 1/25/2017

Copyright Materials

AMERICAN WOOD COUNCIL

Course Description

This course will feature techniques for designing connections for wood members utilizing AWC's 2015 *National Design Specification® (NDS®) for Wood Construction* and *Technical Report 12 - General Dowel Equations for Calculating Lateral Connection Values* (TR12). Topics will include connection design philosophy and behavior, an overview of common fastener types, changes in the 2015 NDS related to cross-laminated timber, and design examples per TR12.

Learning Objectives

- **On completion of this course, participants will:**

1. **Be familiar with current wood member connection solutions and applicable design requirements.**
2. **Be familiar with Technical Report 12 and provisions for connection design beyond NDS requirements.**
3. **Be able to recommend fastening guidelines for wood to steel, wood to concrete, and wood to wood connections.**
4. **Be able to describe effects of moisture on wood member connections and implement proper detailing to mitigate issues that may occur.**

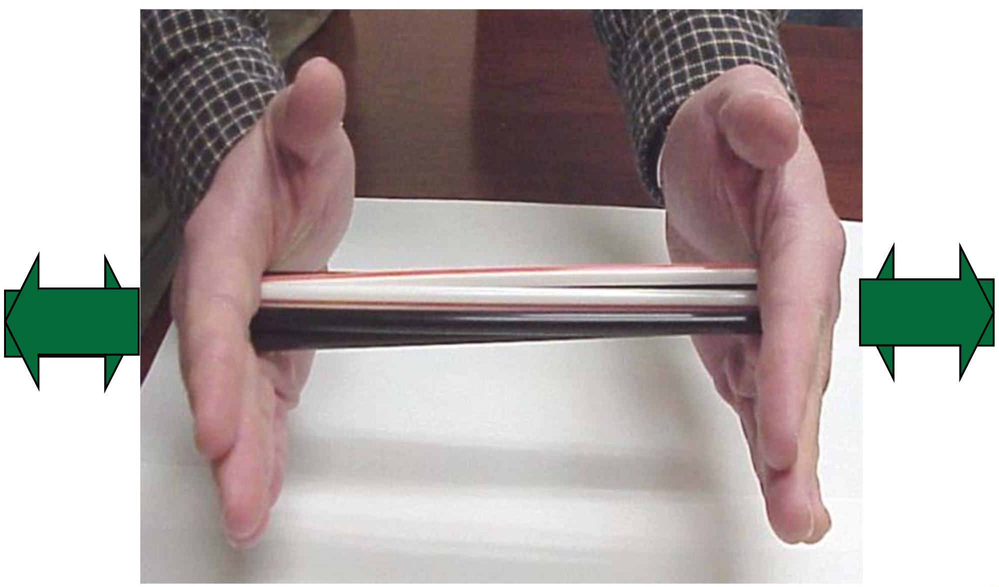
Outline

- **Wood connection design philosophy**
- **Connection behavior**
- **Serviceability challenges**
- **Connection hardware and fastening systems**
- **Connection techniques**
- **Design software**
- **Where to get more information**

Basic Concepts

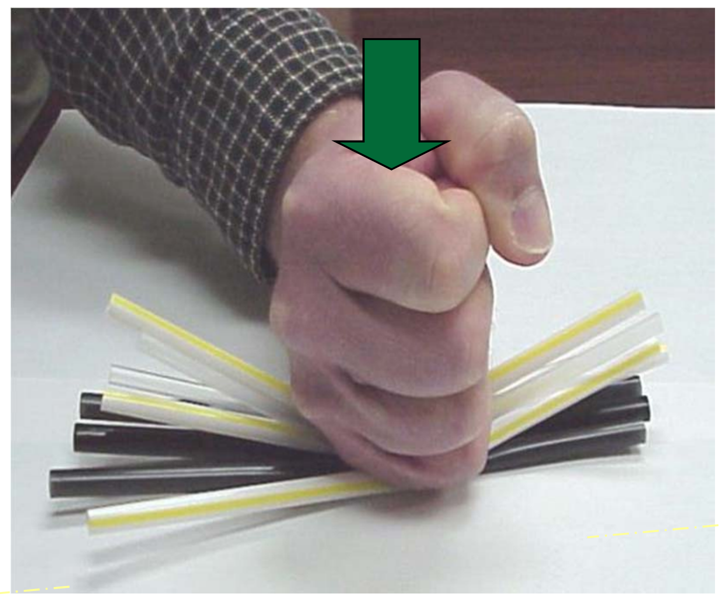
- Model wood cells as a bundle of straws
- Bundle is very strong parallel to axis of the straws

Parallel



Stronger

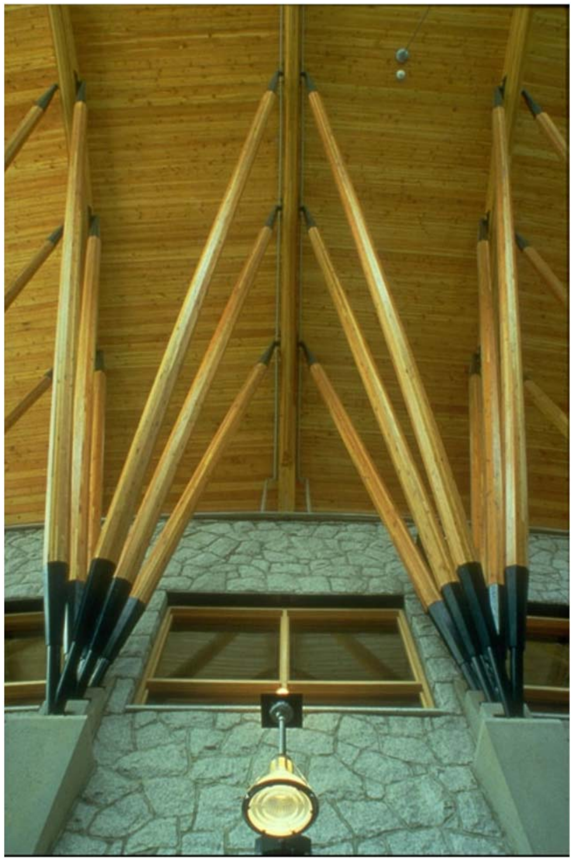
Perpendicular



Less strong

Connecting Wood - Philosophy

- Wood likes compression parallel to grain
  - makes connecting wood very easy

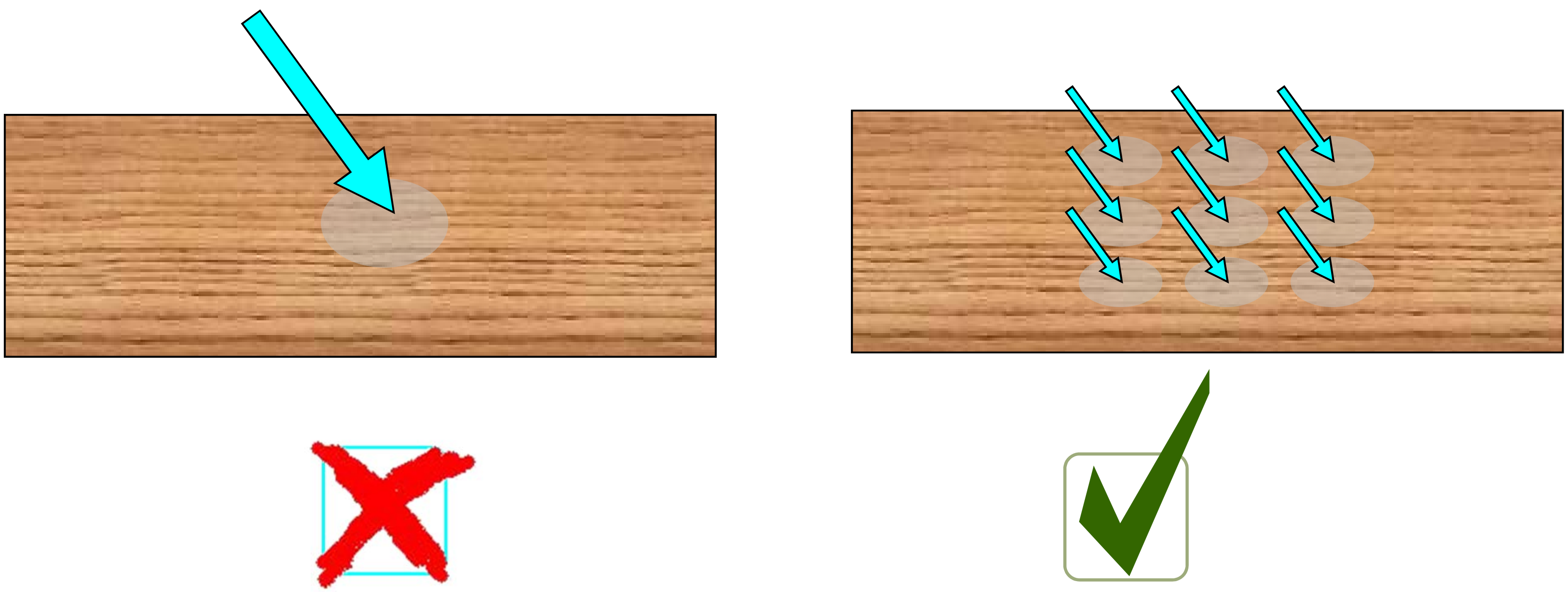


Connecting Wood - Philosophy

- Wood likes compression parallel to grain
  - makes connecting wood very easy

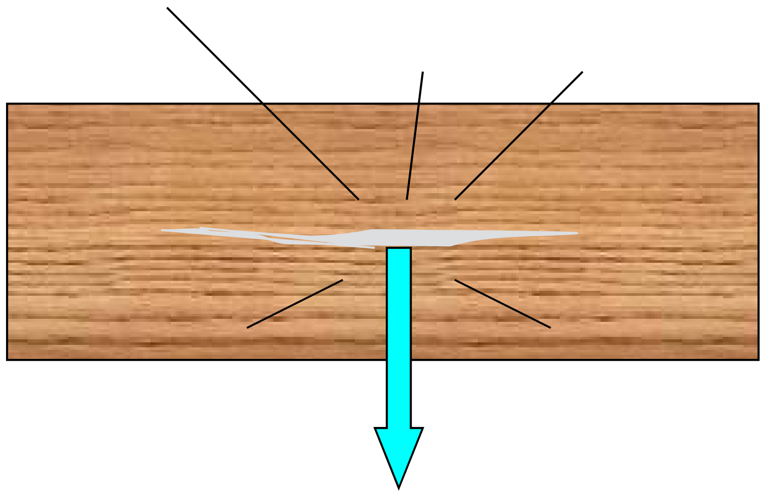
Connecting Wood - Philosophy

- **Wood likes to take on load spread over its surface**



Connecting Wood - Philosophy

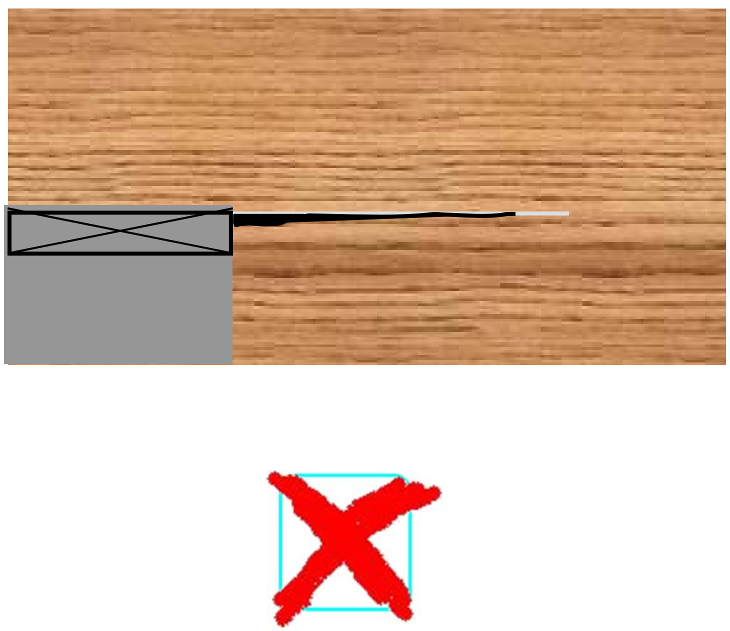
- **Wood and tension perpendicular to grain**
  - **Not recommended**



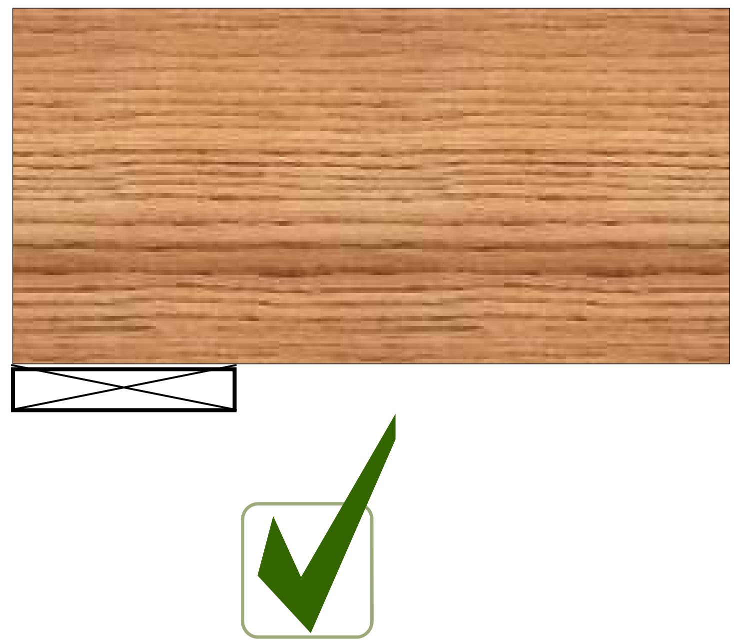
Initiators:
- notches
- large diameter fasteners
- hanging loads

Notching

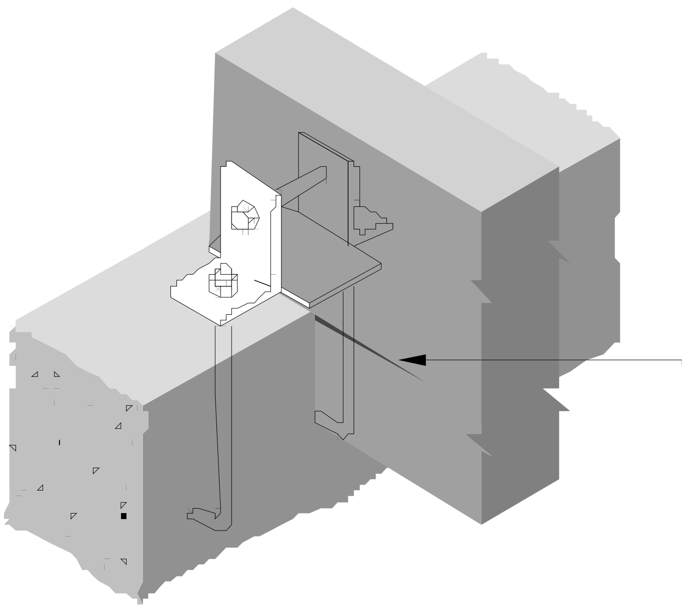
Problem



Solution

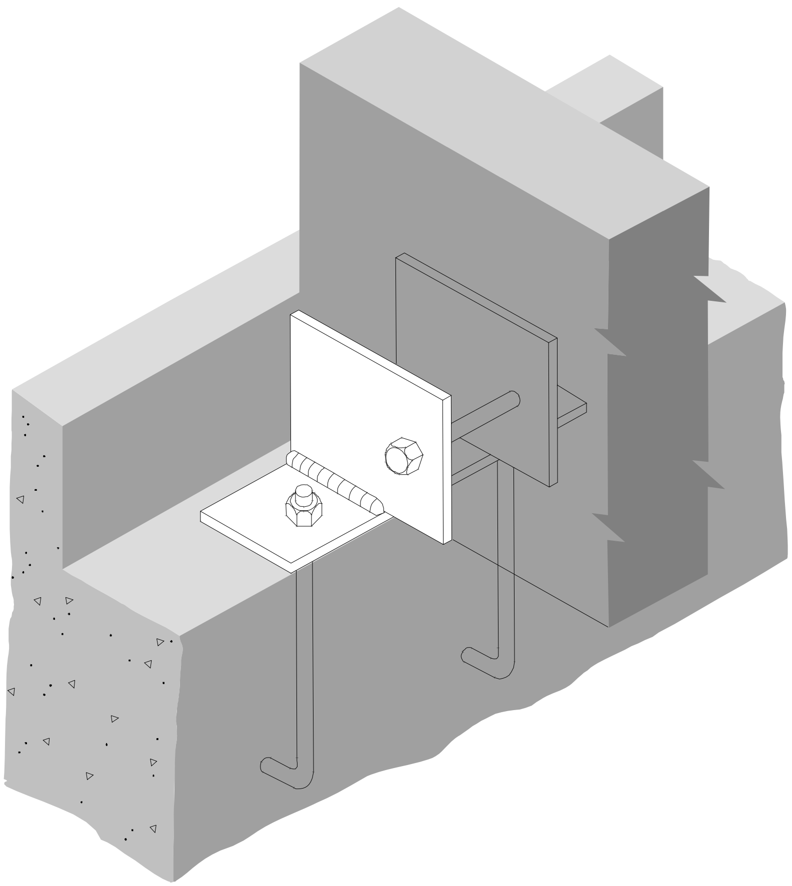


Beam to Concrete



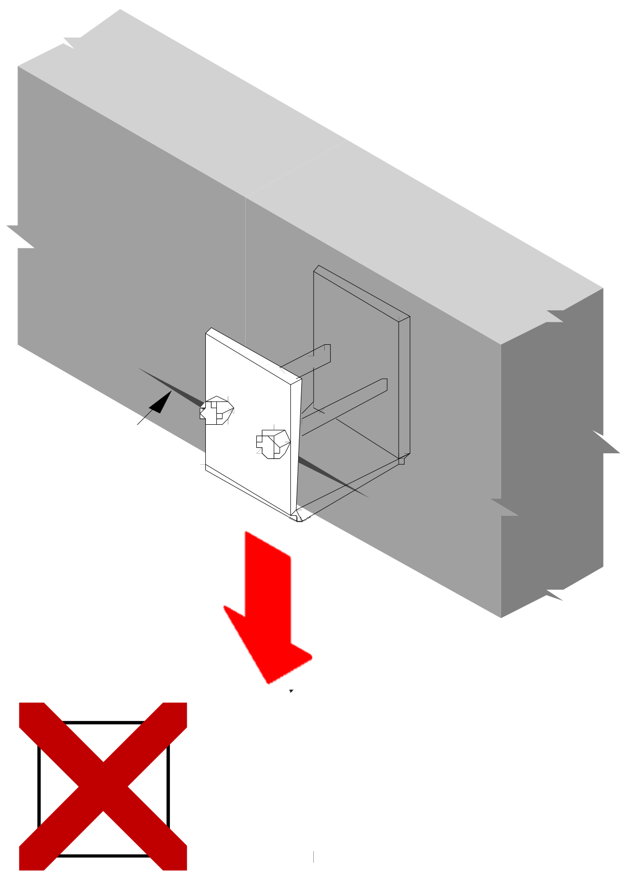
- **Notched Beam Bearing**
  - may cause splitting
  - not recommended

Beam to Concrete

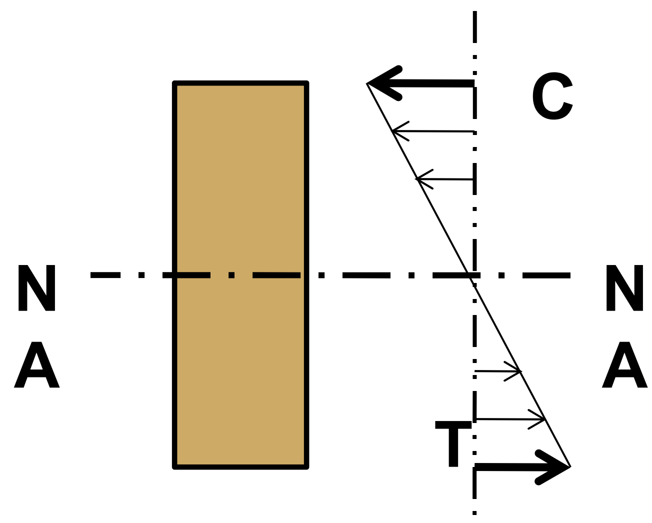


- **Notched Bearing Wall**
  - **alternate to beam notch**

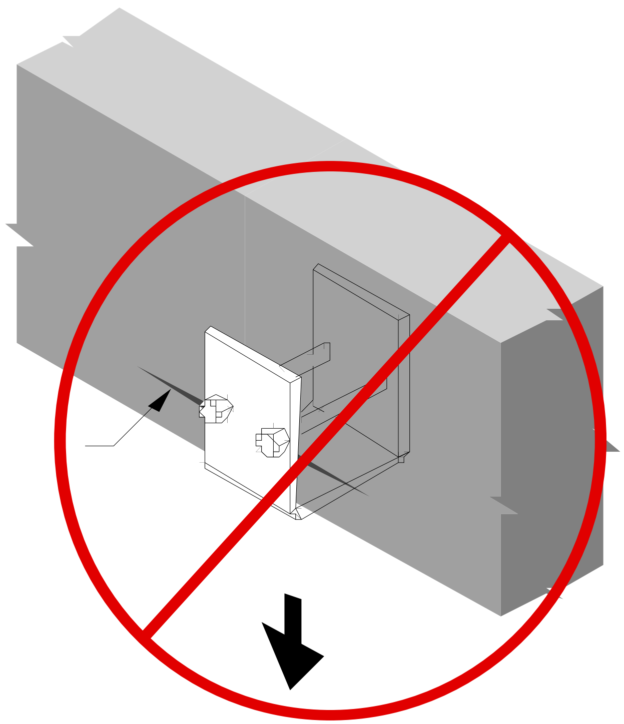
Hanger to Beam



- **Load suspended from lower half of beam**
  - **Tension perpendicular to grain**
  - **May cause splits**



Hanger to Beam



Lower half of beam

- may cause splits
- not recommended

Exception: light load

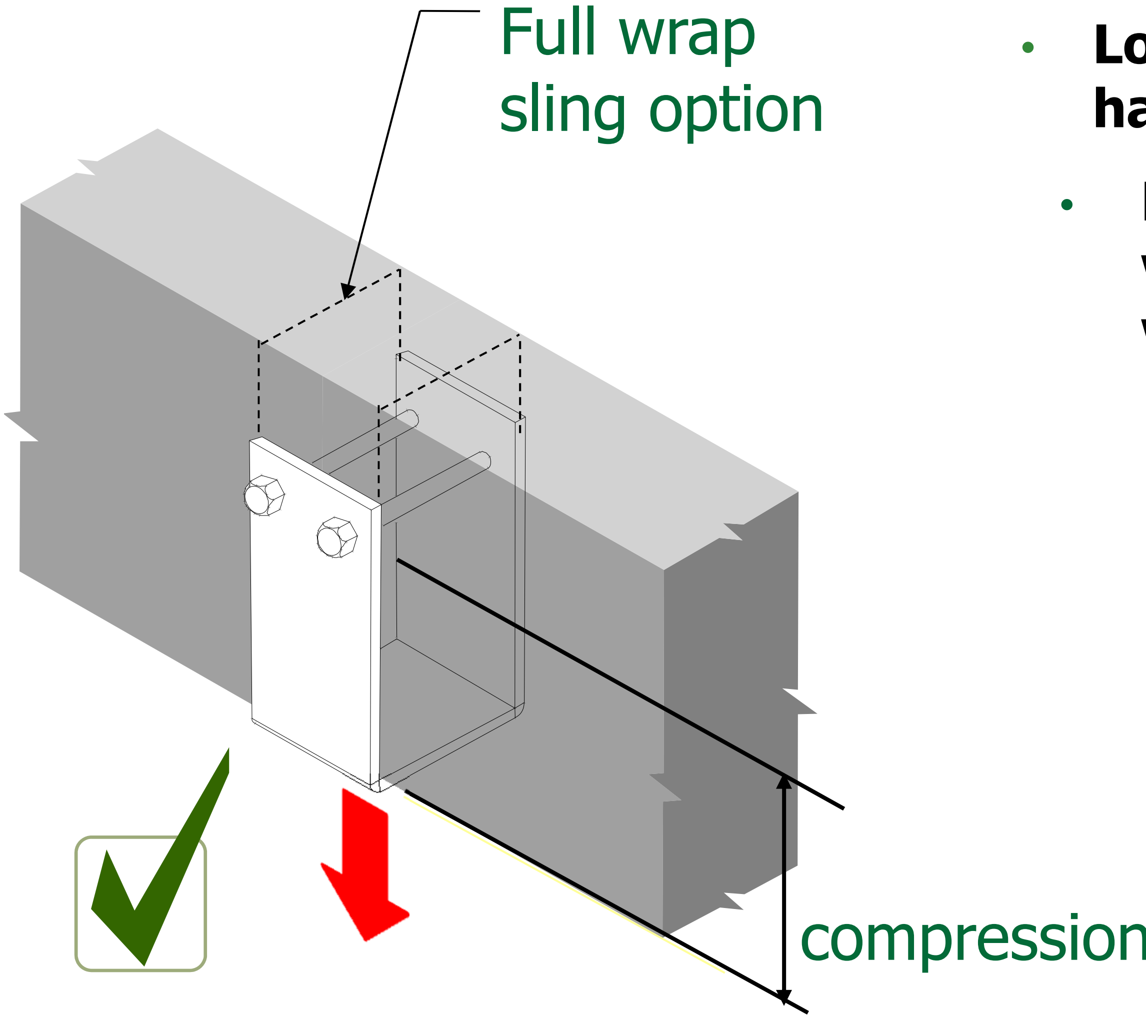
- **<100 lbs**
- **>24” o.c.**

KM4

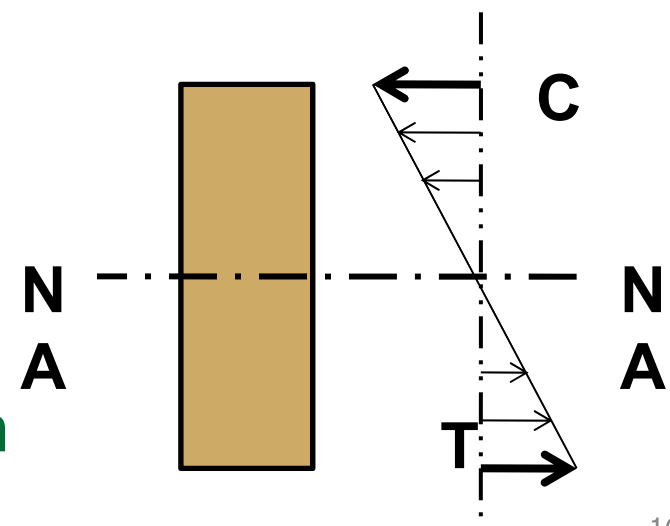
Slide 15

KM4 I believe this is per the exception is per the NDS, you might mention where it states this.
Kam-Biron, Michelle, 1/25/2017

Hanger to Beam



- **Load supported in upper half of beam**
  - **Extended plates puts wood in compression when loaded**

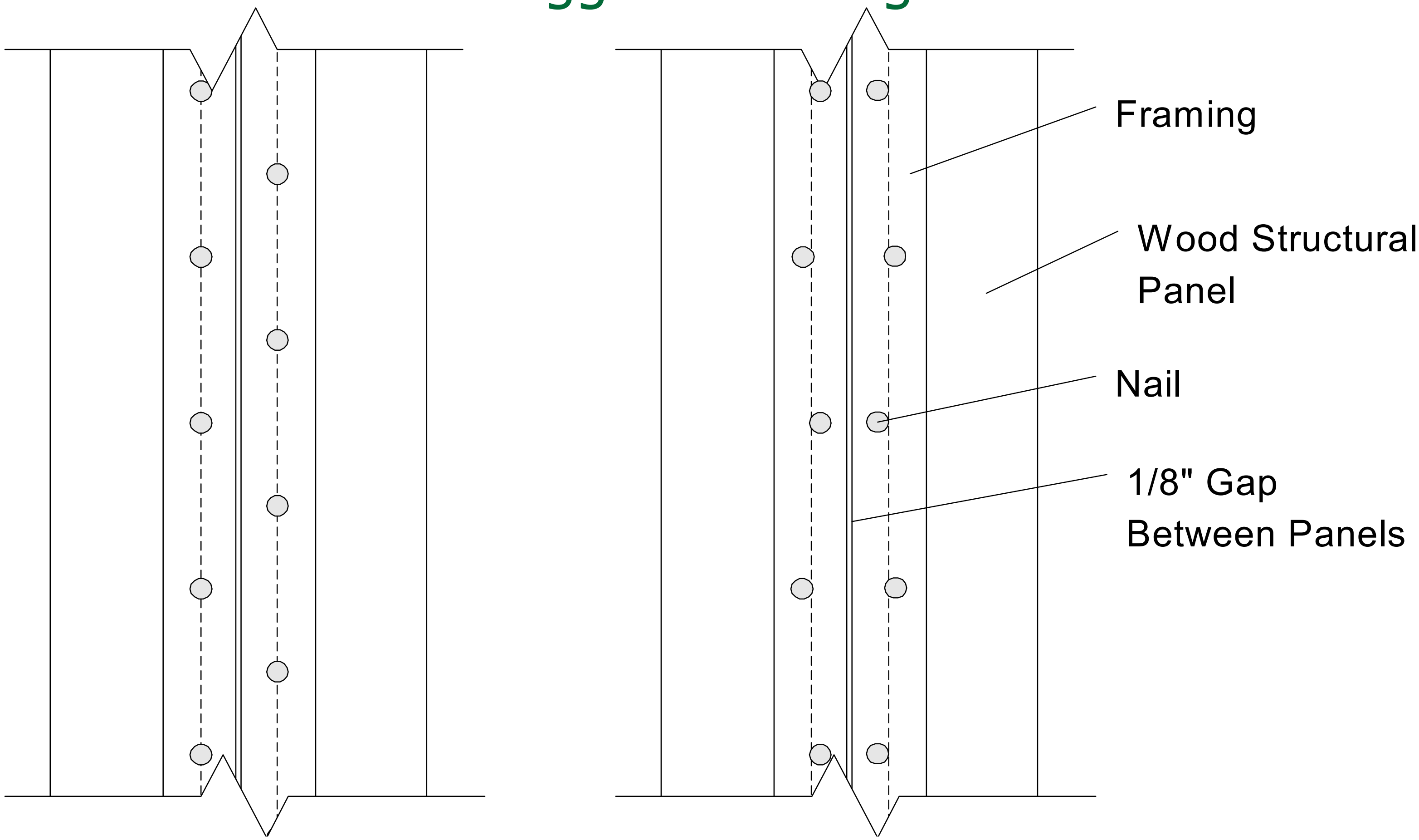


Connecting Wood- Philosophy

- **Splitting happens because wood is relatively weak perpendicular to grain**
  - **Nails too close (act like a wedge)**

Connecting Wood - Philosophy

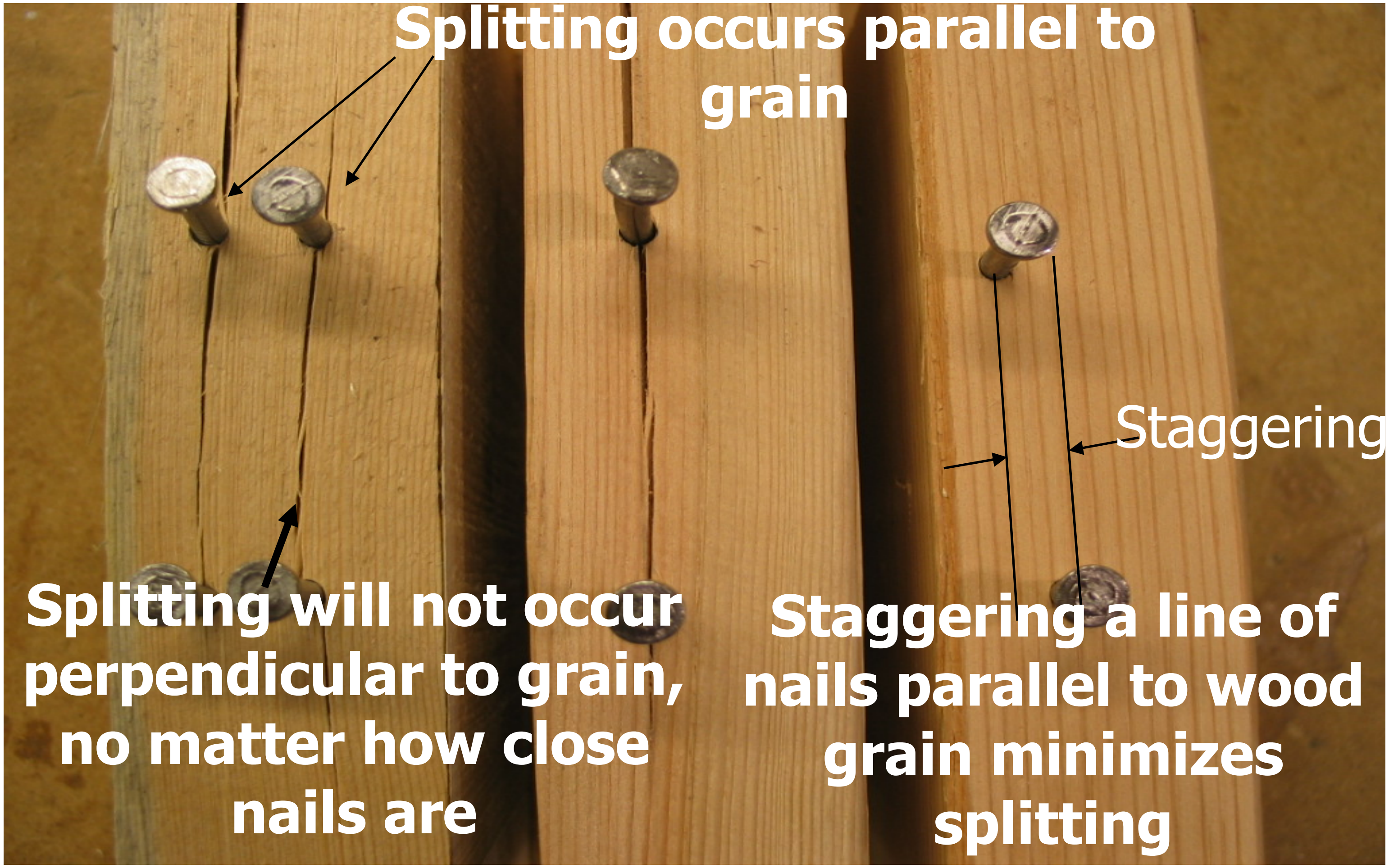
Staggered Nailing



Nailing not staggered

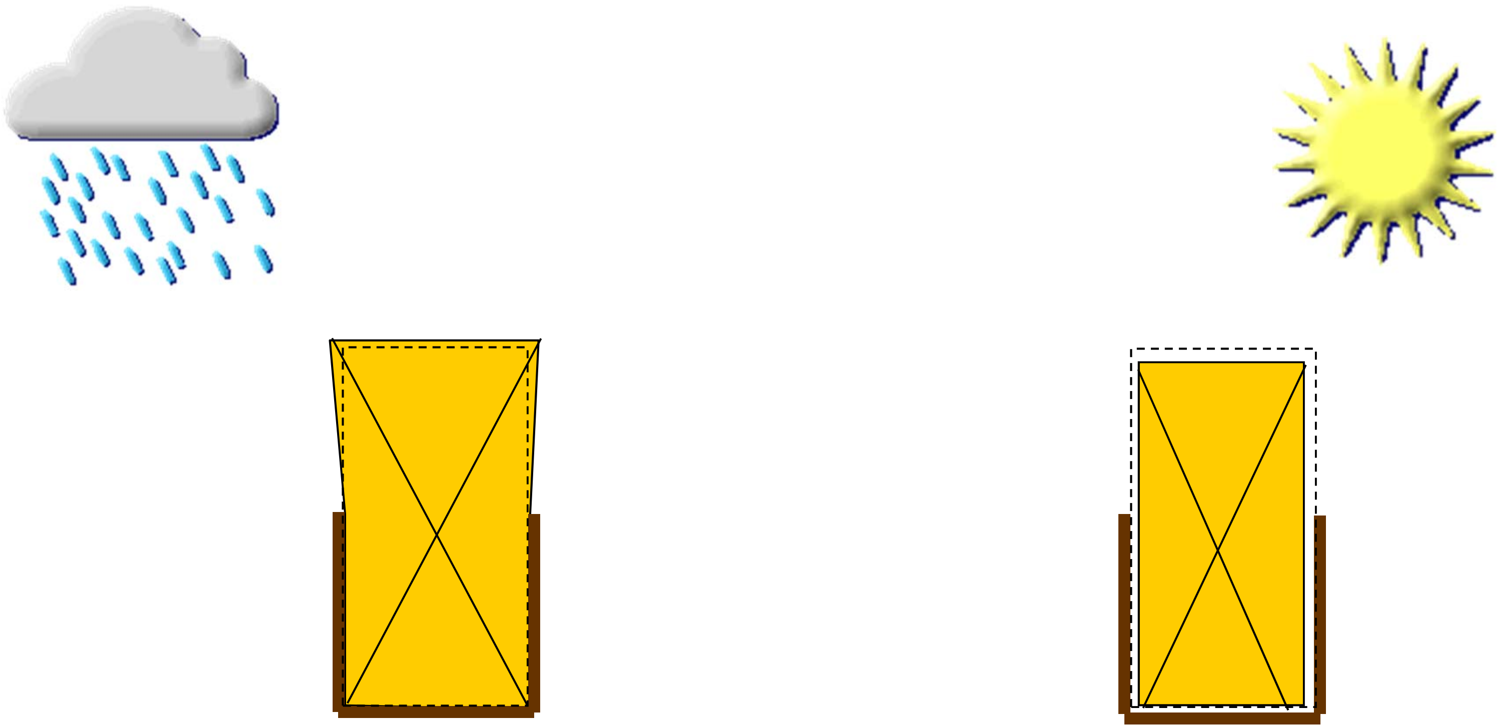
Nailing staggered

Connecting Wood- Philosophy



Connecting Wood - Philosophy

- **Wood, like other hygroscopic materials, moves in varying environments**



Connecting Wood - Philosophy

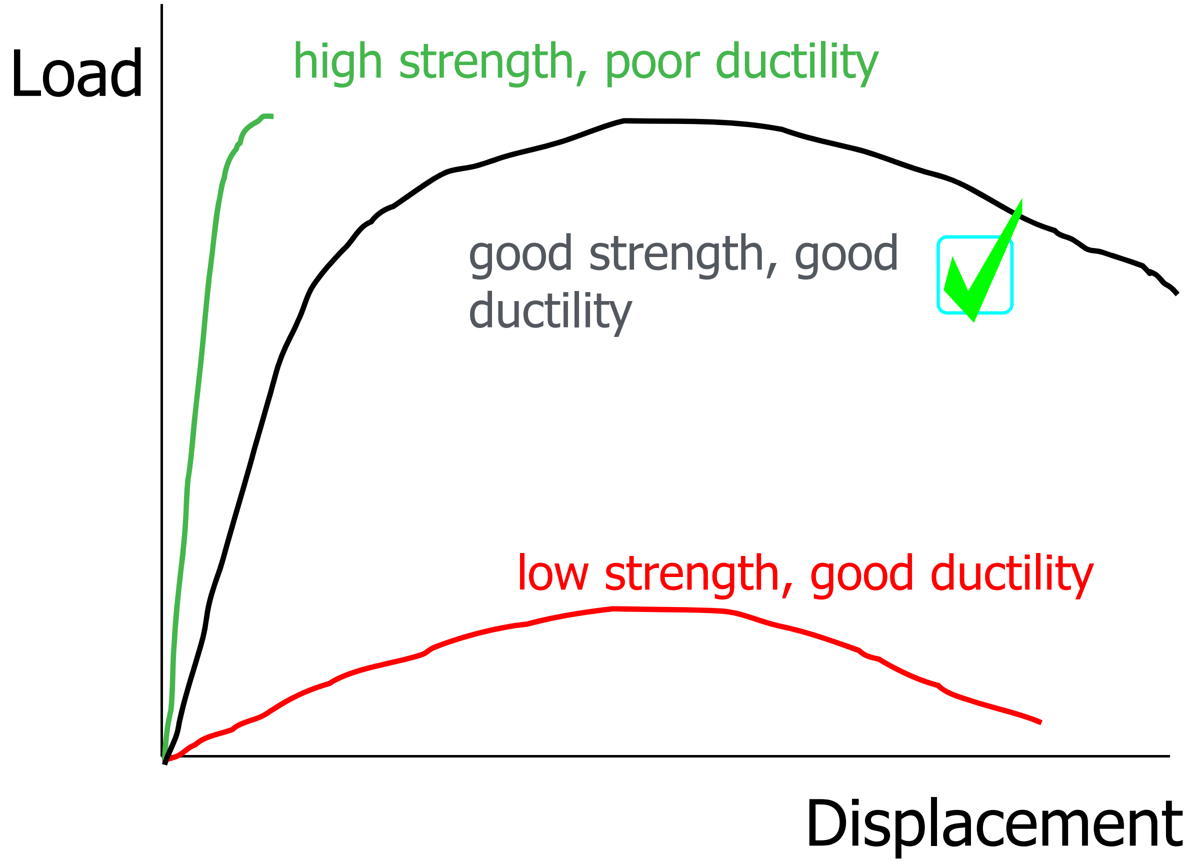
- **Fastener selection is key to connection ductility, strength, performance**

Outline

- **Wood connection design philosophy**
- **Connection behavior**
- **Serviceability challenges**
- **Connection hardware and fastening systems**
- **Connection techniques**
- **Design software**
- **Where to get more information**

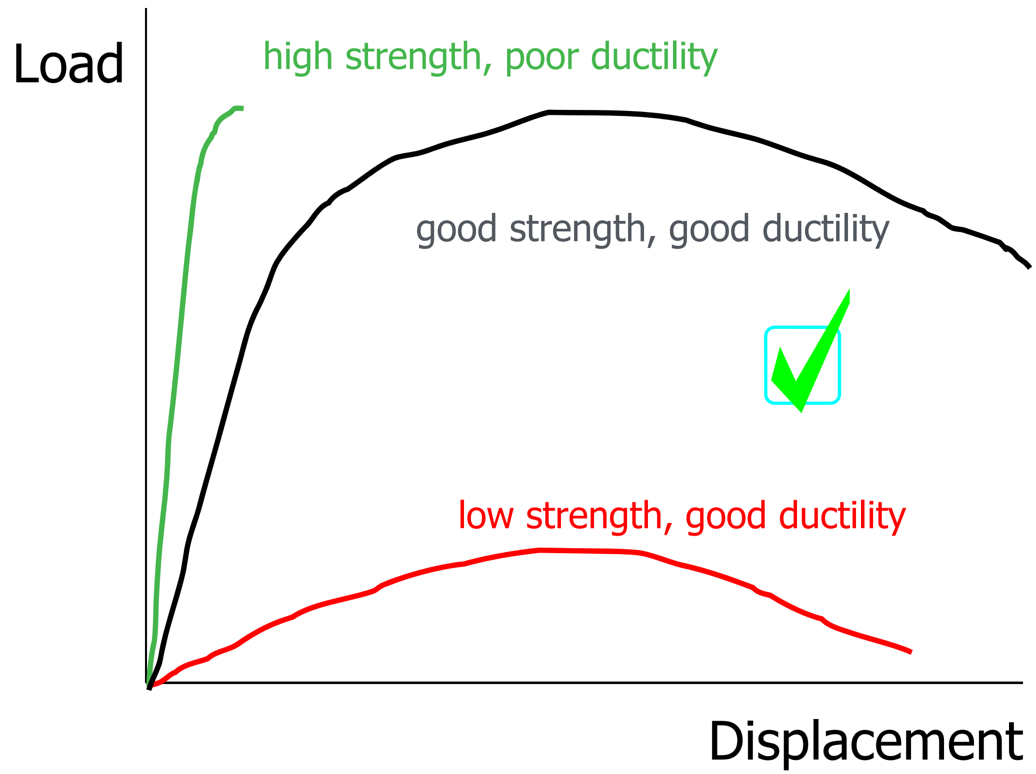
Connection Behavior

- Balance
  - Strength –
  - Ductility-



Connection Behavior

- Balance
- Strength –
  - Size and number of fasteners
- Ductility-
  - Fastener slenderness
  - Spacing
  - End distance



Outline

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Connection Serviceability

- **Issue: direct water ingress**
- **Water is absorbed most quickly through wood end grain**

No end caps or flashing

Connection Serviceability

- **Issue: direct water ingress**
- **Re-direct the water flow around the connection**

☑ end caps and flashing

Connection Serviceability

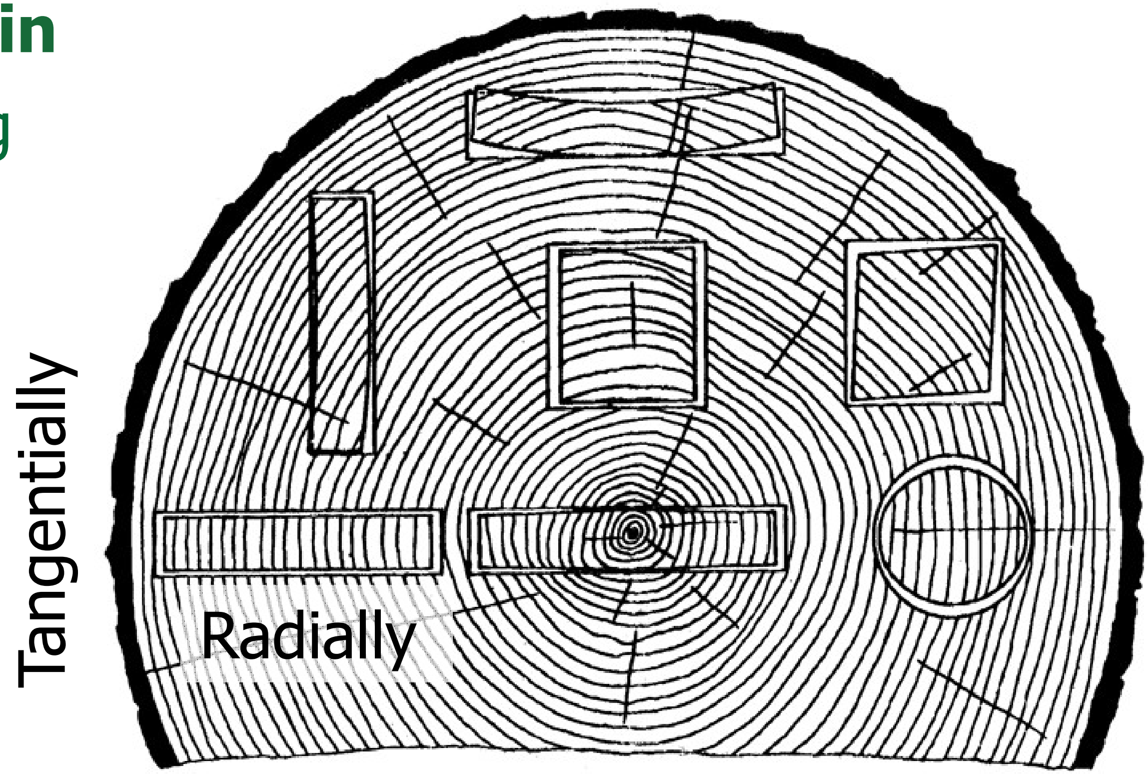
- **Issue: direct water ingress**
- **Or, let water out if it gets in…**

Moister trap -
No weep holes

Moisture Changes In Wood

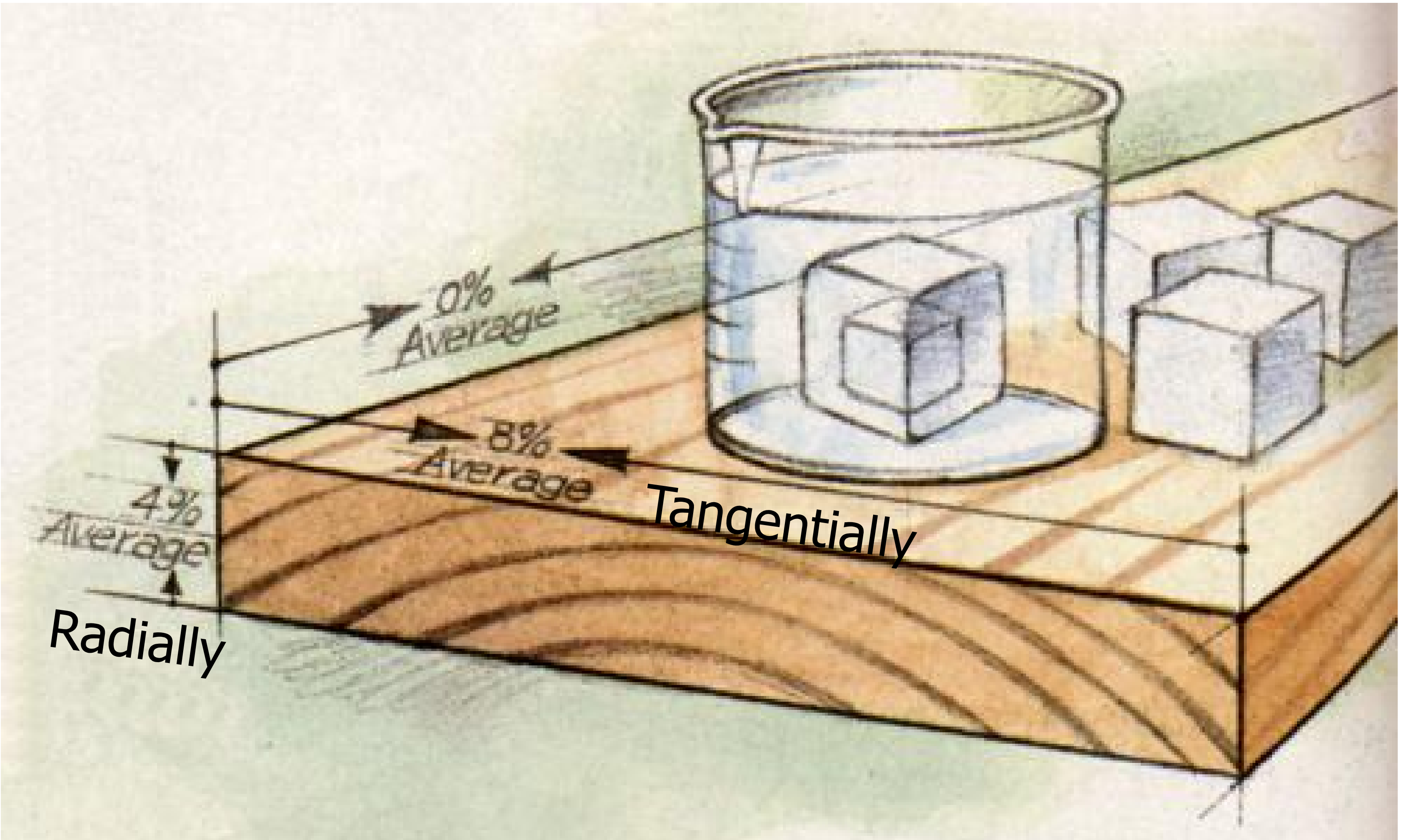
Causes dimensional changes perpendicular to grain

Growing tree is filled with water



As wood dries, it shrinks perp. to grain

Wood Shrinks

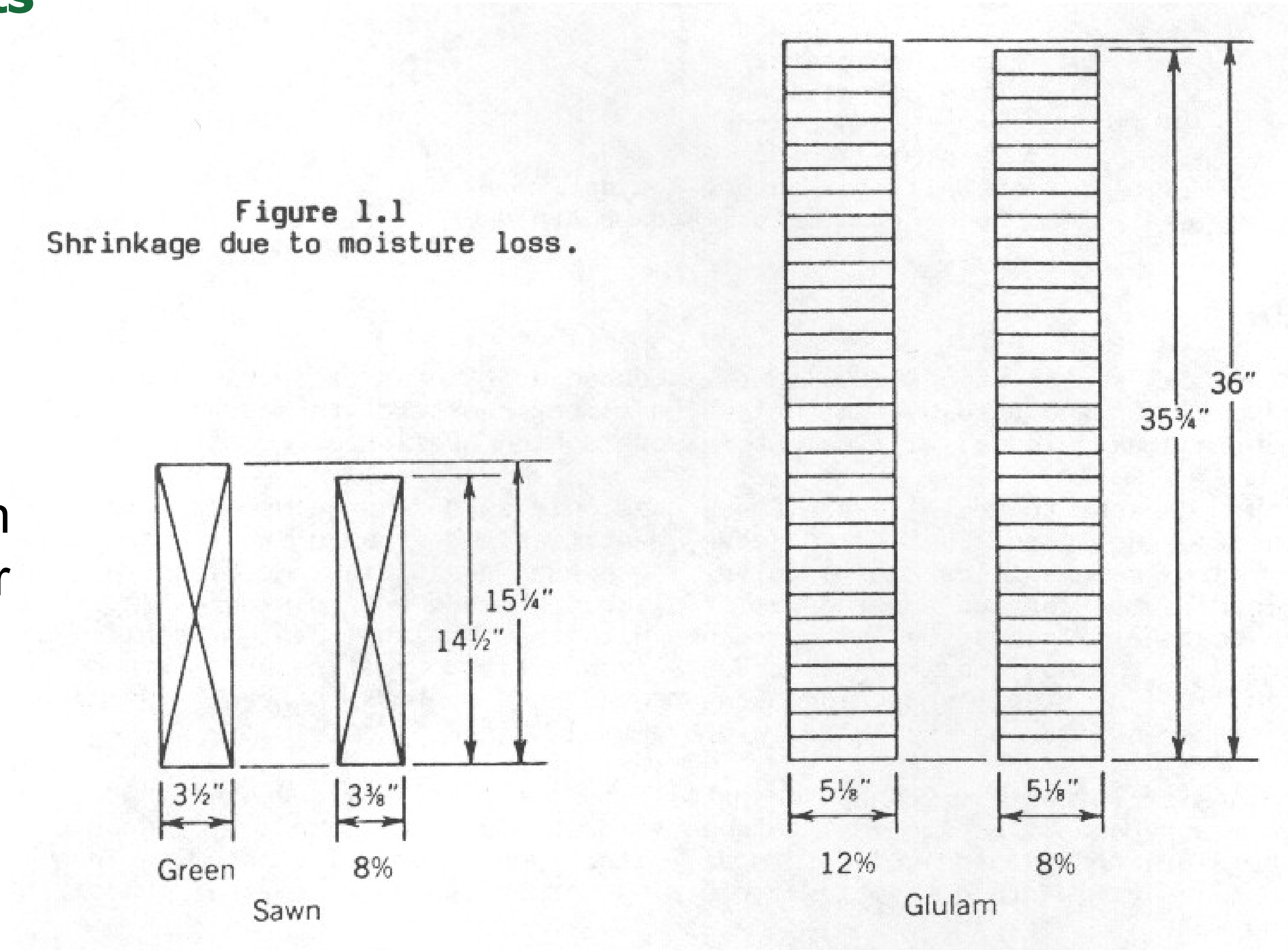


Woodmagazine.com

Connection Serviceability

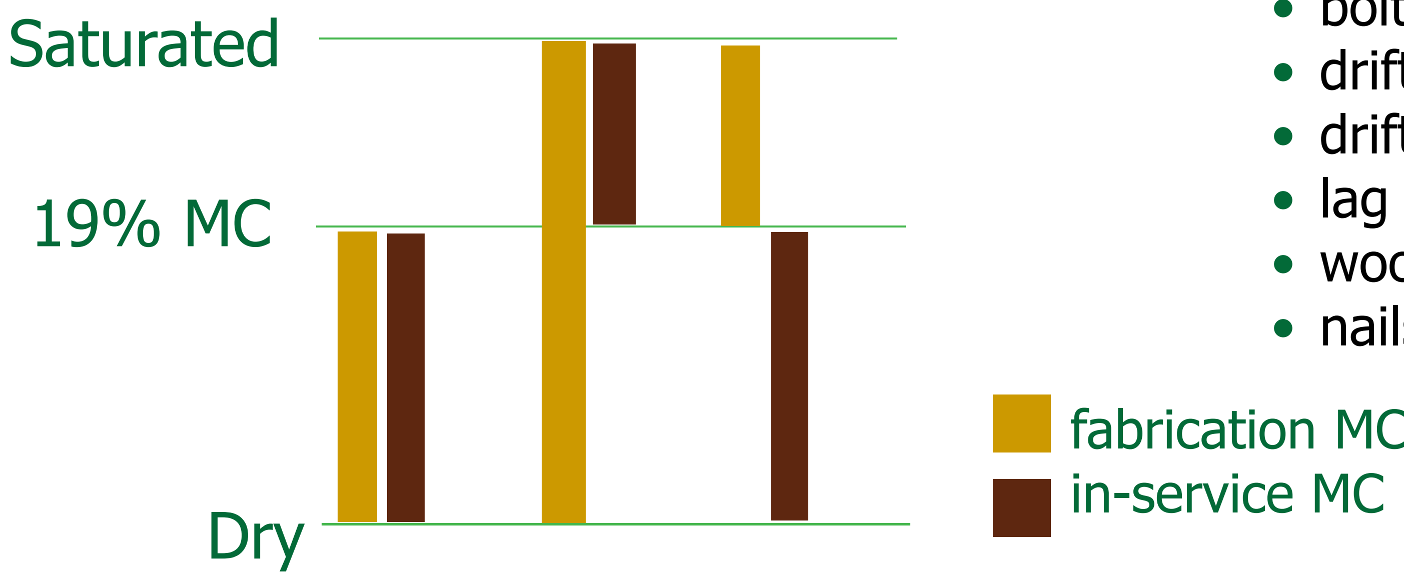
- **Moisture Effects**

1% change in dimension for every 4% change MC



Wet Service Factor, C_M

- Dowel-type connectors
  - bolts
  - drift pins
  - drift bolts
  - lag screws
  - wood screws
  - nails

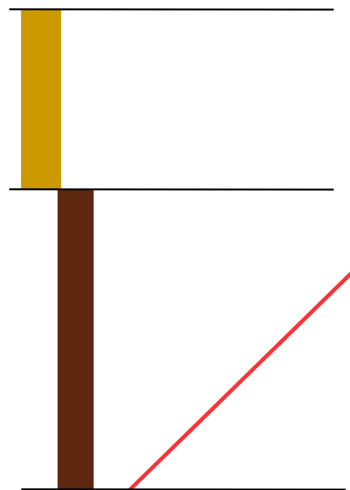


C_M	1.0	0.7	0.4*	Lateral load (*C_M=0.7 for D<1/4″)
	1.0	0.7	1.0	Withdrawal load - lag & wood screws only
	1.0	0.25	0.25	Withdrawal load - nails & spikes

Wet Service Factor, C_M

Saturated

19% MC



Dry

C_M 0.4 Lateral load (D>1/4")

fabrication MC

in-service MC

$C_M = 1.0$ if:

1 fastener

2+ fasteners

split splice plates

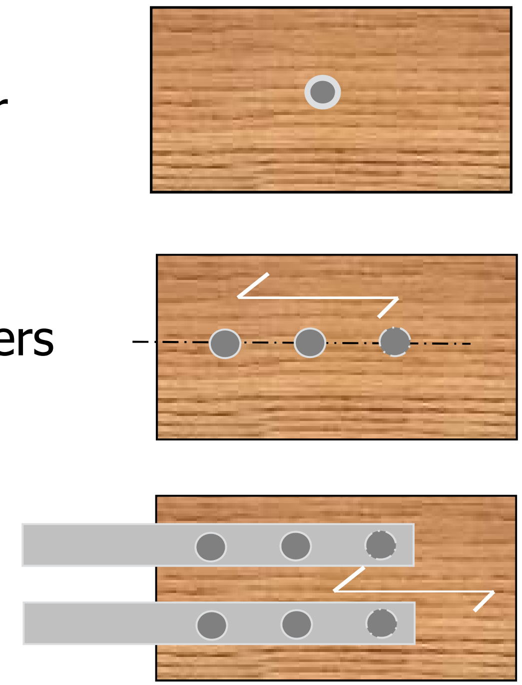
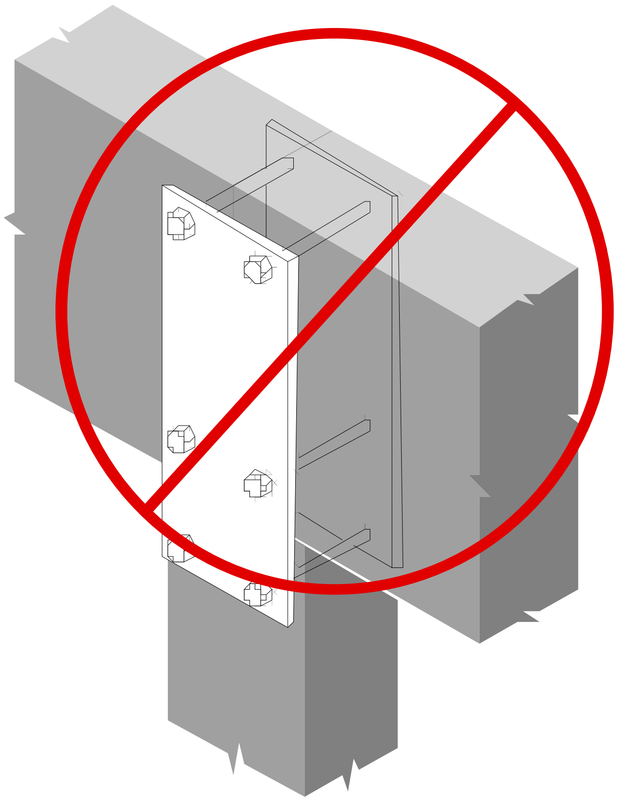


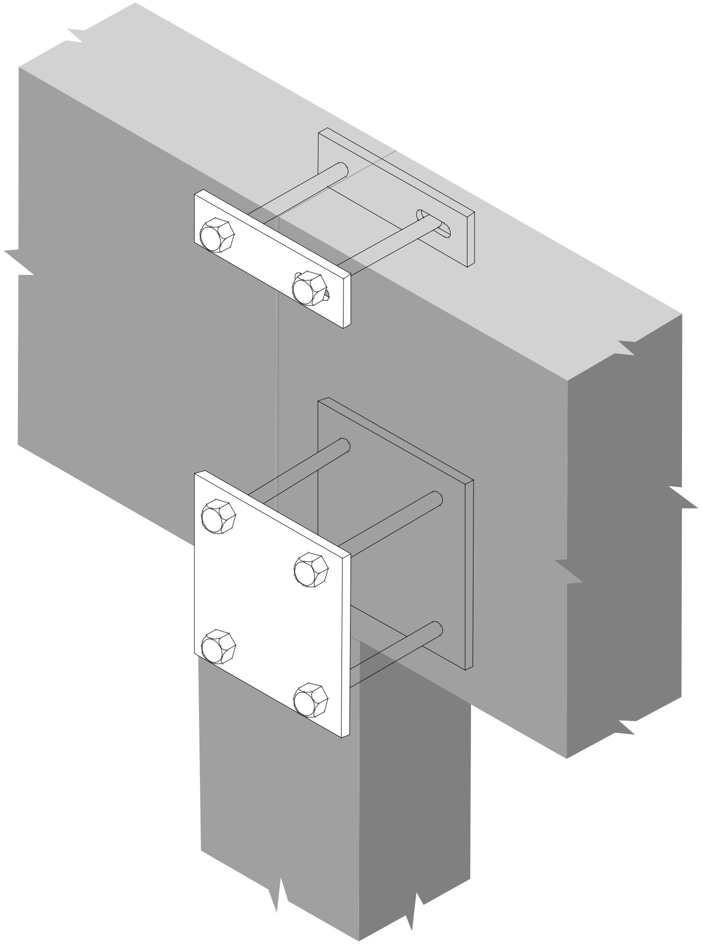
Table 11.3.3 footnote 2

Beam to Column



- **Full-depth side plates**
  - may cause splitting
  - wood shrinkage

Beam to Column

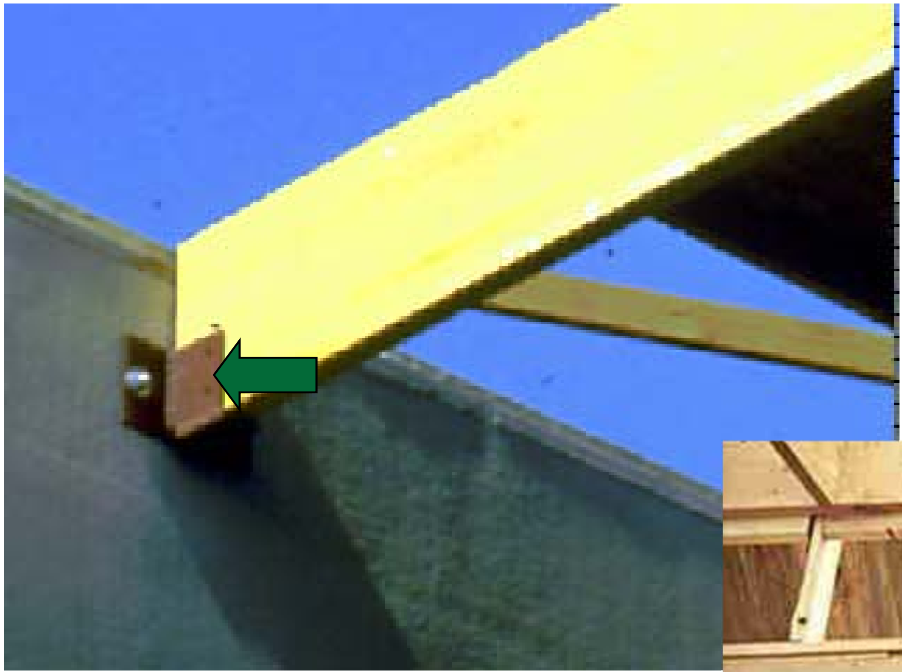


- **Smaller side plates**
  - **transmit force**
  - **allow wood movement**

Beam to Column

- **Problem**
  - **shrinkage**
  - **tension perp**

Beam to Wall

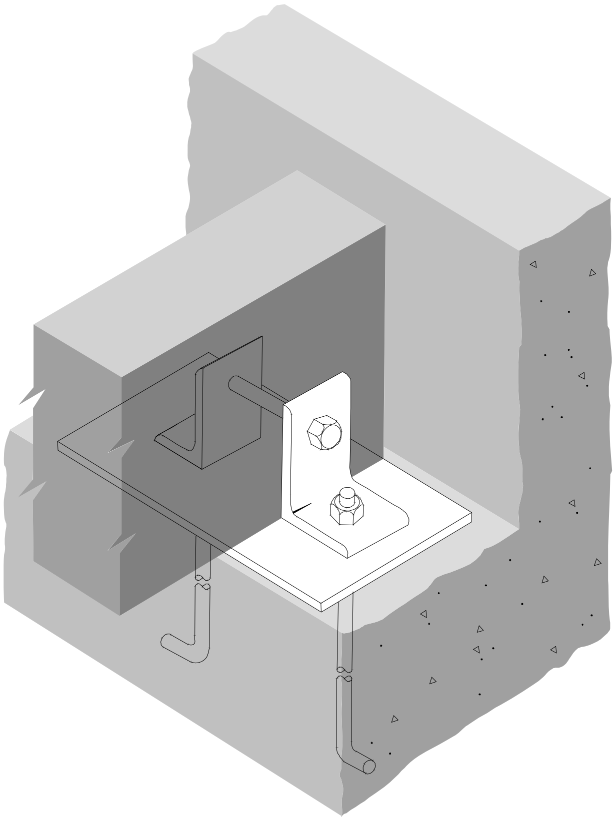


- **Solution**
  - **bolts near bottom**
  - **minimizes effect of shrinkage**

Slotted hardware

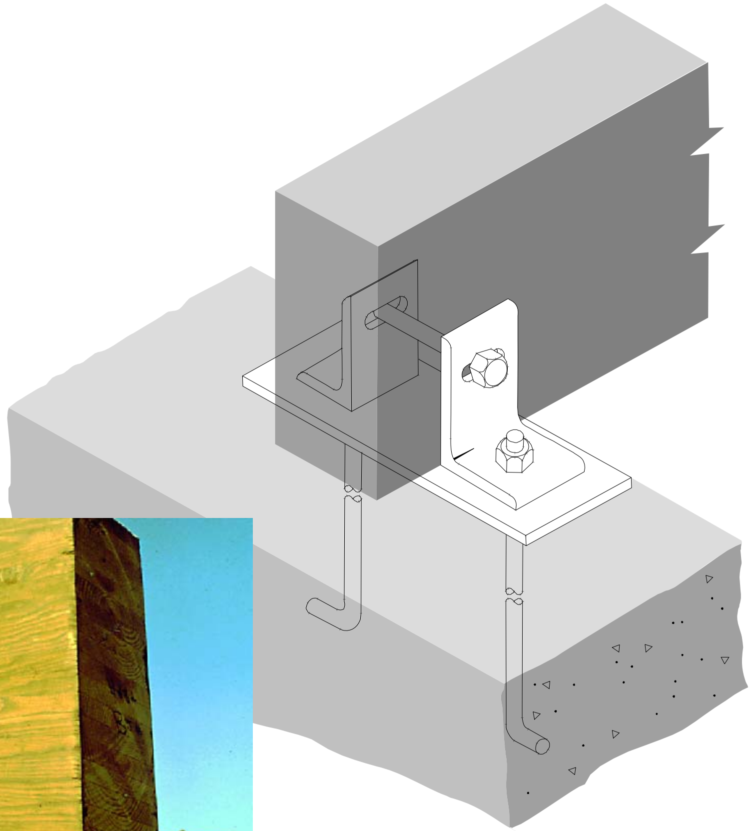
Connection Serviceability

- Avoid contact with cementitious materials



- **Beam on Shelf**
  - **prevent contact with concrete**
  - **provide lateral resistance and uplift**

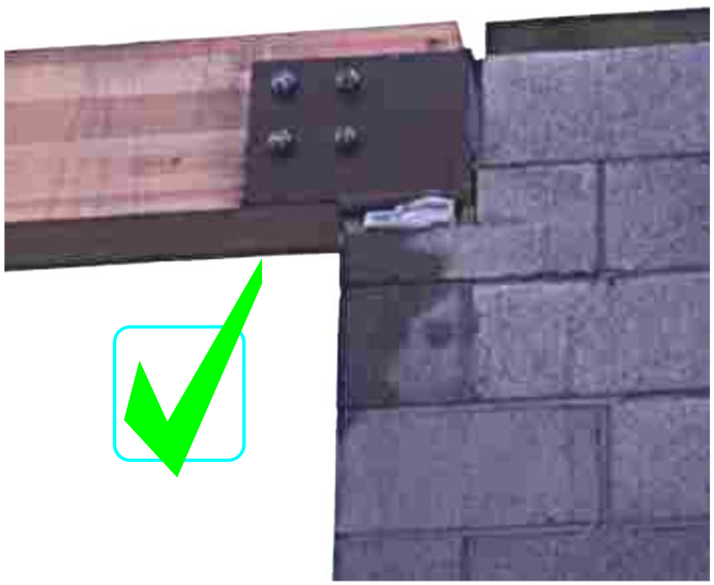
Beam to Concrete



- **Beam on Wall**
  - **prevent contact with concrete**
  - **provide lateral resistance and uplift**
  - **slotted to allow longitudinal movement**
  - **typical for sloped beam**

Beam to Masonry

- Application

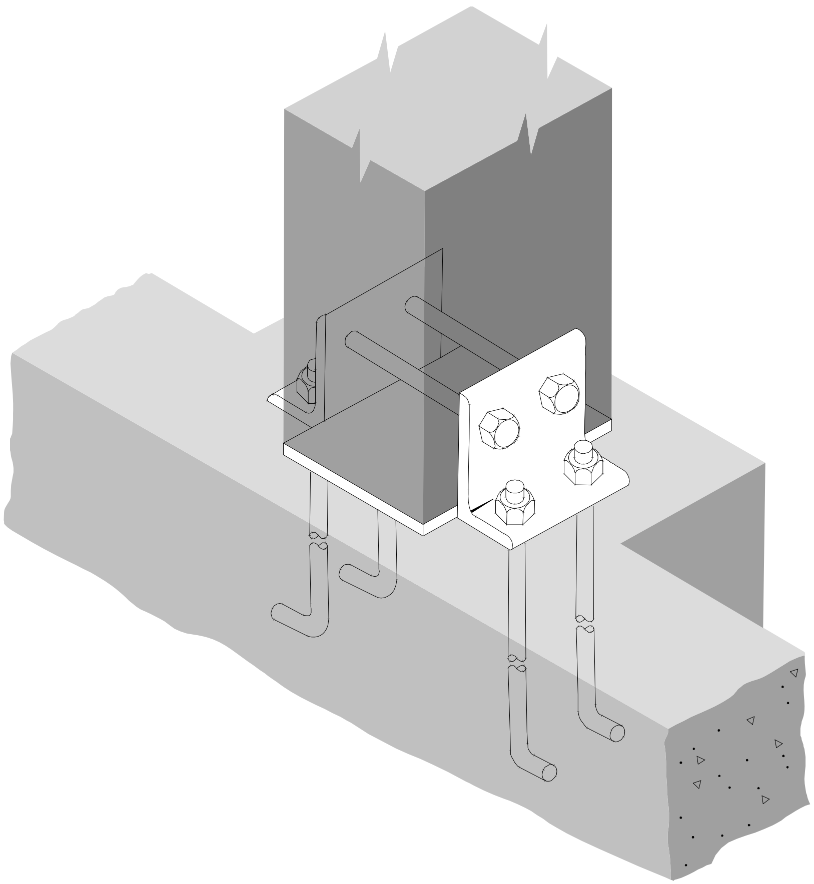


Need 1/2” air gap between wood and masonry

Column to Base

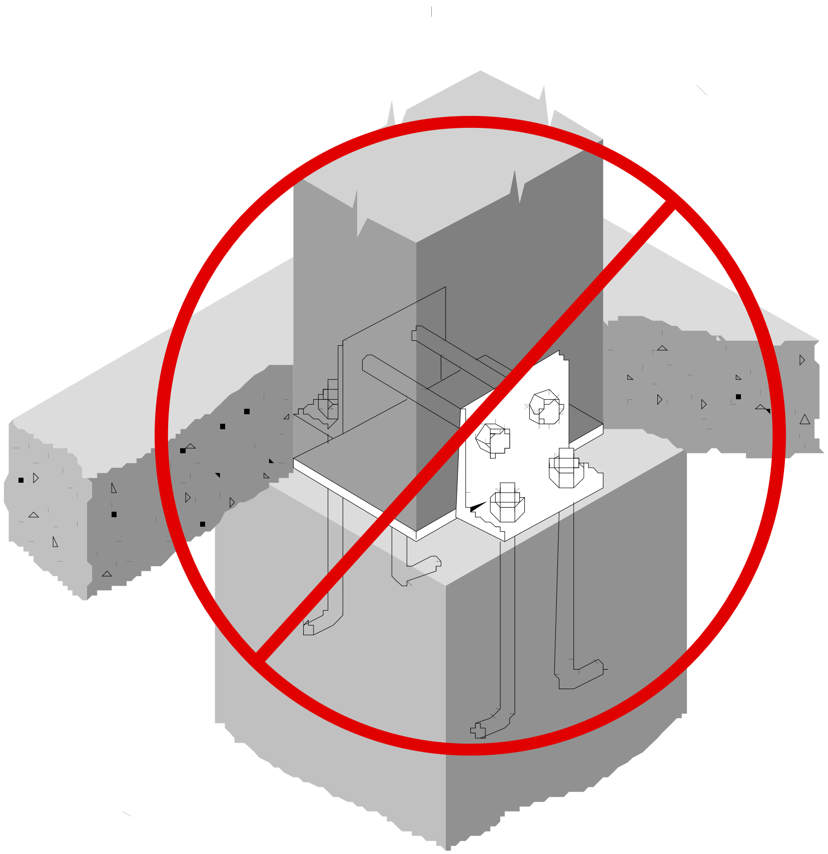
- **Problem**
  - **no weep holes in closed shoe**
  - **moisture entrapped**
  - **decay can result**

Column to Base



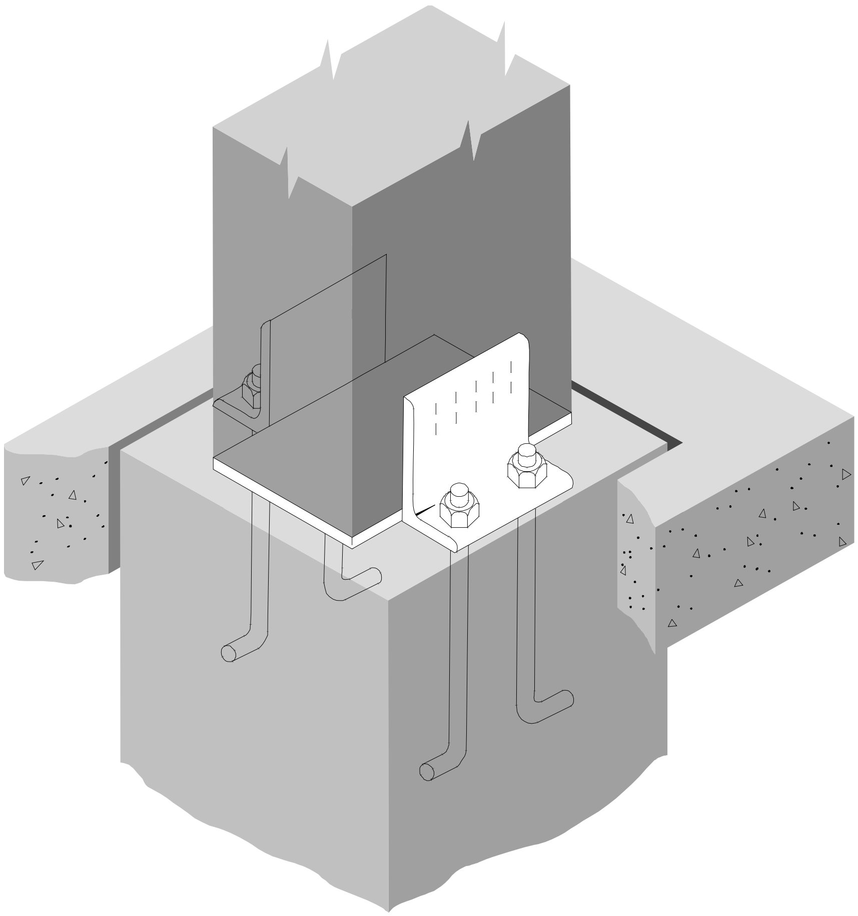
- **Angle brackets**
  - **anchor bolts in brackets**

Hidden Column Base



- **Floor slab poured over connection**
  - **will cause decay**
  - **not recommended**

Column to Base



- **Floor slab poured below connection**

Outline

- **Wood connection design philosophy**
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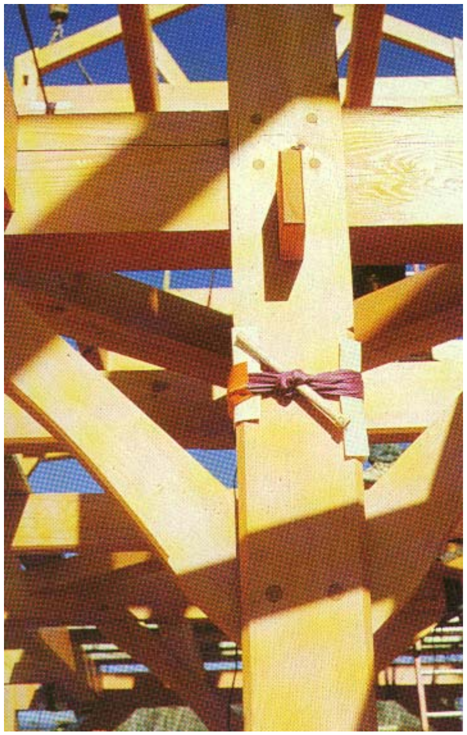
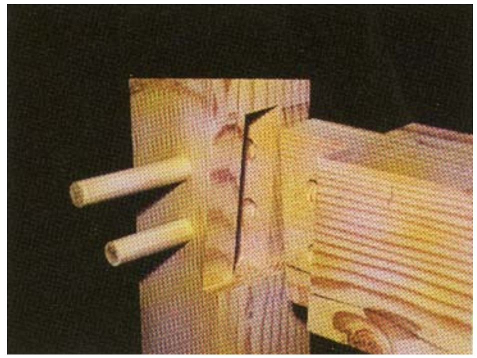
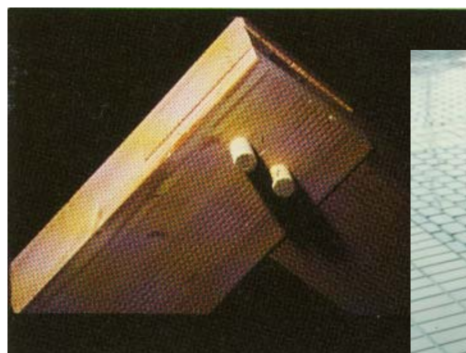
Mechanical Connectors



Traditional Connectors

- **All-wood solution**
- **time tested**
- **practical**
- **extreme efficiencies available with computer numeric control (CNC) machining**


www.tfguild.org
www.timberframe.org

Traditional Connectors

- Long History > 100 years
- Uses automated Computer numerical Control (CNC) milling technology
  - machine joints
  - pre-drill holes
- Timber Framer's Guild - www.tfguild.org

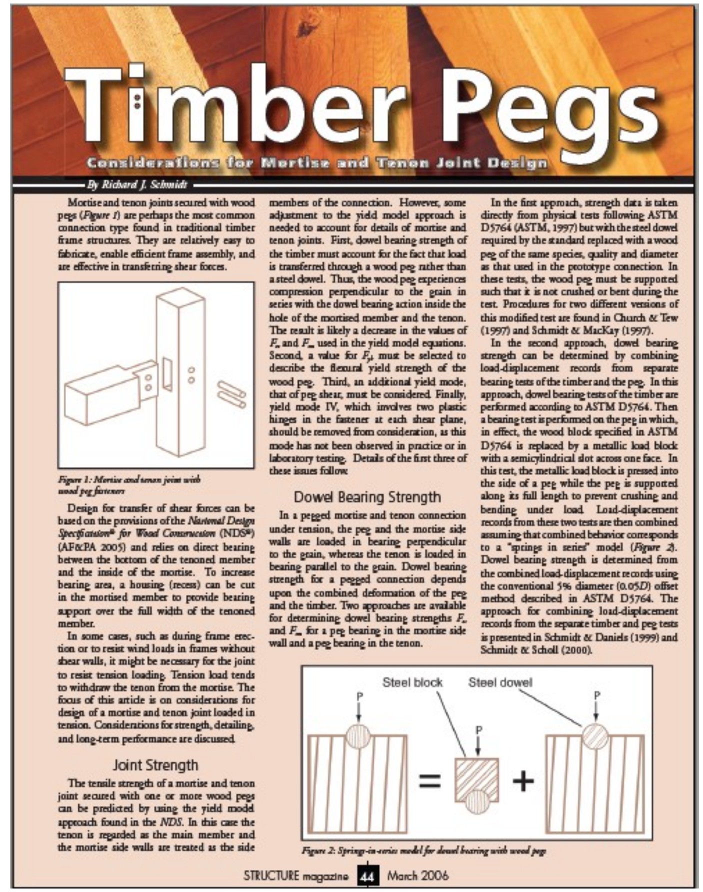

TFEC 1-2010

Standard for Design of Timber Frame Structures and Commentary

http://www.tfguild.org/downloads/TFEC-1-2010-with-Commentary.pdf

Traditional Connectors

- **Wood dowel connection design technology now available**



Timber Pegs

Considerations for Mortise and Tenon Joint Design

By Richard J. Schmidt

Mortise and tenon joints secured with wood pegs (*Figure 1*) are perhaps the most common connection type found in traditional timber frame structures. They are relatively easy to fabricate, enable efficient frame assembly, and are effective in transferring shear forces.

Figure 1: Mortise and tenon joint with wood peg fasteners

Design for transfer of shear forces can be based on the provisions of the *National Design Specification® for Wood Construction* (NDS®) (AF&PA 2005) and relies on direct bearing between the bottom of the tenoned member and the inside of the mortise. To increase bearing area, a housing (recess) can be cut in the mortised member to provide bearing support over the full width of the tenoned member.

In some cases, such as during frame erection or to resist wind loads in frames without shear walls, it might be necessary for the joint to resist tension loading. Tension load tends to withdraw the tenon from the mortise. The focus of this article is on considerations for design of a mortise and tenon joint loaded in tension. Considerations for strength, detailing, and long-term performance are discussed.

Joint Strength

The tensile strength of a mortise and tenon joint secured with one or more wood pegs can be predicted by using the yield model approach found in the *NDS*. In this case the tenon is regarded as the main member and the mortise side walls are treated as the side members of the connection. However, some adjustment to the yield model approach is needed to account for details of mortise and tenon joints. First, dowel bearing strength of the timber must account for the fact that load is transferred through a wood peg rather than a steel dowel. Thus, the wood peg experiences compression perpendicular to the grain in series with the dowel bearing action inside the hole of the mortised member and the tenon. The result is likely a decrease in the values of $F_{e\parallel}$ and $F_{e\perp}$ used in the yield model equations. Second, a value for F_{yb} must be selected to describe the flexural yield strength of the wood peg. Third, an additional yield mode, that of peg shear, must be considered. Finally, yield mode IV, which involves two plastic hinges in the fastener at each shear plane, should be removed from consideration, as this mode has not been observed in practice or in laboratory testing. Details of the first three of these issues follow.

Dowel Bearing Strength

In a pegged mortise and tenon connection under tension, the peg and the mortise side walls are loaded in bearing perpendicular to the grain, whereas the tenon is loaded in bearing parallel to the grain. Dowel bearing strength for a pegged connection depends upon the combined deformation of the peg and the timber. Two approaches are available for determining dowel bearing strengths $F_{e\parallel}$ and $F_{e\perp}$ for a peg bearing in the mortise side wall and a peg bearing in the tenon.

In the first approach, strength data is taken directly from physical tests following ASTM D5764 (ASTM, 1997) but with the steel dowel required by the standard replaced with a wood peg of the same species, quality and diameter as that used in the prototype connection. In these tests, the wood peg must be supported such that it is not crushed or bent during the test. Procedures for two different versions of this modified test are found in Church & Tew (1997) and Schmidt & MacKay (1997).

In the second approach, dowel bearing strength can be determined by combining load-displacement records from separate bearing tests of the timber and the peg. In this approach, dowel bearing tests of the timber are performed according to ASTM D5764. Then a bearing test is performed on the peg in which, in effect, the wood block specified in ASTM D5764 is replaced by a metallic load block with a semicylindrical slot across one face. In this test, the metallic load block is pressed into the side of a peg while the peg is supported along its full length to prevent crushing and bending under load. Load-displacement records from these two tests are then combined assuming that combined behavior corresponds to a "springs in series" model (*Figure 2*). Dowel bearing strength is determined from the combined load-displacement records using the conventional 5% diameter (0.05*D*) offset method described in ASTM D5764. The approach for combining load-displacement records from the separate timber and peg tests is presented in Schmidt & Daniels (1999) and Schmidt & Scholl (2000).

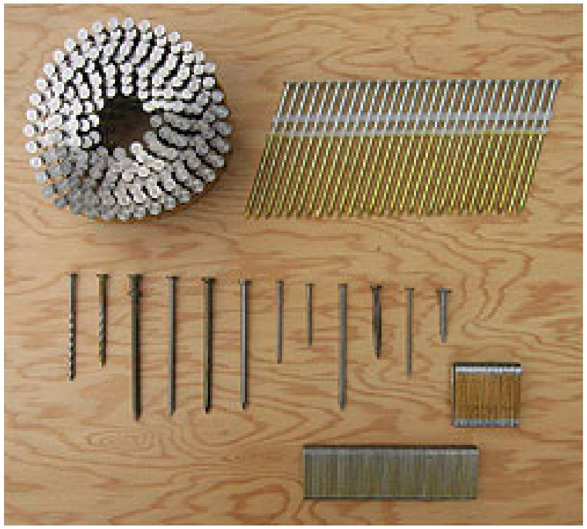
Figure 2: Springs-in-series model for dowel bearing with wood peg

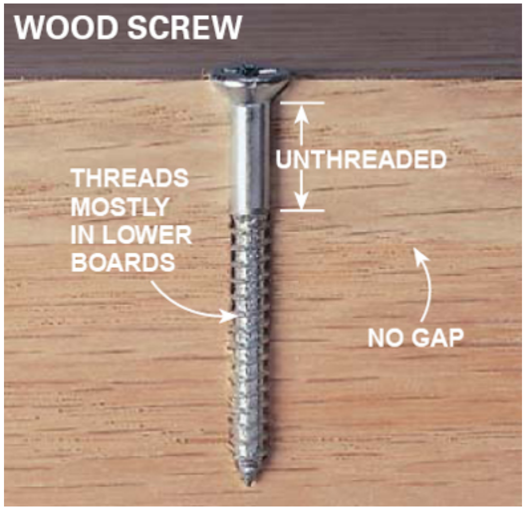
STRUCTURE magazine 44 March 2006

Schmidt, R.J. (2006): *Timber Pegs – Considerations for Mortise and Tenon Joint Design*, **Structure Magazine**, March 2006, NCSEA, 13(3):44-47.
http://www.structuremag.org/wp-content/uploads/2014/09/SF-Timber-Pegs-March-061.pdf

Mechanical Connectors

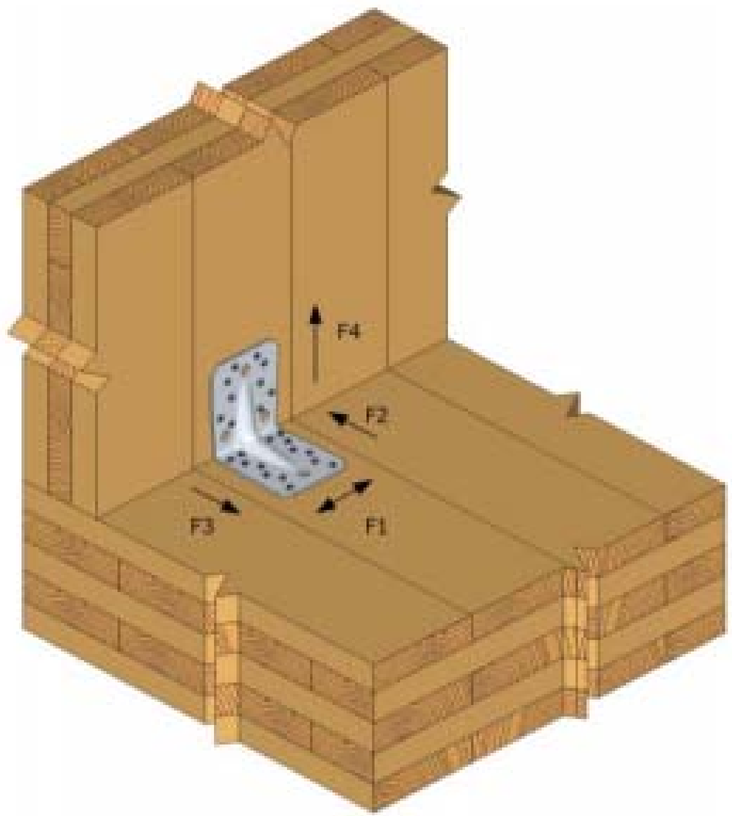
- Common Fasteners
    - Nails
    - Staples
    - Wood Screws
    - Metal plate connectors
    - Lag screws
    - Bolts

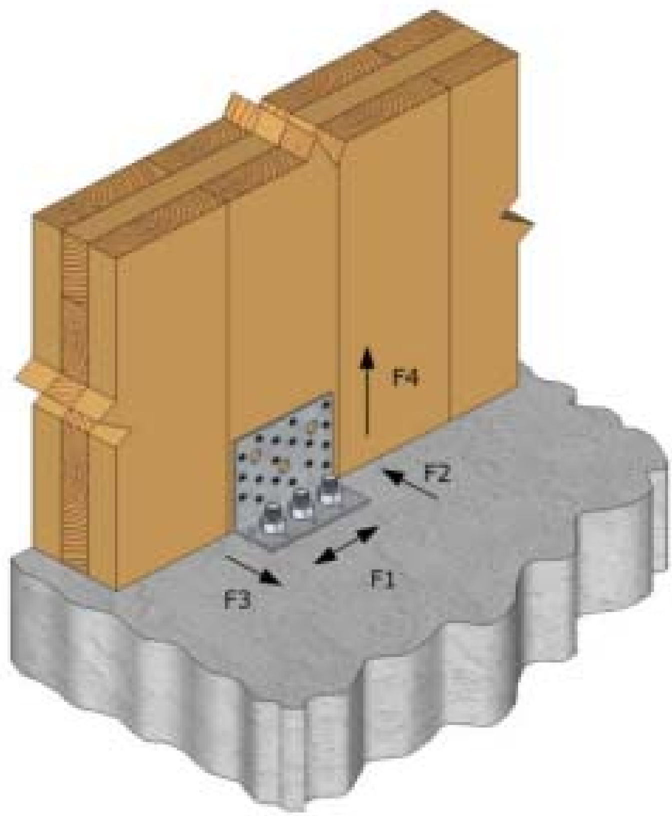




Typical Panel Connectors

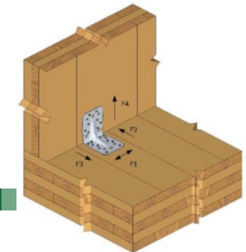
Typical Panel Connectors





Resource: Simpson Strong-Tie

Typical Panel Connectors



Fastener Values

- Included in U.S. design literature

Fastener Type	Reference
Bolts	NDS or ER
Lag Screws	NDS or ER
Wood Screws	NDS or ER
Nails & Spikes	NDS or ER
Split Ring Connectors	NDS
Shear Plate Connectors	NDS
Drift Bolts & Drift Pins	NDS
Metal Plate Connectors	ER
Hangers & Framing Anchors	ER
Staples	ER

Evaluation Reports (ER) are developed for proprietary products

Outline

- **Wood connection design philosophy**
- **Connection behavior**
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- **Connection hardware and fastening systems**
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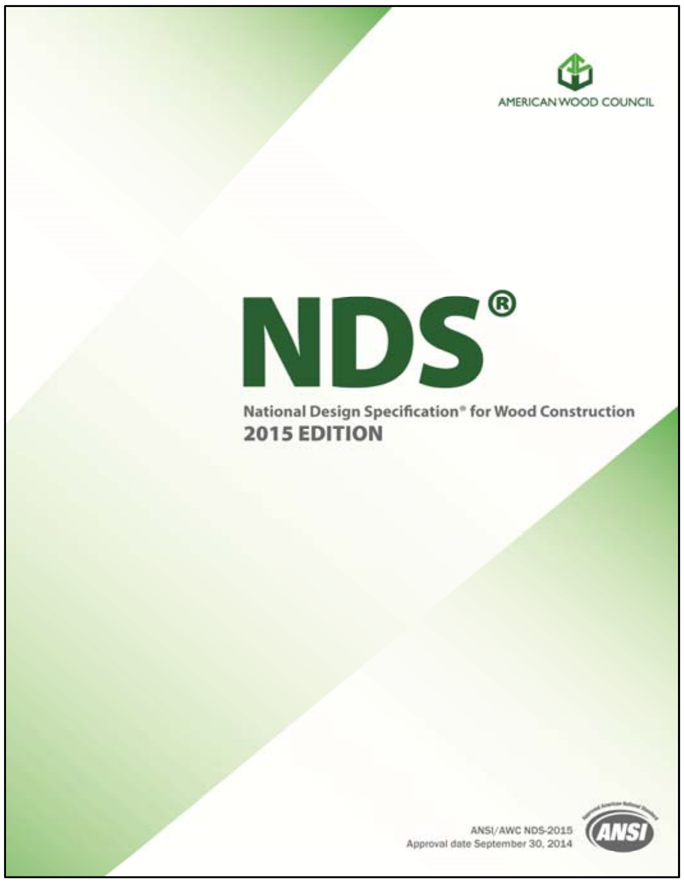
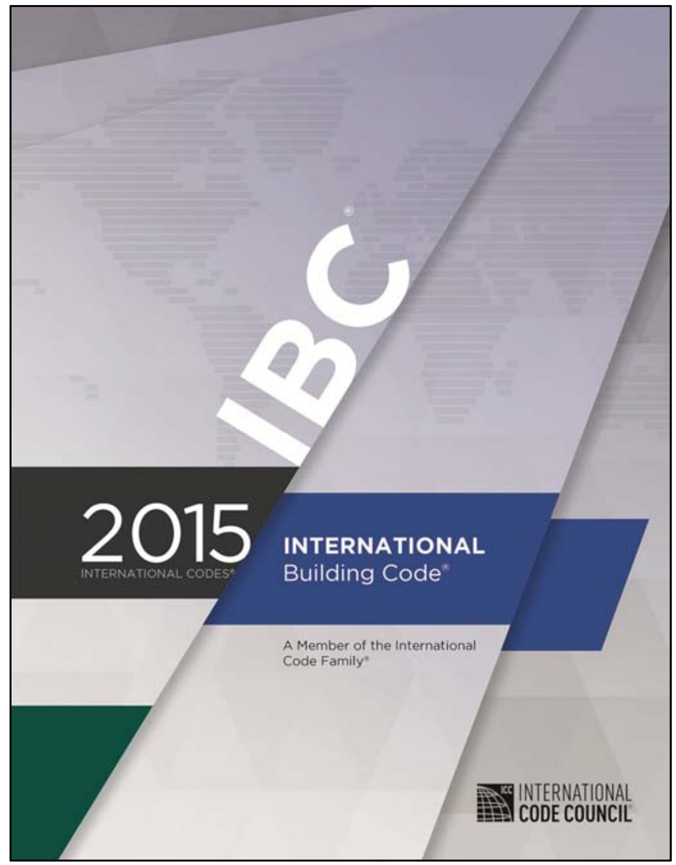
Governing Codes for Wood Design

2015 NDS referenced in 2015 IBC

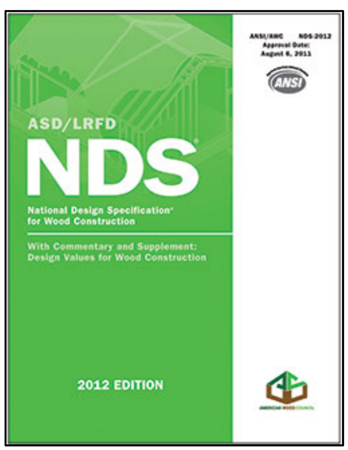




2015 NDS Chapter Reorganization

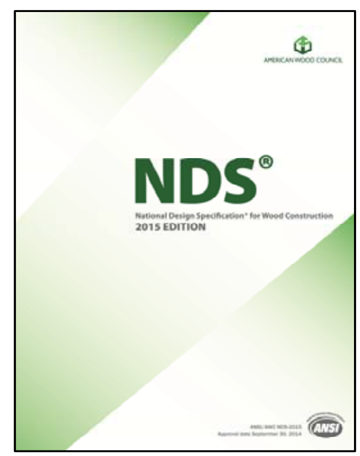
2012 NDS

- 1-3 General
- 4-9 Products
- 10-13 Connections
- 14 Shear Walls & Diaphragms
- 15 Special Loading
- 16 Fire



2015 NDS

- 1-3 General
- 4-10 Products +CLT
- 11-14 Connections
- Shear Walls & Diaphragms
- 15 Special Loading
- 16 Fire



NDS Chapter 11 – Mechanical Connections

- **ASD and LRFD accommodated through Table 11.3.1**
- **Dowel fasteners**
- **Split ring/shear plate**
- **Timber rivets**
- **Spike grids**

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	
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

New chapter numbering for 2015 NDS!

NDS Dowel-fastener Connections

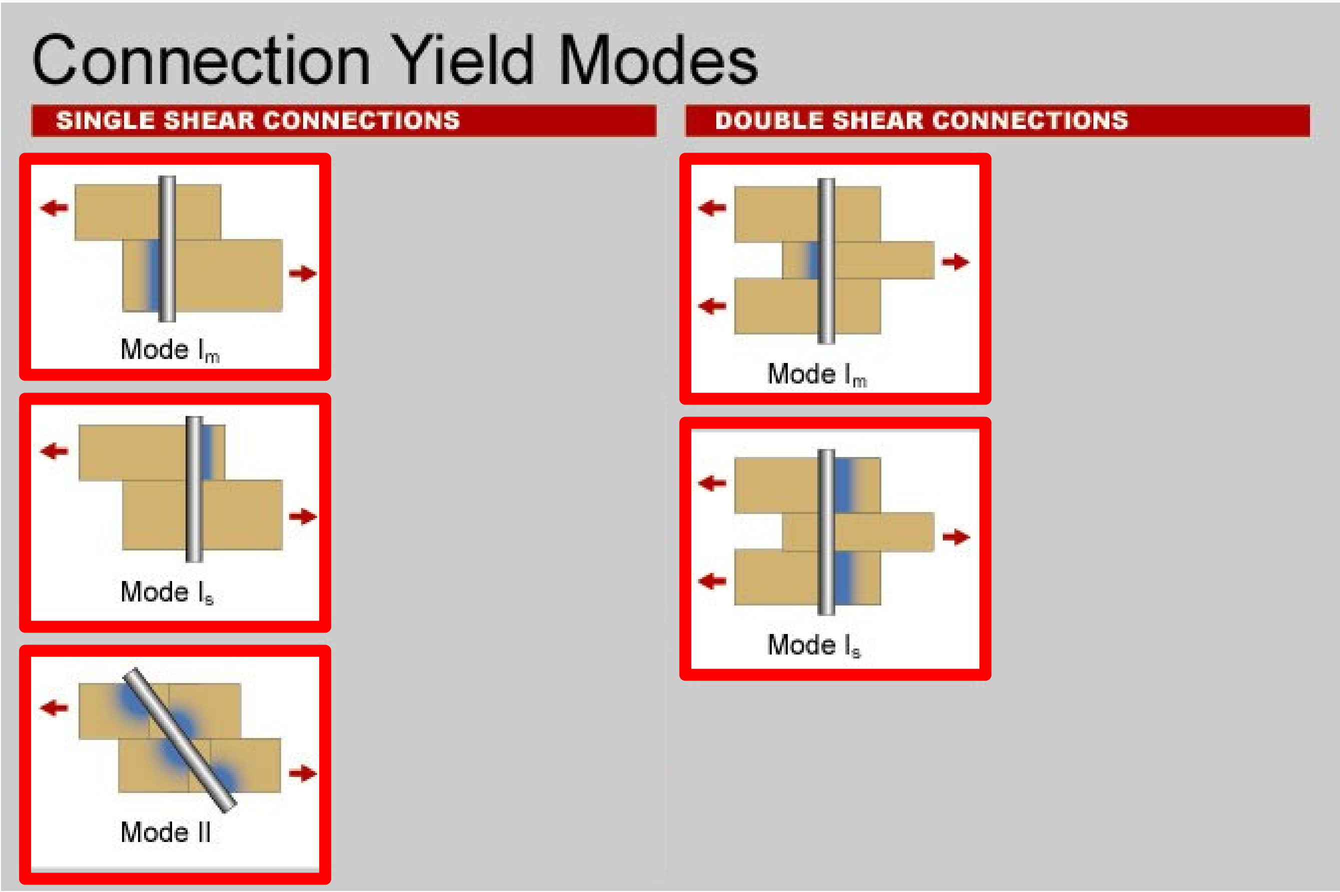
- **2015 NDS Chapter 12 (New location)**
- **Can be used for any dowel-shaped fastener**
- **Includes lateral and withdrawal provisions**
  - **Bolts**
  - **Lag screws**
  - **Wood screws**
  - **Nails**
  - **Spikes**
  - **Drift bolts**
  - **Drift pins**

Dowel-fastener withdrawal

- **Withdrawal calculated based on fastener penetration**
  - **W value is per inch of fastener penetration**
    - Threaded fasteners use thread penetration
- **Lag screws**
  - **$W = 1800\ G^{3/2}\ D^{3/4}$**
- **Wood screws**
  - **$W = 2850\ G^{2}\ D$**
- **Nails (smooth shank)**
  - **$W = 1380\ G^{5/2}\ D$**

No withdrawal in end grain allowed for nails or wood screws!

Yield Modes



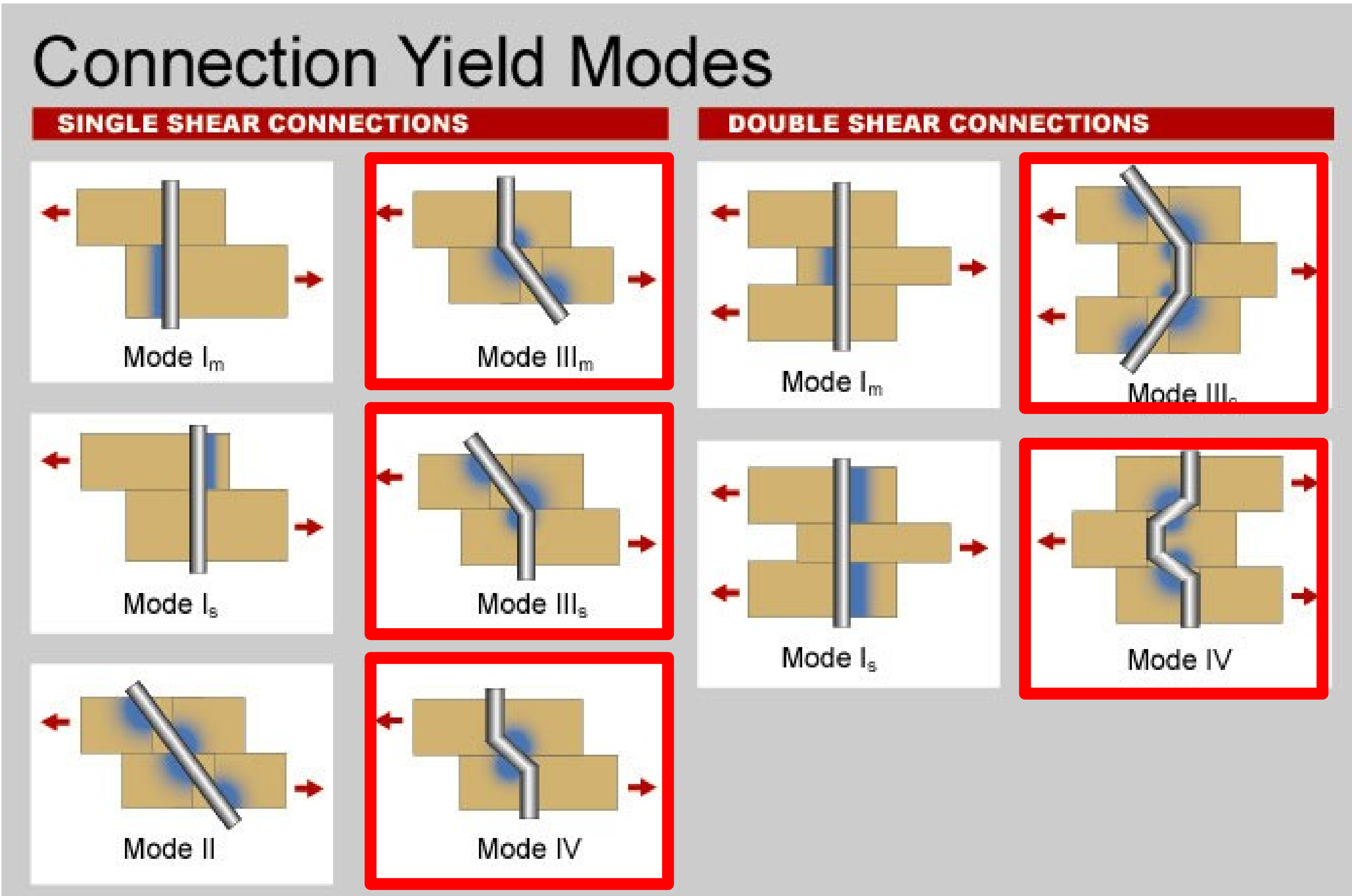
MODE I

•bearing-dominated yield of wood fibers

MODE II

•pivoting of fastener with localized crushing of wood fibers

Yield Modes



MODE III

- fastener yield in bending at one plastic hinge and bearing – dominated yield of wood fibers

MODE IV

- fastener yield in bending at two plastic hinges and bearing – dominated yield of wood fibers

Dowel Bearing Strength

Table 12.3.3 Dowel Bearing Strengths, F_e, for Dowel-Type Fastener

Specific[1] Gravity, G	Dowel bearing strength in pounds per square incl						
	F_e	$F_{e\parallel}$	$F_{e\perp}$				
	D<1/4"	1/4" ≤ D ≤ 1"	D=1/4"	D=5/16"	D=3/8"	D=7/16"	D=1/2"
0.73	9300	8200	7750	6900	6300	5850	5450
0.72	9050	8050	7600				
0.71	8850	7950	7400				
0.70	8600	7850	7250				
0.69	8400	7750	7100				
0.68	8150	7600	6950				

Table 12.3.3B Dowel Bearing Strengths for Wood Structural Panels

Wood Structural Panel	Specific[1] Gravity, G	Dowel Bearing Strength, F_e, in pounds per square inch (psi) for D≤1/4"
Plywood		
Structural 1, Marine	0.50	4650
Other Grades[1]	0.42	3350
Oriented Strand Board		
All Grades	0.50	4650

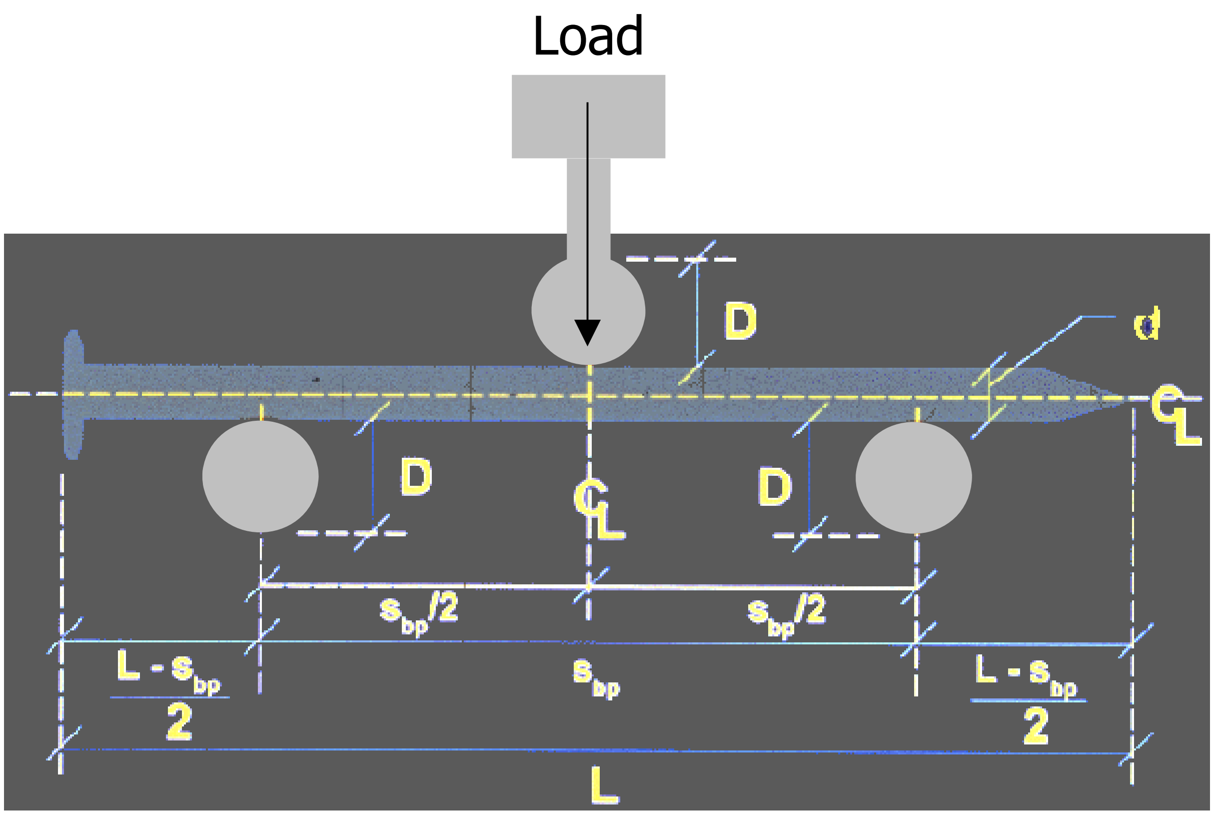
$$F_{e\parallel} = 11200G$$

$$F_{e\perp} = 6100G^{1.45}/\sqrt{D}$$

$$F_e \text{ for } D < 1/4" = 16600\,G^{1.84}$$

Fastener Bending Yield Test

Center-Point Bending Test



Fastener Bending Yield Strength

Table I1 Fastener Bending Yield Strengths, F_{yb}

Fastener Type	F_{yb} (psi)
Bolt, lag screw (with D ≥ 3/8"), drift pin (SAE J429 Grade 1 - F_y = 36,000 psi and F_u = 60,000 psi)	45,000
Common, box, or sinker nail, spike, lag screw, wood screw (low to medium carbon steel)	
0.099" ≤ D ≤ 0.142"	100,000
0.142" < D ≤ 0.177"	90,000
0.177" < D ≤ 0.236"	80,000
0.236" < D ≤ 0.273"	70,000
0.273" < D ≤ 0.344"	60,000
0.344" < D ≤ 0.375"	45,000
Hardened steel nail (medium carbon steel) including post-frame ring shank nails	
0.120" ≤ D ≤ 0.142"	130,000
0.142" < D ≤ 0.192"	115,000
0.192" < D ≤ 0.207"	100,000

Yield Limit Equations

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)

- **4 Modes of failure**
- **6 Yield equations**
- **Single & double shear**

Lowest Yield “Z” value = Connection Capacity

Yield Limit Equations

Notes:

$$k_1 = \frac{\sqrt{R_e + 2R_e^2(1 + R_t + R_t^2) + R_t^2 R_e^3} - R_e(1 + R_t)}{(1 + R_e)}$$

$$k_2 = -1 + \sqrt{2(1 + R_e) + \frac{2F_{yb}(1 + 2R_e)D^2}{3F_{em}\ell_m^2}}$$

$$k_3 = -1 + \sqrt{\frac{2(1 + R_e)}{R_e} + \frac{2F_{yb}(2 + R_e)D^2}{3F_{em}\ell_s^2}}$$

D = diameter, in. (see 12.3.7)
F_{yb} = dowel bending yield strength, psi
R_d = reduction term (see Table 12.3.1B)
R_e = F_{em}/F_{es}
R_t = ℓ_m/ℓ_s
ℓ_m = main member dowel bearing length, in.
ℓ_s = side member dowel bearing length, in.
F_{em} = main member dowel bearing strength, psi (see Table 12.3.3)
F_{es} = side member dowel bearing strength, psi (see Table 12.3.3)

Yield Limit Equations

Table 12.3.1B Reduction Term, R_d

Fastener Size	Yield Mode	Reduction Term, R_d
$0.25" \leq D \leq 1"$	I_m, I_s	$4\ K_\theta$
	II	$3.6\ K_\theta$
	III_m, III_s, IV	$3.2\ K_\theta$
$D < 0.25"$	I_m, I_s, II, III_m, III_s, IV	K_D[1]

Notes:

K_θ = $1 + 0.25(\theta/90)$

θ = maximum angle between the direction of load and the direction of grain ($0^\circ \leq \theta \leq 90^\circ$) for any member in a connection

D = diameter, in. (see 12.3.7)

K_D = 2.2 for $D \leq 0.17"$

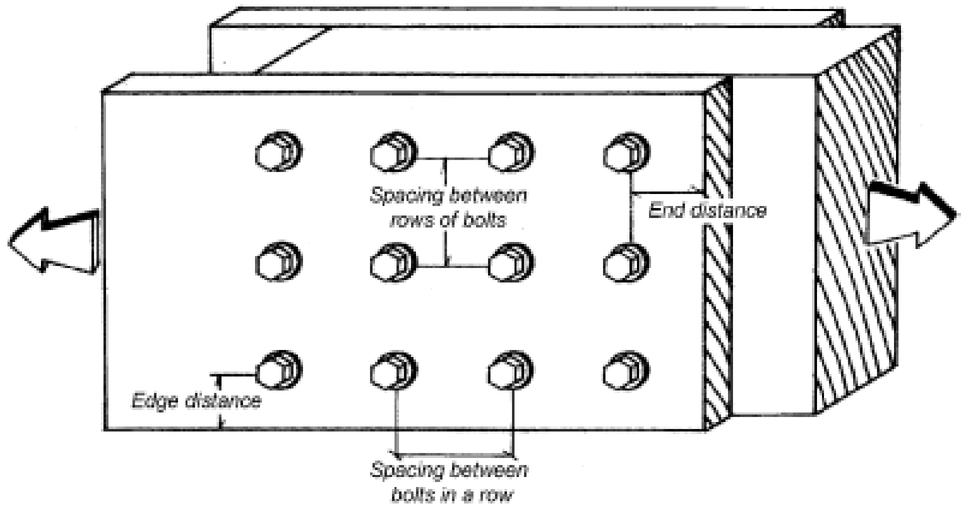
K_D = $10D + 0.5$ for $0.17" < D < 0.25"$

1. For threaded fasteners where nominal diameter (see Appendix L) is greater than or equal to 0.25" and root diameter is less than 0.25", $R_d = K_D K_\theta$.

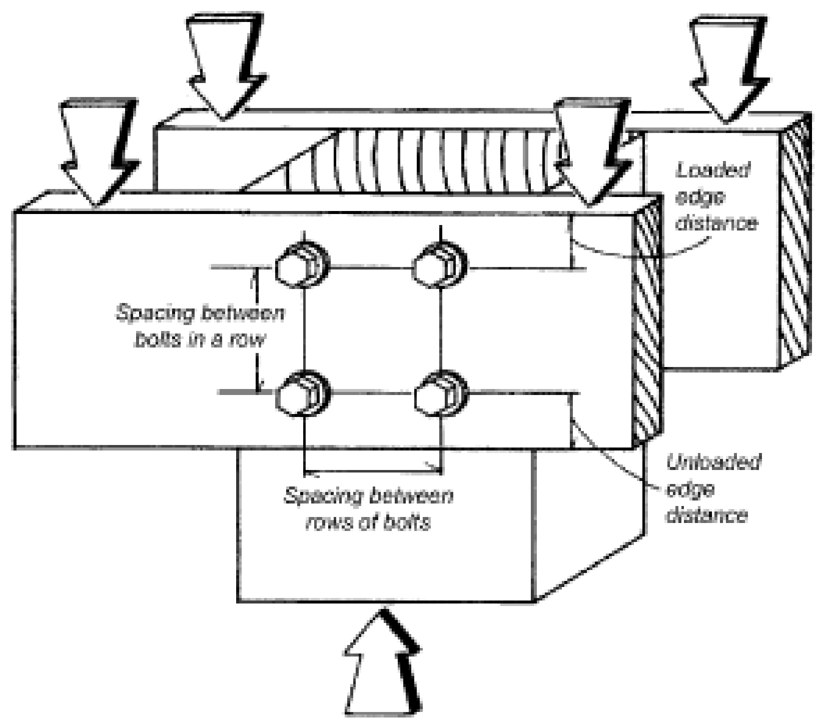
Also applied in TR12 equations!

Spacing, End, & Edge Distance

Figure 12G Bolted Connection Geometry



Parallel to grain loading in all wood members ($Z_{||}$)



Perpendicular to grain loading in the side member and parallel to grain loading in the main member ($Z_{s\perp}$)

Spacing, End, & Edge Distance

Table 12.5.1A End Distance Requirements

Direction of Loading	End Distances: Minimum end distance for $C_\Delta = 0.5$	End Distances: Minimum end distance for $C_\Delta = 1.0$
Perpendicular to Grain	2D	4D
Parallel to Grain, Compression: (fastener bearing away from member end)	2D	4D
Parallel to Grain, Tension: (fastener bearing toward member end)		
for softwoods	3.5D	7D
for hardwoods	2.5D	5D

Table 12.5.1C Edge Distance Requirements[1,2]

Direction of Loading	Minimum Edge Distance
Parallel to Grain:	
where $\ell/D \leq 6$	1.5D
where $\ell/D > 6$	1.5D or ½ the spacing between rows, whichever is greater
Perpendicular to Grain:[2]	
loaded edge	4D
unloaded edge	1.5D

Table 12.5.1E Edge and End Distance and Spacing Requirements for Lag Screws Loaded in Withdrawal and Not Loaded Laterally

Orientation	Minimum Distance/Spacing
Edge Distance	1.5D
End Distance	4D
Spacing	4D

Spacing, End, & Edge Distance

Table 12.5.1B Spacing Requirements for Fasteners in a Row

Direction of Loading	Spacing: Minimum spacing	Spacing: Minimum spacing for $C_{\Delta} = 1.0$
Parallel to Grain	3D	4D
Perpendicular to Grain	3D	Required spacing for attached members

Table 12.5.1D Spacing Requirements Between Rows[1]

Direction of Loading	Minimum Spacing
Parallel to Grain	1.5D
Perpendicular to Grain:	
where $\ell/D \le 2$	2.5D
where $2 < \ell/D < 6$	$(5\ell + 10D) / 8$
where $\ell/D \ge 6$	5D

Spacing, End, & Edge Distance

Figure 12H **Spacing Between Outer Rows of Bolts**

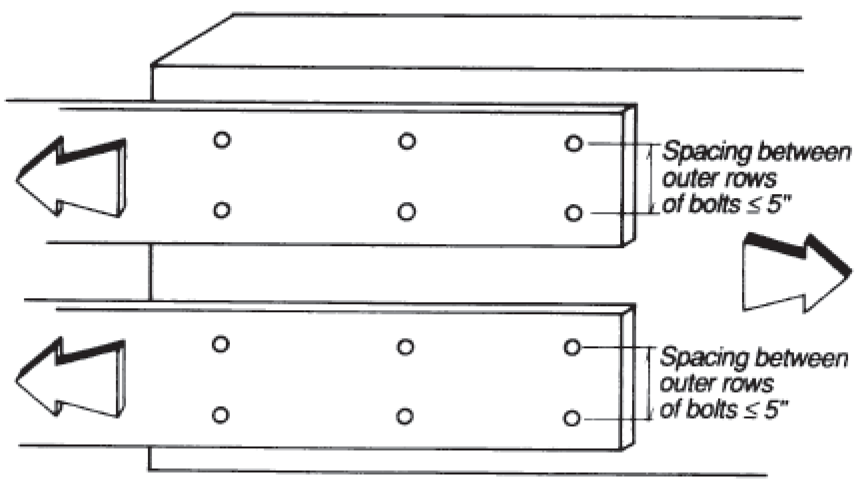


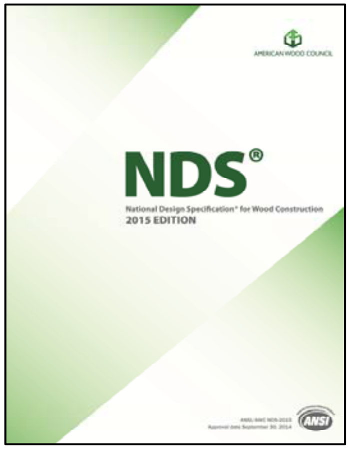
Table 12.5.1F **Perpendicular to Grain Distance Requirements for Outermost Fasteners in Structural Glued Laminated Timber Members**

Fastener Type	Moisture Content: At Time of Fabrication	Moisture Content: In-Service	Maximum Distance Between Outer Rows
All Fasteners	>16%	<16%	5"
	Any	>16%	5"
Bolts	<16%	<16%	10"
Lag Screws	<16%	<16%	6"
Drift Pins	<16%	<16%	6"

- Unless special detailing is provided to accommodate cross-grain shrinkage of the wood member.

NDS Appendix E

- **Appendix E – Local Stresses in Fastener Groups (Non-mandatory)**
  - **Groups of closely spaced fasteners loaded parallel to grain**
    - Net Section Tension Capacity
    - Row Tear-Out Capacity
    - Group Tear-Out Capacity
  - **Example problems**
    - Staggered rows of bolts
    - Single row of bolts
    - Row of split rings

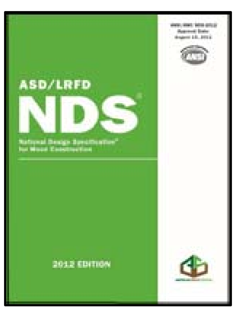


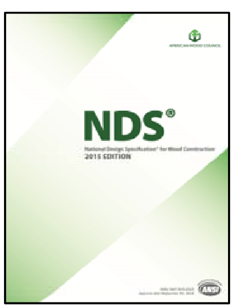
Chapter 12-Dowels

12.3.7 Dowel Diameter

12.3.7.1 Where used in Tables 12.3.1A or 12.3.1B, the fastener diameter shall be taken as D for unthreaded full-body diameter fasteners and D_r for reduced body diameter fasteners or threaded fasteners except as provided in 12.3.7.2.

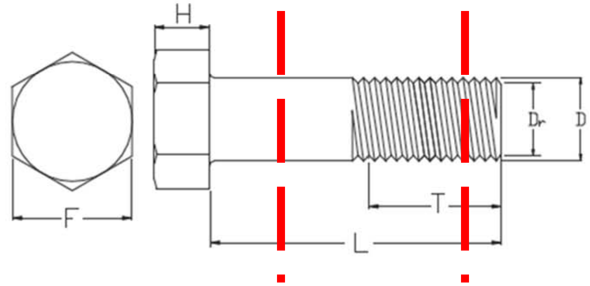
12.3.7.2 For threaded full-body fasteners (see Appendix L), D shall be permitted to be used in lieu of D_r where the bearing length of the threads does not exceed ¼ of the full bearing length in the member holding the threads. Alternatively, a more detailed analysis accounting for the moment and bearing resistance of the threaded portion of the fastener shall be permitted (see Appendix I).





Appendix L (Non-mandatory) Typical Dimensions for Dowel-Type Fasteners and Washers[1]

Table L1 Standard Hex Bolts[1]

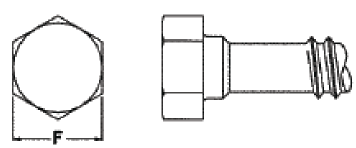


Full-Body Fastener

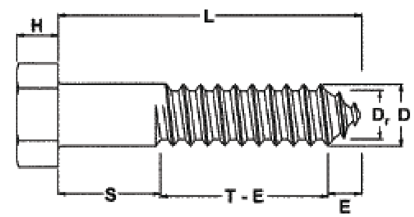
D = diameter
D_r = root diameter
T = thread length
L = bolt length
F = width of head across flats
H = height of head

Table L2 Standard Hex Lag Screws[1]

D = diameter
D_r = root diameter
S = unthreaded body length
T = minimum thread length[2]



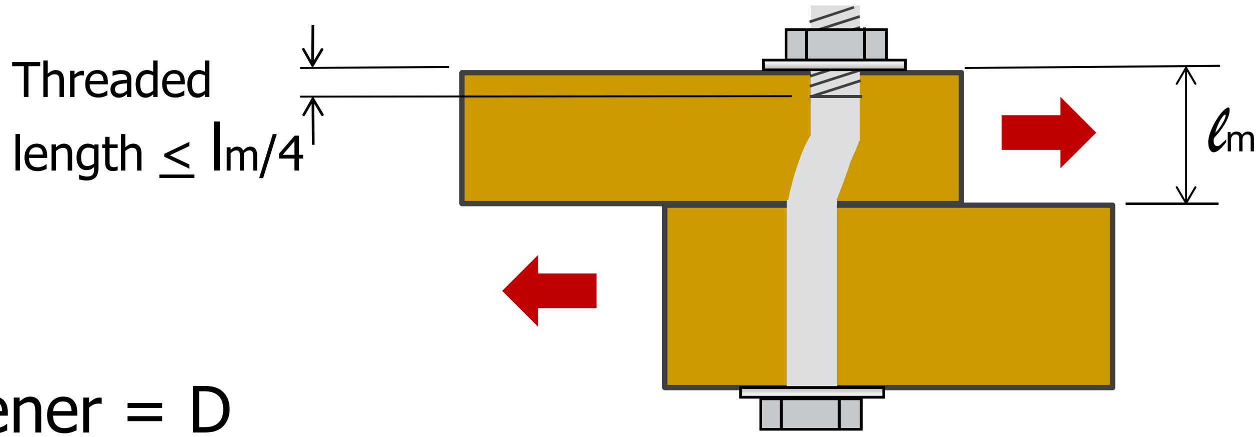
Reduced Body Diameter



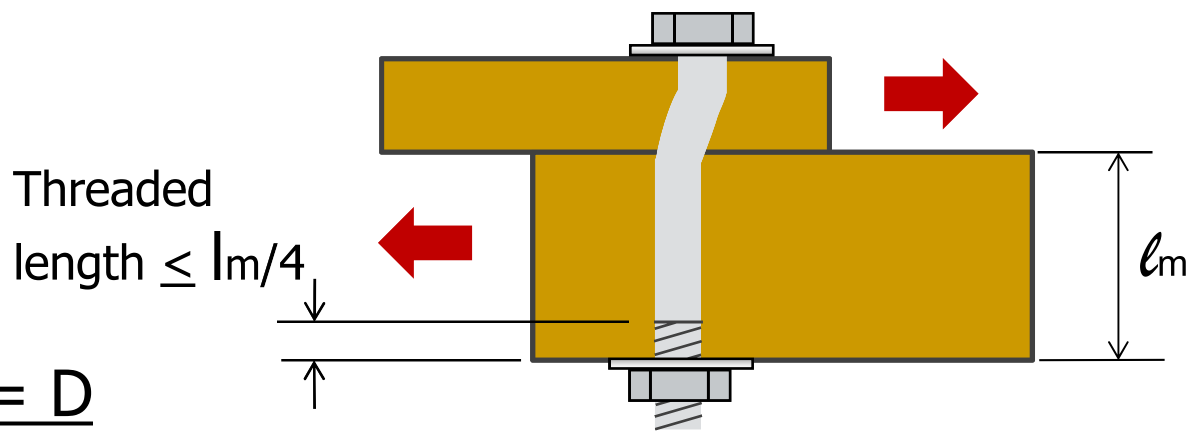
Full-Body Diameter

E = length of tapered tip
L = lag screw length
N = number of threads/inch
F = width of head across flats
H = height of head

Dowel Diameters

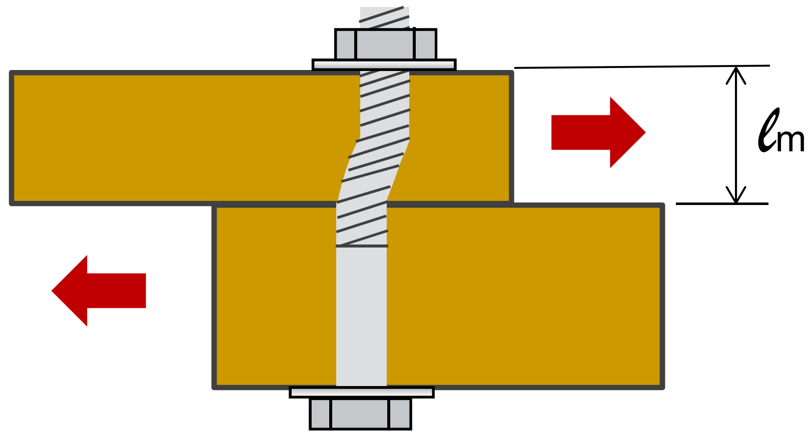


Dia. Fastener = D



Dia. Fastener = D

Dowel Diameters



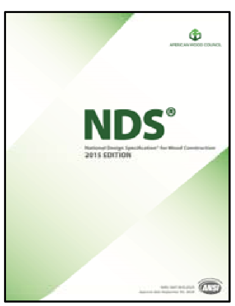
Dia. Fastener = D_r

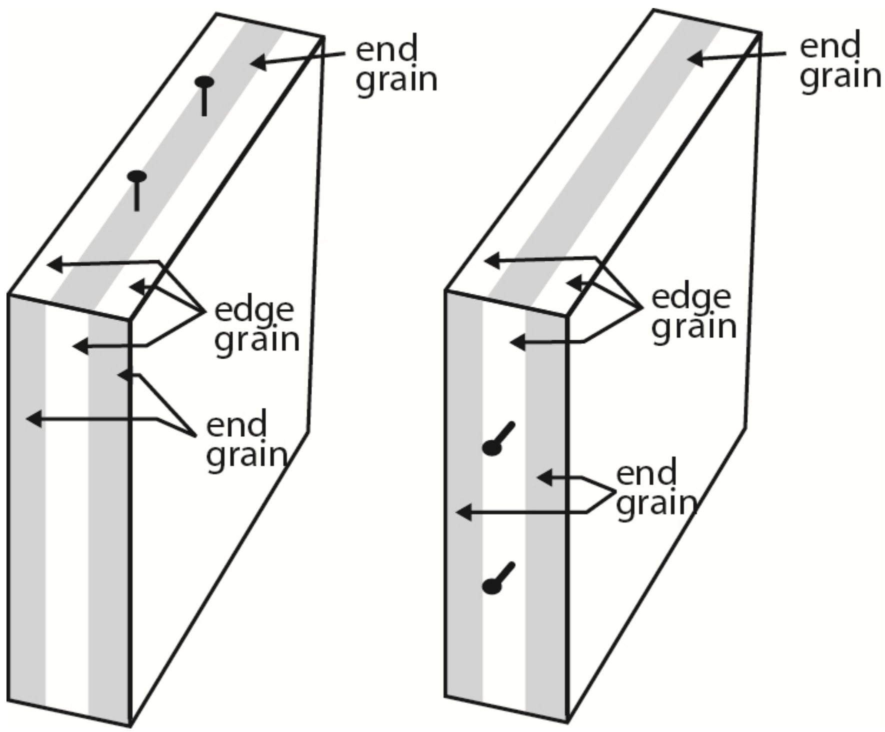
- **NDS Chapter 12 Tables use D_r for lateral yield equations**
  - **Assumes shear plane passes through threads**

Chapter 12 – Dowel-type Fasteners

New

12.2.1.5 Where lag screws are loaded in withdrawal from the narrow edge of cross-laminated timber, the reference withdrawal value, W, shall be multiplied by the end grain factor, C_{eg}=0.75, regardless of grain orientation.



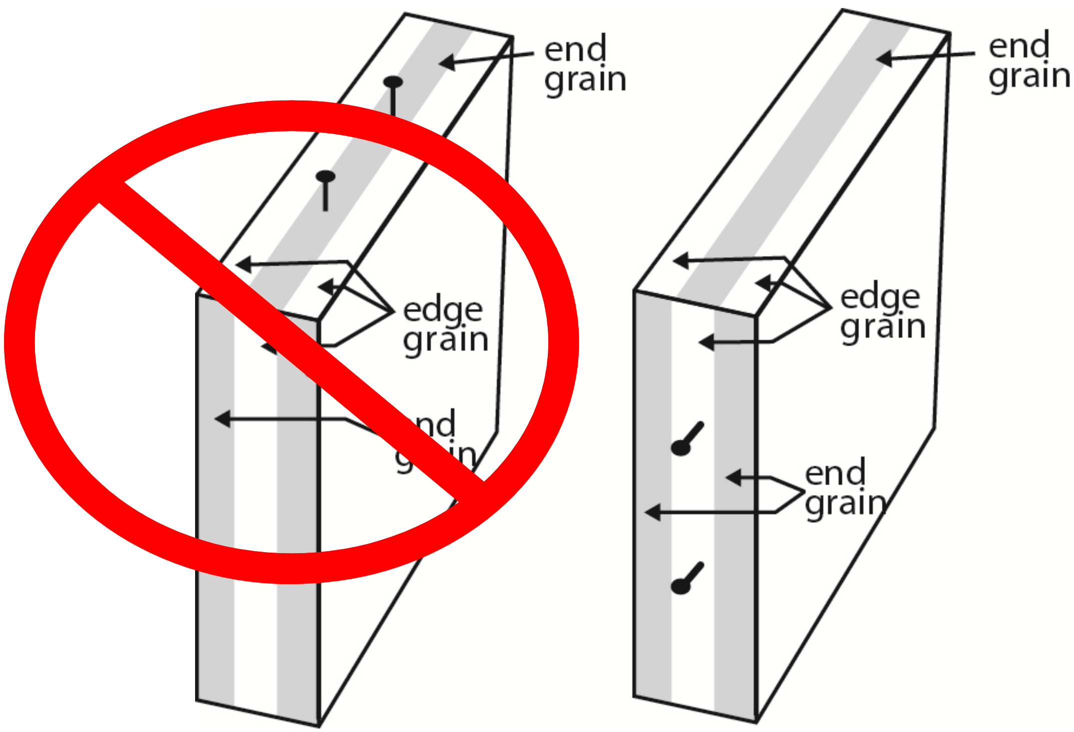


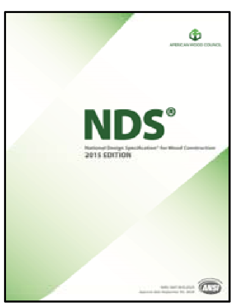
Chapter 12 – Dowel-type Fasteners

New

12.2.2.4 Wood screws shall not be loaded in withdrawal from end-grain of laminations in cross-laminated timber (C_{eg}=0.0).

12.2.3.6 Nails, and spikes shall not be loaded in withdrawal from end-grain of laminations in cross-laminated timber (C_{eg}=0.0).





Chapter 12 – Dowel-type Fasteners

12.3.3 Dowel Bearing Strength

New

12.3.3.5 Dowel bearing strengths, F_e, for dowel-type fasteners installed into the panel face of cross-laminated timber shall be based on the direction of loading with respect to the grain orientation of the cross-laminated timber ply at the shear plane.

12.3.3.6 Where dowel-type fasteners are installed in the narrow edge of cross-laminated timber panels, the dowel bearing strength shall be $F_{e\perp}$ for D≥1/4" and F_e for D<1/4".

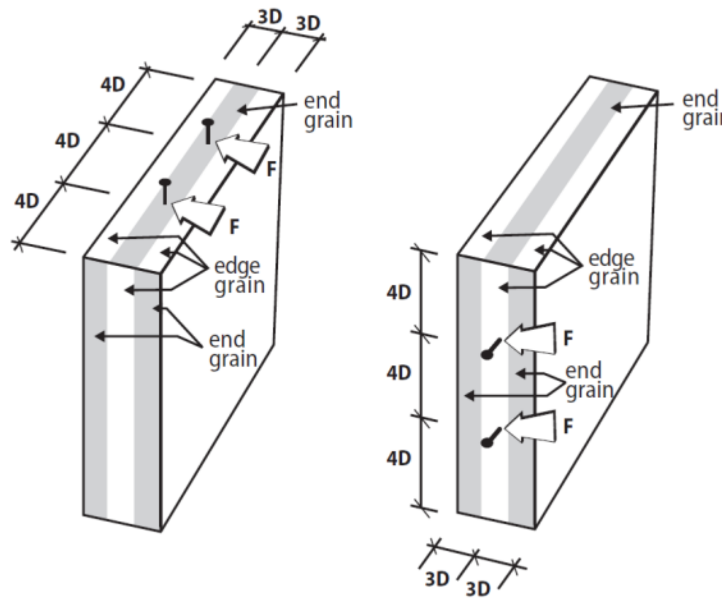
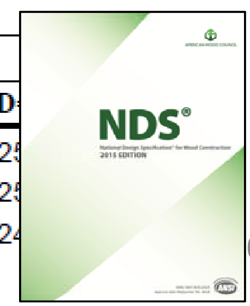


Table 12.3.3 Dowel Bearing Strengths, F_e, for Dowel-Type Fasteners in Wood Members

Specific[1] Gravity, G	Dowel bearing strength in pounds per square inch (psi)[2]										
	F_e	$F_{e\parallel}$	$F_{e\perp}$								
	D<1/4"	1/4" ≤ D ≤ 1"	D=1/4"	D=5/16"	D=3/8"	D=7/16"	D=1/2"	D=5/8"	D=3/4"	D=7/8"	D
0.55	5550	6150	5150	4600	4200	3900	3650	3250	2950	2750	25
0.54	5350	6050	5000	4450	4100	3750	3550	3150	2900	2650	25
0.53	5150	5950	4850	4350	3950	3650	3450	3050	2800	2600	24



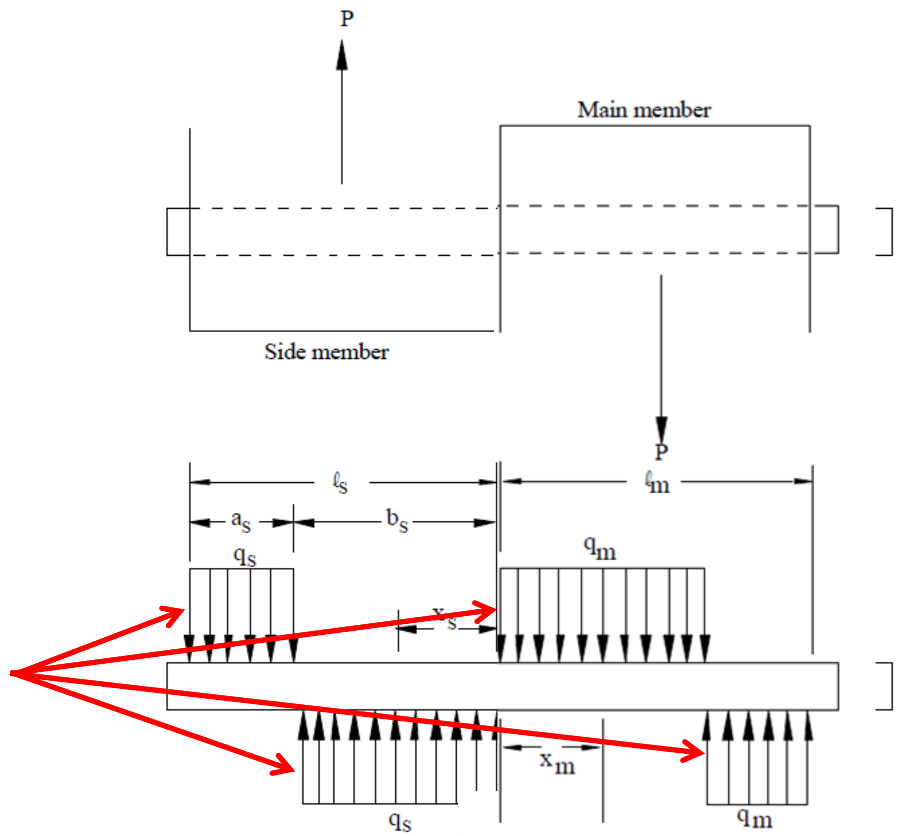
Chapter 12 – Dowel-type Fasteners

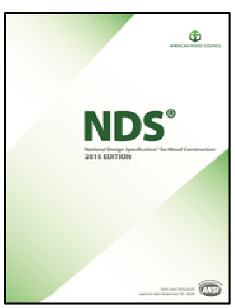
12.3.5 Dowel Bearing Length

New

12.3.5.1 Dowel bearing length in the side member(s) and main member, ℓ_s and ℓ_m, shall be determined based on the length of dowel bearing perpendicular to the application of load.

12.3.5.2 For cross-laminated timber where the direction of loading relative to the grain orientation at the shear plane is parallel to grain, the dowel bearing length in the perpendicular plies shall be reduced by multiplying the bearing length of those plies by the ratio of dowel bearing strength perpendicular to grain to dowel bearing strength parallel to grain ($F_{e\perp} / F_{e\parallel}$).





Non-uniform for CLT

Chapter 12 – Dowel-type Fasteners

- Adjust ℓ_m or ℓ_s to compensate for orthogonal grain orientations in adjacent layers
- Parallel to grain: $F_{e\perp}/F_{e\|}$

Example: ½″ bolt in southern pine 3-ply CLT with 1-½″ laminations

$\ell_m = t_{1\|} + t_{2\perp} + t_{3\|} = 3(1.5) = 4.5''$

$\ell_{m\text{-}adj} = t_{1\|} + t_{2\perp}(F_{e\perp}/F_{e\|}) + t_{3\|}$

$= 1.5 + 1.5(3650/6150) + 1.5 = 3.9''$

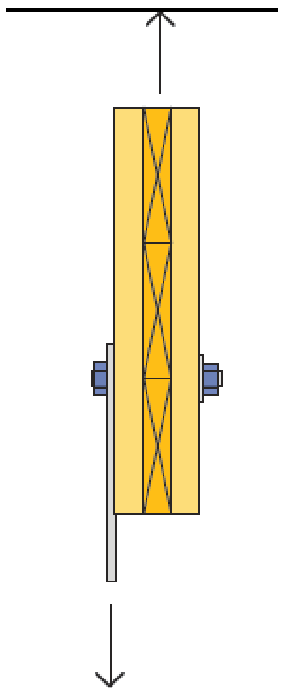
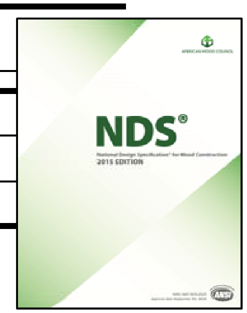


Table 12.3.3 Dowel Bearing Strengths, F_e, for Dowel-Type Fasteners in Wood Members

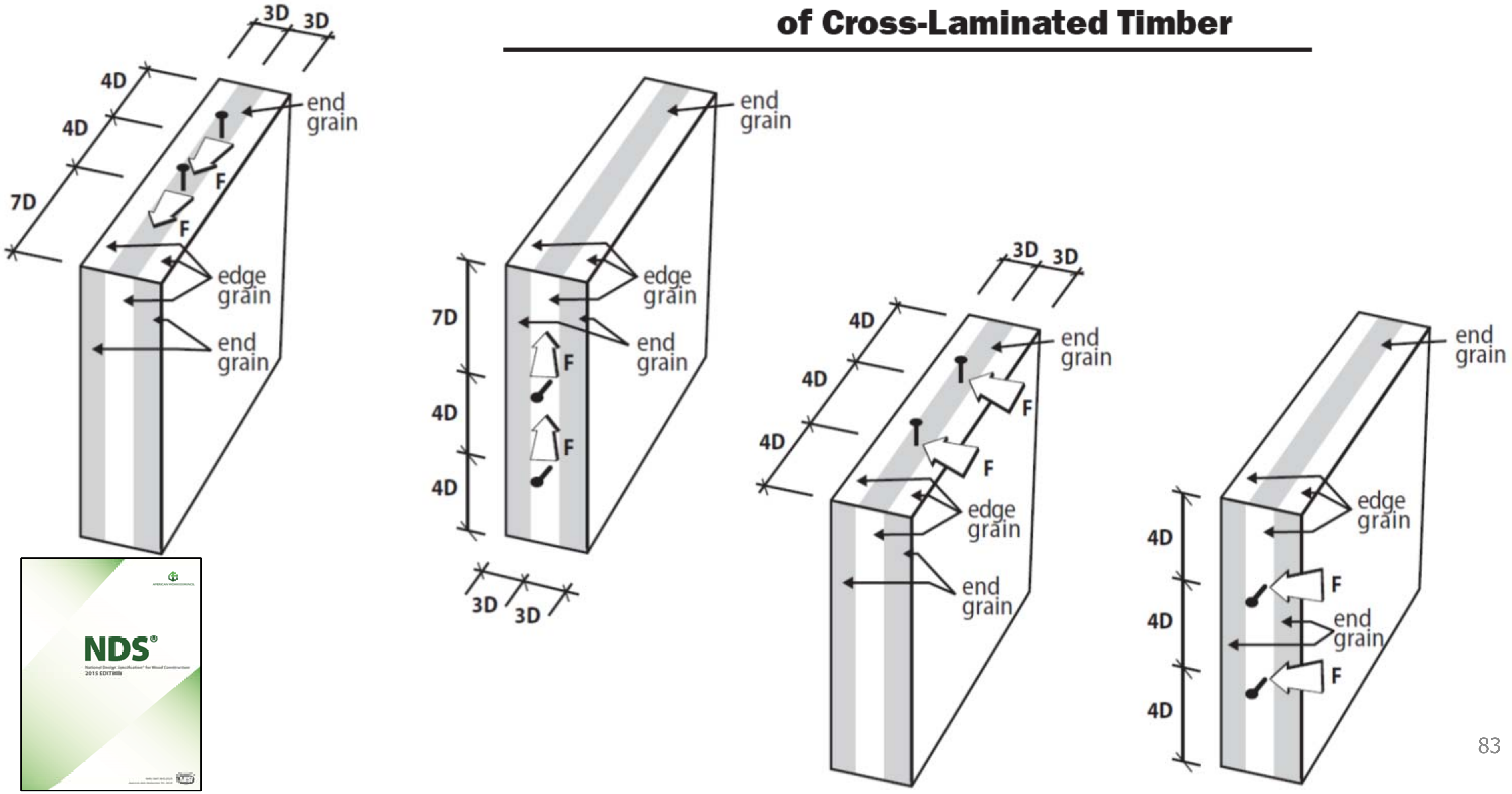
Specific[1] Gravity, G	Dowel bearing strength in pounds per square inch (psi)[2]									
	F_e	$F_{e\|}$	$F_{e\perp}$							
	D<1/4"	1/4" ≤ D ≤ 1"	D=1/4"	D=5/16"	D=3/8"	D=7/16"	D=1/2"	D=5/8"	D=3/4"	D=7/8"	
0.55	5550	6150	5150	4600	4200	3900	3650	3250	2950	2750	
0.54	5350	6050	5000	4450	4100	3750	3550	3150	2900	2650	
0.53	5150	5950	4850	4350	3950	3650	3450	3050	2800	2600	2450



Chapter 12 – Dowel-type Fasteners

Figure 12I **End Distance, Edge Distance and Fastener Spacing Requirements in Narrow Edge of Cross-Laminated Timber**

New



Chapter 12 – Dowel-type Fasteners

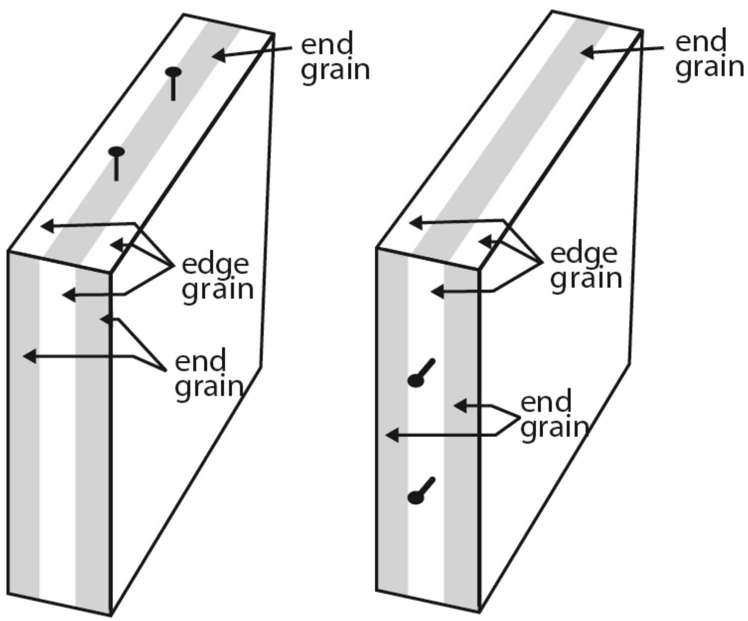
12.5.2 End Grain Factor, C_{eg}

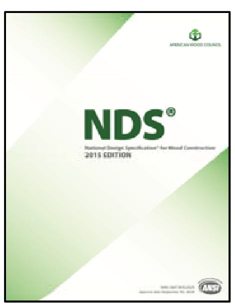
12.5.2.2 Where dowel-type fasteners are inserted in the end grain of the main member, with the fastener axis parallel to the wood fibers, reference lateral design values, Z, shall be multiplied by the end grain factor, C_{eg} = 0.67.

12.5.2.3 Where dowel-type fasteners with D≥1/4" are loaded laterally in the narrow edge of cross-laminated timber, the reference lateral design value, Z, shall be multiplied by the end grain factor, C_{eg}=0.67, regardless of grain orientation.

New

- **Lateral – any end grain**
  - **D<1/4" C_{eg}=0.67**
- **Lateral – any CLT edge**
  - **D≥1/4" C_{eg}=0.67**

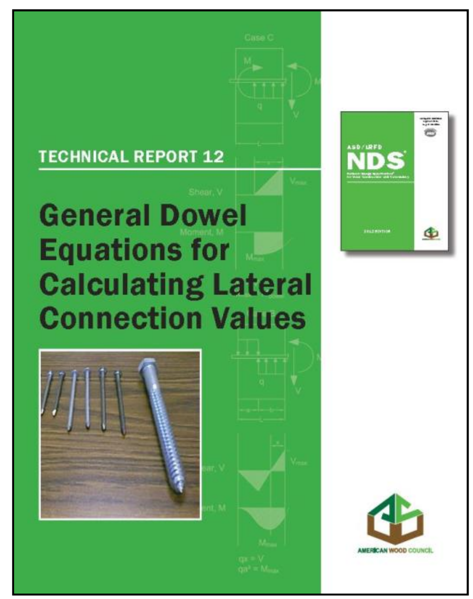




Technical Report 12

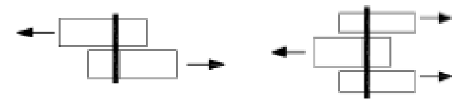
- **Background and derivation of the mechanics-based approach for calculating lateral connection capacity used in the NDS**
- **Provides additional flexibility and broader applicability to the NDS provisions**
  - **Connections with gaps between members**
  - **Connecting wood to members with hollow cross sections**

http://www.awc.org/codes-standards/publications

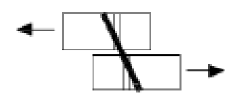
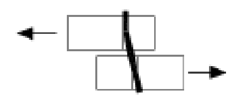


Technical Report 12

Table 1-1 General Dowel Equations for Solid Cross Section Members[2]

Yield Mode	Single Shear	Double Shear	Description
I_m	$P = q_m L_m$	$P = q_m L_m$	
I_s	$P = q_s L_s$	$P = 2\, q_s L_s$	
II-IV	$P = \frac{-B + \sqrt{B^2 - 4AC}}{2A}$	$P = \frac{-B + \sqrt{B^2 - 4AC}}{A}$	General equation for member bearing and dowel yielding

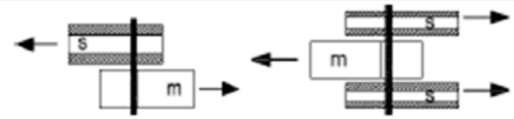
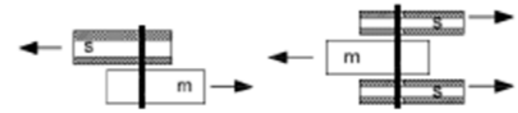
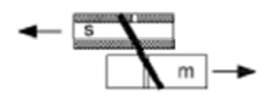
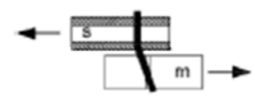
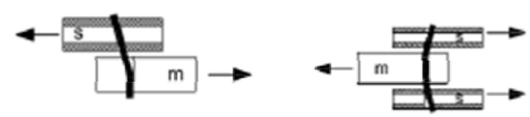
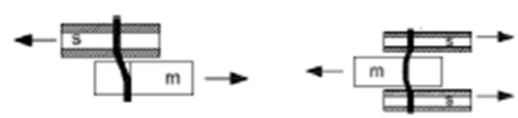
Inputs A, B, & C for Yield Modes II-IV

Yield Mode	A	B	C	Description
II[1]	$A = \frac{1}{4q_s} + \frac{1}{4q_m}$	$B = \frac{L_s}{2} + g + \frac{L_m}{2}$	$C = -\frac{q_s L_s^2}{4} - \frac{q_m L_m^2}{4}$	
III_m[1]	$A = \frac{1}{2q_s} + \frac{1}{4q_m}$	$B = g + \frac{L_m}{2}$	$C = -M_s - \frac{q_m L_m^2}{4}$	
III_s	$A = \frac{1}{4q_s} + \frac{1}{2q_m}$	$B = \frac{L_s}{2} + g$	$C = -\frac{q_s L_s^2}{4} - M_m$	
IV	$A = \frac{1}{2q_s} + \frac{1}{2q_m}$	$B = g$	$C = -M_s - M_m$	

[1]Yield Modes II and III_m do not apply for double shear connections.
[2]See Section 1.6 for notation.

Technical Report 12

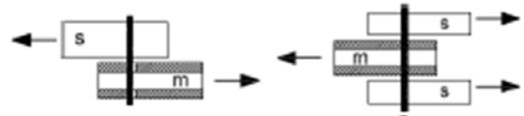
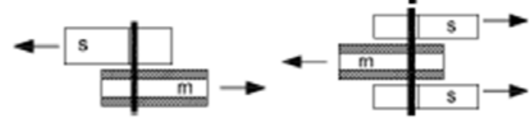
Table 1-2 General Dowel Equations for Solid Cross-Section Main Member and Hollow Cross Section Side Member(s)[2]

Yield Mode	Single Shear	Double Shear		Description
I_m	$P = q_m L_m$	$P = q_m L_m$		
I_s	$P = 2 q_s t_{ws}$	$P = 4 q_s t_{ws}$		
II-IV	$P = \frac{-B + \sqrt{B^2 - 4AC}}{2A}$	$P = \frac{-B + \sqrt{B^2 - 4AC}}{A}$		General equation for member bearing and dowel yielding
	Inputs A, B, & C for Yield Modes II-IV			
II[1]	$A = \frac{1}{4 q_s} + \frac{1}{4 q_m}$	$B = t_{ws} + v_s + g + \frac{L_m}{2}$	$C = -q_s t_{ws}(t_{ws} + v_s) - \frac{q_m L_m^2}{4}$	
III_m[1]	$A = \frac{1}{2 q_s} + \frac{1}{4 q_m}$	$B = g + \frac{L_m}{2}$	$C = -M_s - \frac{q_m L_m^2}{4}$	
III_s	$A = \frac{1}{4 q_s} + \frac{1}{2 q_m}$	$B = t_{ws} + v_s + g$	$C = -q_s t_{ws}(t_{ws} + v_s) - M_m$	
IV	$A = \frac{1}{2 q_s} + \frac{1}{2 q_m}$	$B = g$	$C = -M_s - M_m$	

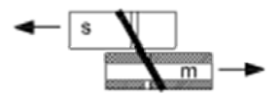
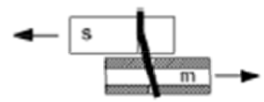
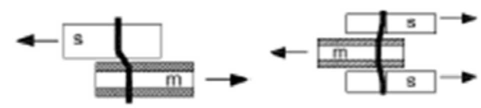
[1]Yield Modes II and III_m do not apply for double shear connections.
[2]See Section 1.6 for notation.

Technical Report 12

Table 1-3 General Dowel Equations for Hollow Cross Section Main Member and Solid Cross Section Side Member(s)[2]

Yield Mode	Single Shear	Double Shear	Description
I_m	$P = 2q_m t_{wm}$	$P = 2q_m t_{wm}$	
I_s	$P = q_s L_s$	$P = 2q_s L_s$	
II-IV	$P = \frac{-B + \sqrt{B^2 - 4AC}}{2A}$	$P = \frac{-B + \sqrt{B^2 - 4AC}}{A}$	General equation for member bearing and dowel yielding

Inputs A, B, & C for Yield Modes II-IV

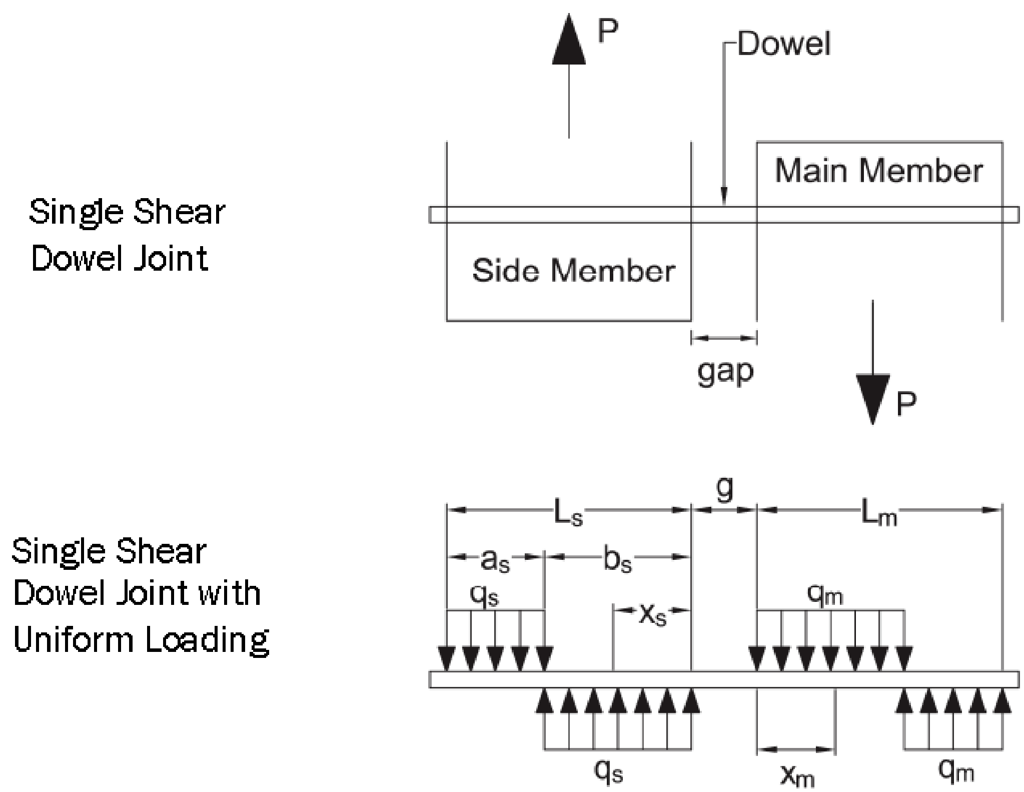
Yield Mode	A	B	C	Description
II[1]	$A = \frac{1}{4q_s} + \frac{1}{4q_m}$	$B = t_{wm} + v_m + g + \frac{L_s}{2}$	$C = -q_m t_{wm}(t_{wm} + v_m) - \frac{q_s L_s^2}{4}$	
III_m[1]	$A = \frac{1}{2q_s} + \frac{1}{4q_m}$	$B = g + t_{wm} + v_m$	$C = -M_s - q_m t_{wm}(t_{wm} + v_m)$	
III_s	$A = \frac{1}{4q_s} + \frac{1}{2q_m}$	$B = \frac{L_s}{2} + g$	$C = -\frac{q_s L_s^2}{4} - M_m$	
IV	$A = \frac{1}{2q_s} + \frac{1}{2q_m}$	$B = g$	$C = -M_s - M_m$	

[1]Yield Modes II and III_m do not apply for double shear connections.
[2]See Section 1.6 for notation.

Technical Report 12

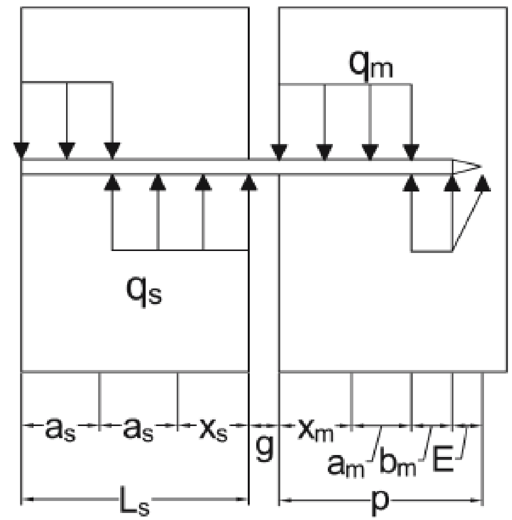
- **Allows for evaluation of connections with gaps between connected members**

Figure 2-5 Single Shear Connection - Mode II



Technical Report 12

- **Tapered tip fasteners**
  - **NDS 12.5.3 defines "E" as length of tapered tip**
    - Lag screws – E defined in Appendix L
    - Wood screws, nails – E assumed to be 2D
  - **Tapered tip does not count towards bearing length (L_m) in TR12 Tapered tip equations.**



Technical Report 12

- **Tapered tip equations**
  - **Mode I_m**

$$P = q_m\left(p - \frac{E}{2}\right)$$

  - **Mode I_s**

$$P = q_s\left(2L_s - \frac{E}{2}\right)$$

  - **Mode II**

$$P^2\left(\frac{1}{4q_s} + \frac{1}{4q_m}\right) + P\left(\frac{L_s}{2} + g + \frac{p}{2} - \frac{E}{4}\right) - \left(\frac{q_s L_s^2}{4} + \frac{q_m p^2}{4} - \frac{q_m pE}{4} + \frac{q_m 5E^2}{48}\right) = 0$$

  - **Mode III_m**

$$P^2\left(\frac{1}{2q_s} + \frac{1}{4q_m}\right) + P\left(g + \frac{p}{2} - \frac{E}{4}\right) - \left(M_s + \frac{q_m p^2}{4} - \frac{q_m pE}{4} + \frac{q_m 5E^2}{48}\right) = 0$$

  - **Mode III_s**

Single Shear:

$$P^2\left(\frac{1}{4q_s} + \frac{1}{2q_m}\right) + P\left(\frac{L_s}{2} + g\right) - \left(\frac{q_s L_s^2}{4} + M_{dm}\right) = 0$$

Double Shear:

$$\frac{P^2}{4}\left(\frac{1}{4q_s} + \frac{1}{2q_m}\right) + \frac{P}{2}\left(\frac{L_s}{2} + g\right) - \left(\frac{q_s L_s^2}{4} + M_{dm}\right) = 0$$

- **Mode IV**

Single Shear:

$$P^2\left(\frac{1}{2q_s} + \frac{1}{2q_m}\right) + P\,g - \left(M_{ds} + M_{dm}\right) = 0$$

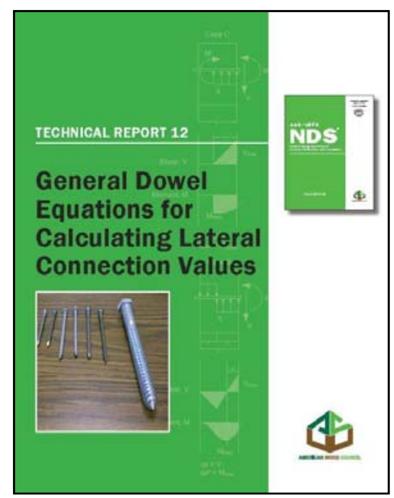
Double Shear:

$$\frac{P^2}{4}\left(\frac{1}{2q_s} + \frac{1}{2q_m}\right) + \frac{P\,g}{2} - \left(M_{ds} + M_{dm}\right) = 0$$

TR12 shows NDS approximations are <1% different from using expanded equation!

Technical Report 12

- **TR12 presents mechanics-based equations**
  - **Gives same results as NDS energy-based approach**
- **Equations in TR12 calculate P, must be divided by R_d (NDS Table 12.3.1B) to convert to NDS Z basis**
- **TR12 Appendix available with supplementary information**



Technical Report 12 Appendix

- **Contains additional data for TR12 equation inputs**
  - **Dowel bearing values for:**
    - Wood
    - Steel
    - Concrete
    - Stainless steel
    - Aluminum
  - **Dowel bending values for fastener materials:**
    - Steel and stainless steel bolts and lag screws
    - Low-to-medium carbon steel nails
    - Hardened steel nails (including post-frame ring-shank)

Table A1. Dowel Bearing Strength, F_e

Material	Nominal Bearing Stress	NDS Dowel Bearing Strength, F_e, Equation (psi)	NDS Reference Value, F_e (psi)
Wood members[3] (for D ≥ 1/4")			
Parallel to grain ($F_{e\parallel}$)		11200 G	NDS Table 12.3.3
Perpendicular to grain ($F_{e\perp}$)		$6100\ G^{1.45}/D^{0.5}$	NDS Table 12.3.3
Wood members[3] (D < 1/4")			
Parallel and perpendicular to grain (F_e)		$16600\ G^{1.84}$	NDS Table 12.3.3
Wood Structural Panels[3]			
Plywood (for D ≤ 1/4")			
Structural 1, Marine ($G_{eqv} = 0.5$)		$16600\ G^{1.84}$	4650
Other Grades ($G_{eqv} = 0.42$)		$16600\ G^{1.84}$	3350
(Note: Use $G_{eqv} = 0.42$ when species of the plies is not known. When species of the plies is known, specific gravity listed for the actual species and the corresponding dowel bearing strength may			

P

Table A2. Dowel Bending Yield Strength, F_{yb}

Fastener	NDS Dowel Bending Yield Strength, F_{yb}, Equation(psi)	NDS Reference Value, F_{yb} (psi)
Bolt, lag screw (with D ≥ 3/8"), drift pin		
SAE J429 Grade 1: $F_y = 36$ ksi, $F_u = 60$ ksi	$F_y/2 + F_u/2$	45,000
ASTM A320, Class 1, Type B8 and B8M:		
Stainless Steel S30400: $F_y = 30$ ksi, $F_u = 75$ ksi		-
Stainless Steel S30403: $F_y = 25$ ksi, $F_u = 70$ ksi		-
Stainless Steel S31600: $F_y = 30$ ksi, $F_u = 75$ ksi		-
Stainless Steel S31603: $F_y = 25$ ksi, $F_u = 70$ ksi		-
Common, box, or sinker nail, spike, lag screw, wood screw (low to medium carbon steel)	130,400 – 213,900D	
0.099" ≤ D ≤ 0.142"		100,000
0.142" < D ≤ 0.177"		90,000
0.177" < D ≤ 0.236"		80,000

Example Problem #1

- **Calculate W for ¼″ diameter, 2.5″ long lag screw connecting 2-2x SYP (G = 0.55) members**
  - **$W = 1800\ G^{3/2}\ D^{3/4}$ = 260 lbs/in (calculate or NDS Table 12.2A)**
  - **Calculate penetration into main member for withdrawal capacity**
    - NDS Appendix L gives lag screw dimensions
      - Length of unthreaded section = ¾″
      - Length of threaded section (including tip) = 1¾″
      - Length of threaded section (excluding tip) = $1^{19}/_{32}$″
    - p = screw length – length of side member – length of tip
    - p = 2.5″ – 1.5″ – (1¾″ - $1^{19}/_{32}$″) = <u>0.84″ of penetration</u>
  - **Unadjusted capacity = W*p = (260 lbs/in * 0.84 in) = 219 lbs**
  - **Apply adjustment factors per Table 11.3.1 to get adjusted W′**

Example Problem #2

- **Calculate unadjusted Z for ½″ diameter bolt connecting two 2x DF-L (G = 0.5) members with a 1″ gap between them**
  - **Both members loaded parallel to grain ($K_\theta = 1$)**
    - D = 0.5″
    - $F_{e||}$ = 5600 psi (NDS Table 12.3.3); $q_s = q_m = F_{e||} * D$ = 5600 psi * 0.5″ = 2800 lb/in
    - $L_s = L_m$ = 1.5″
    - F_{yb} = 45,000 psi
    - g = 1″

I_m	$P = q_m L_m$
I_s	$P = q_s L_s$

		Inputs A, B, & C for Yield Modes II-IV	
II[1]	$A = \frac{1}{4q_s} + \frac{1}{4q_m}$	$B = \frac{L_s}{2} + g + \frac{L_m}{2}$	$C = -\frac{q_s L_s^2}{4} - \frac{q_m L_m^2}{4}$
III_m[1]	$A = \frac{1}{2q_s} + \frac{1}{4q_m}$	$B = g + \frac{L_m}{2}$	$C = -M_s - \frac{q_m L_m^2}{4}$
III_s	$A = \frac{1}{4q_s} + \frac{1}{2q_m}$	$B = \frac{L_s}{2} + g$	$C = -\frac{q_s L_s^2}{4} - M_m$
IV	$A = \frac{1}{2q_s} + \frac{1}{2q_m}$	$B = g$	$C = -M_s - M_m$

Example Problem #2

- **Calculate unadjusted Z for ½" diameter bolt connecting two 2x DF-L (G = 0.5) members with a 1" gap between them**
  - **$M_m = M_s = (F_b D^3)/6 = (45{,}000\ psi)*(0.5''\hat{}3)/6 = 937.5$ lb-in**
    - Substituting values into TR12 equations yields P values
    - Divide P values by R_d to obtain Z

Mode	P (lbs)	R_d	Z (lbs)
I_m	4200	$4K_\theta = 4$	1050
I_s	4200	$4K_\theta = 4$	1050
II	1163	$3.6K_\theta = 3.6$	323
III_m	1211	$3.2K_\theta = 3.2$	378
III_s	1211	$3.2K_\theta = 3.2$	378
IV	1285	$3.2K_\theta = 3.2$	402

Z = 323 lbs

Example Problem #3

- **Compare lateral Z values for single shear nail connection at 6D, 8D, 10D, and 12D penetration using TR12 tapered tip equations**
  - **8d common nail D = 0.131", tapered tip length, E = 2D = 0.262"**
  - **Main member F_{em} = 4,700 psi (loaded parallel to grain); ASTM A653, Grade 33 steel side member, thickness = 0.06", F_{es} = 61,850 psi**
  - **L_m = p (penetration into main member); L_s = 0.06" (side member thickness)**

Penetration Depth (p)	Z (lbs)	Controlling mode
12D (1.57")	97	III_s
10D (1.31")	97	III_s
8D (1.05")	97	III_s
6D (0.79")	79	II

Example Problem #3

- **Compare Z values for single shear nail connection at 6D, 8D, 10D, and 12D penetration using NDS L_m assumption for tapered tip**
  - **8d common nail D = 0.131", tapered tip length, E = 2D = 0.262"**
  - **Main member F_{em} = 4,700 psi (loaded parallel to grain); ASTM A653, Grade 33 steel side member, thickness = 0.06", F_{es} = 61,850 psi**
  - **L_m = p – E/2 (NDS assumption) ; L_s = 0.06" (side member thickness)**

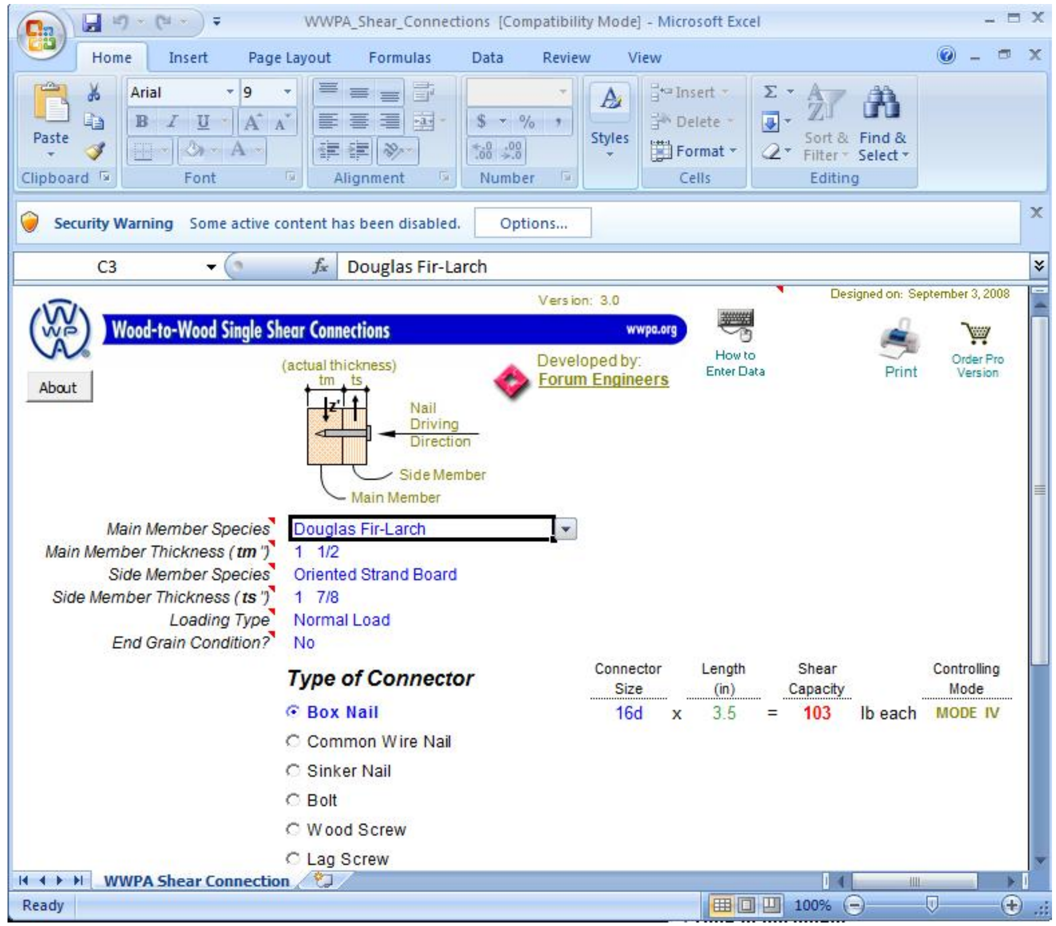
Penetration Depth (p)	Z (lbs)	Controlling mode
12D (1.57")	97	III_s
10D (1.31")	97	III_s
8D (1.05")	97	III_s
6D (0.79")	78	II

Outline

- **Wood connection design philosophy**
- **Connection behavior**
- **Serviceability challenges**
- **Connection hardware and fastening systems**
- **Connection techniques**
- **Design software**
- **Where to get more information**

Software Solutions Exist

- WWPA Lumber Design Suite
  - Beams and Joists
  - Post and Studs
  - Wood to Wood Shear Connections (nails, bolts, wood screws and lag screws)



http://www2.wwpa.org/TECHGUIDEPAGES/DesignSoftware/tabid/859/Default.aspx

Example Problem – Connections Calculator

- **AWC Connections Calculator**
  - **Can calculate lateral and withdrawal capacities**
    - http://awc.org/codes-standards/calculators-software/connectioncalc

Calculators

Example Problem – Connections Calculator

Design Method	Allowable Stress Design (ASD)
Connection Type	Lateral loading
Fastener Type	Nail
Loading Scenario	Single Shear

Submit Initial Values

Design Method	Allowable Stress Design (ASD)
Connection Type	Lateral loading
Fastener Type	Nail
Loading Scenario	Single Shear

Submit Initial Values

Main Member Type	Douglas Fir-Larch
Main Member Thickness	2.5 in.
Side Member Type	Steel
Side Member Thickness	16 gage
Nail Type	Common Wire
Nail Size	8d (D = 0.131 in.; L = 2.5 in.)
Load Duration Factor	C_D = 1.0
Wet Service Factor	C_M = 1.0
End Grain Factor	C_eg = 1.0
Temperature Factor	C_t = 1.0
Diaphragm Factor	C_di = 1.0

Calculate Connection Capacity

Connection Yield Mode Descriptions | Limits of Use

Diaphragm Factor Help | Load Duration Factor Help | Technical Help

Show Printable View

Connection Yield Modes

Im	676 lbs.
Is	221 lbs.
II	274 lbs.
IIIm	283 lbs.
IIIs	97 lbs.
IV	132 lbs.

Z'

Adjusted ASD Capacity	**97 lbs.**

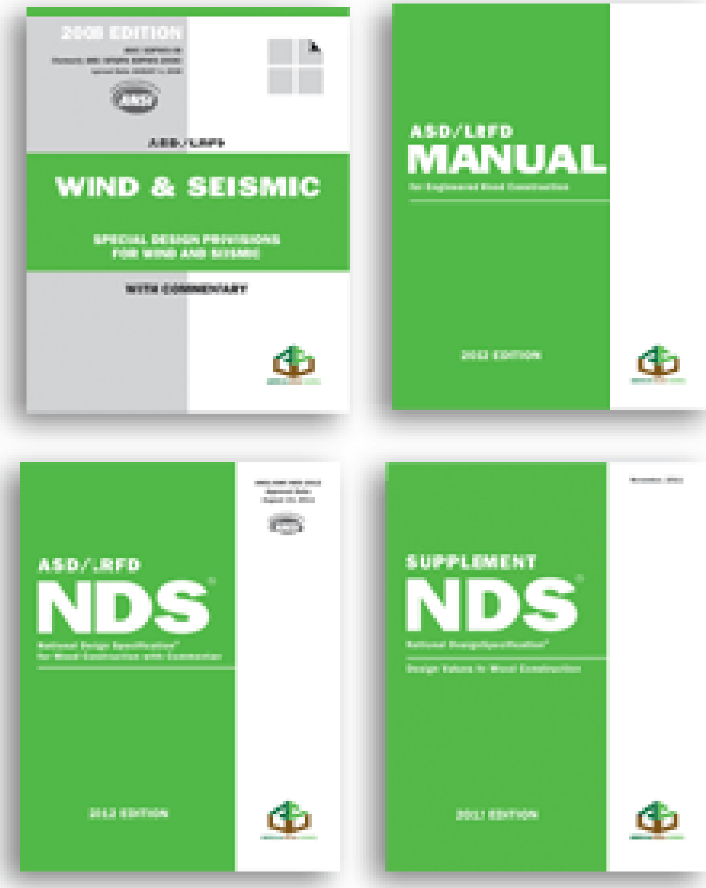
Outline

- **Wood connection design philosophy**
- **Connection behavior**
- **Serviceability challenges**
- **Connection hardware and fastening systems**
- **Connection techniques**
- **Design software**
- **Where to get more information**

KM5

More info???

- **2012 NDS**



Slide 104

KM5 Update to 2015 mention the what's changed icon.

Kam-Biron, Michelle, 1/25/2017

More info???

- **Technical papers on Timber rivets:** **http://www.awc.org/helpoutreach/faq/faqFiles/Timber_rivets.html**

  - **Timber rivets in structural composite lumber**
  - **Simplified analysis of timber rivet connections**
  - **Timber rivet connections in U.S. domestic species**
  - **Timber Rivets-Structure Magazine**
  - **Seismic Behavior of Timber Rivets in Wood Construction**
  - **Seismic Performance of Riveted Connections in Heavy Timber Construction**
  - **Timber rivet suppliers**

More info???

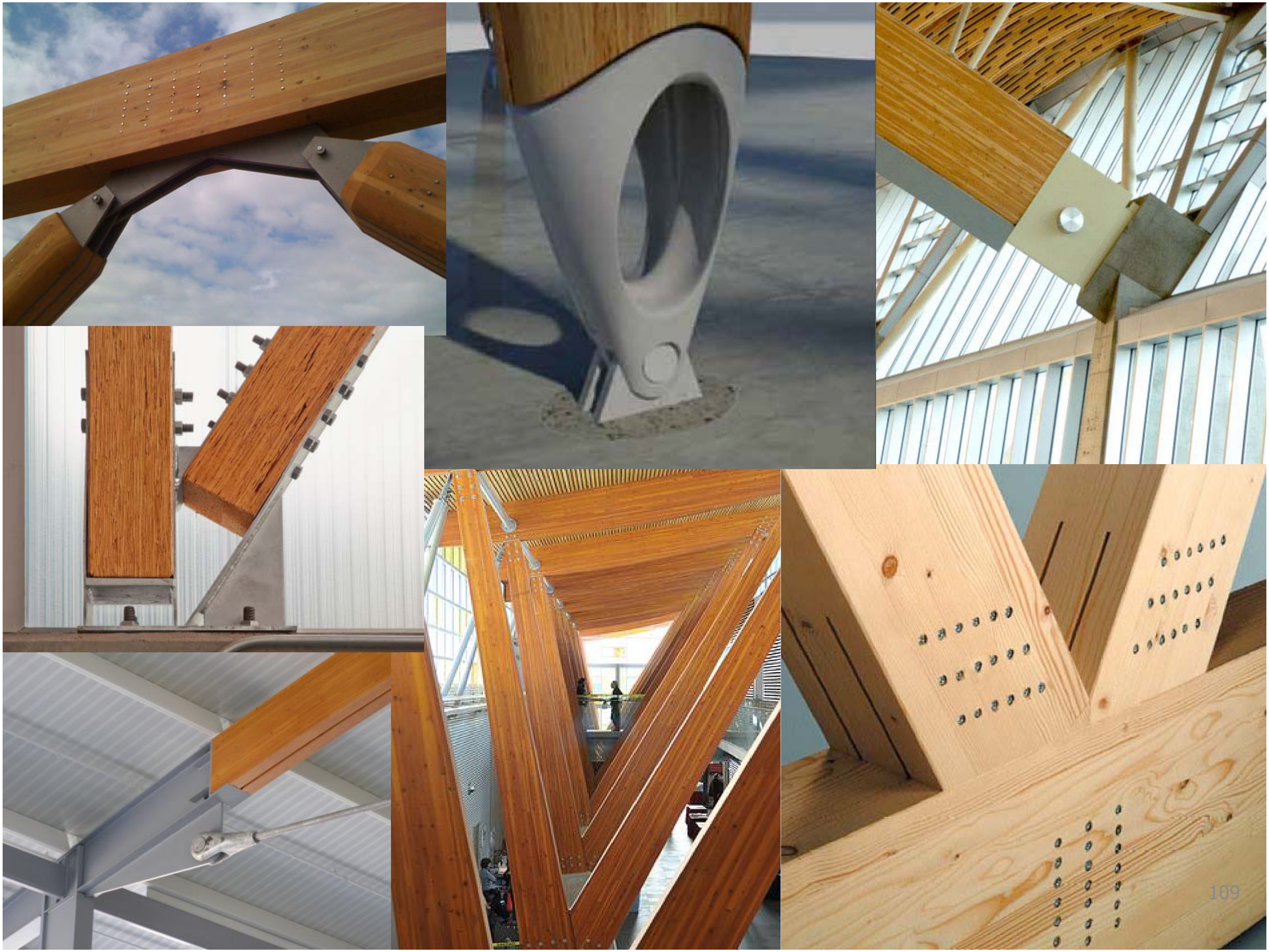
- **Load-carrying behavior of steel-to-timber dowel connections: http://timber.ce.wsu.edu/Resources/papers/2-4-1.pdf**
- **New Concealed Connectors Bring More Options for Timber Structures http://www.structuremag.org/Archives/2007-1/p42-43D-Insights-ConcealedConnectorsJan07.pdf**

Take Home Messages...

- **Transfer loads in compression / bearing whenever possible**
- **Allow for dimensional changes in the wood due to potential in-service moisture cycling**
- **Avoid the use of details which induce tension perp stresses in the wood**
- **Avoid moisture entrapment in connections**
- **Separate wood from direct contact with masonry or concrete**
- **Avoid eccentricity in joint details**
- **Minimize exposure of end grain**

Connections

...and you thought connecting wood was complicated!



Questions?

- **This concludes The American Institute of Architects Continuing Education Systems Course**

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AMERICAN WOOD COUNCIL