Connection Philosophy

- Tension perpendicular to grain
  - Wood’s weak link
  - Avoid if possible
  - Reinforce if not

initiators:
- Notches
- Hanging loads
- Eccentricity

Outline

- Connection philosophy
- NDS Chapter-by-chapter description
- Changes from previous editions
- Examples
  - Part 1: Member Design Webinar
  - Available at WoodWorks.org

Notching

Problem

Solution
**Hanger to Beam**

- Lower half of beam: may cause splits, not recommended

**Beam to Concrete**

- Notched Beam Bearing: may cause splitting, not recommended

**Hanger to Beam**

- Upper half of beam: extended plates move fasteners away from tension side of bending member

**Beam to Concrete**

- Notched Bearing Wall: alternate to beam notch
Beam to Concrete

Sloped Beam
- not fully supported
- may split
- exposes end grain
- **not recommended**

Sloped Beam
- notched concrete wall
- alternate to beam notch

Outline
- Connection philosophy
- **NDS Chapter-by-chapter description**
- Changes from previous editions
- Examples

NDS 2005 Chapters

- 2005
  1. General Requirements for Building Design
  2. Design Values for Structural Members
  3. Design Provisions and Equations
  4. Sawn Lumber
  5. Structural Glued Laminated Timber
  6. Round Timber Poles and Piles
  7. Prefabricated Wood I-Joists
  8. Structural Composite Lumber
  9. Wood Structural Panels
  10. Mechanical Connections
  11. Dowel-Type Fasteners
  12. Split Ring and Shear Plate Connectors
  13. Timber Rivets
  14. Shear Walls and Diaphragms
  15. Special Loading Conditions
  16. Fire Design of Wood Members

Today's focus
10.2.2 Multiple Fastener Connections
When a connection contains two or more fasteners of the same type and similar size, each of which exhibits the same yield mode (see Appendix I), the total adjusted design value for the connection shall be the sum of the adjusted design values for each individual fastener. Local stresses in connections using multiple fasteners shall be checked in accordance with principles of engineering mechanics (see 10.1.2).
**2005 NDS Appendix E**

- **Appendix E - Local Stresses in Fastener Groups**
- New topic introduced in *2001 NDS*

### Appendix E (Non-mandatory) Local Stresses in Fastener Groups

**E.1. General**

Where a fastener group is composed of closely-spaced fasteners loaded parallel to grain, the capacity of the fastener group may be limited by wood failure at the net section or tear-out around the fasteners caused by local stresses. One method to evaluate member strength for local stresses around fastener groups is outlined in the example below.

\[
Z_{i} = \frac{F_{i}}{2} (mS_{\text{min}}) 2 \text{ shear area}
\]

where:

\[
\frac{F_{i}}{2} = F_{i}^* Z_{\text{min}}
\]

**Example:**

Assuming a shear line on each side of bolts in a row (observed in tests of bolted connections). Equation (E.3-1) becomes:

\[
Z_{i} = \frac{F_{i}}{2} (mS_{\text{min}}) 2 \text{ shear area}
\]

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---

**Local Stresses in Fastener Groups**

- Closely spaced fasteners
  - Brittle failure
  - Lower capacity
  
  Wood failure mechanisms need to be considered in design.

---

**Local Stresses in Fastener Groups**

**Appendix E NDS Expressions**

- **Net tension:**

\[
Z_{NT} = F_{i}^* A_{\text{net}}
\]

- **Row tear-out:**

\[
Z_{RT} = n_{i} F_{i}^* t_{s_{\text{min}}}
\]

\[
Z_{RT} = \sum_{i=1}^{n} Z_{RT_i}
\]

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Local Stresses in Fastener Groups

- **Appendix E** NDS Expressions
  - Group tear-out

\[ Z'_{GT} = \frac{Z'_{RT\text{-top}}}{2} + \frac{Z'_{RT\text{-bottom}}}{2} + F_i A_{\text{group-net}} \]

- Note: spacing between outer rows of fasteners paralleling the member on a single splice plate ≤ 5"

Fasteners on Common Splice Plate

Good detailing to allow for shrinkage

<table>
<thead>
<tr>
<th>Direction of Loading</th>
<th>Minimum Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parallel to Grain</td>
<td>1.5D</td>
</tr>
<tr>
<td>Perpendicular to Grain</td>
<td></td>
</tr>
<tr>
<td>when E/D ≤ 0.8</td>
<td>2.5D</td>
</tr>
<tr>
<td>when 0.8 &lt; E/D ≤ 1.6</td>
<td>(1.5D + 0.5F_i)</td>
</tr>
<tr>
<td>when E/D &gt; 1.6</td>
<td>3.0D</td>
</tr>
</tbody>
</table>

1. The D/F ratio used to determine the minimum spacing between rows shall be the lesser of (a) length of fastener or wood member (D + F) or (b) [length of fastener + wood member (D) / 2] + 0.5F_i. In the absence of the member or a single splice plate (see Figure 11.183) (see Figure 11.183).

Example

Truss Bottom Chord and Splice

- Design the bottom chord of a sawn lumber commercial/industrial truss to support a tensile force (T) of 20,000 lbs (D+L)
- Assume a dry moisture service condition, un-incised material and a load duration factor of 1.0.
**Local Stresses in Fastener Groups**

**Solution**

- Try 4x12 No.1 Hem Fir:
  
  \[ T' = 24,600 \text{ lbs} \]

**Solution**

- Single shear steel splice plate
  - Neglect eccentricity
  - Rows spaced at 1/3 depth – within NDS limits

Using Appendix E provisions:

**Net Section Tension**

Net cross section area

\[
Z_{NT'} = 625(32.8) = 20,500 \text{ lbs} > 20,000 \text{ lbs}\]

\[
Z_{NT'} = 625(32.8) = 20,500 \text{ lbs} > 20,000 \text{ lbs} \text{ OK}
\]

**Row Tear-out Capacity**

- From the NDS Supplement
  \[ F'_v = 150\text{ psi} \]

Critical spacing \( s_{critical} \) is lesser of end distance (7D)

\[ 7D = 7(0.875) = 6.125'' \]

or fastener spacing (4D)

\[ 4D = 4(0.875) = 3.5'' \]

\[ 3.75'' > 1.5D = 1.31'' \]

\[ 3.75'' > 1.5D = 1.31'' \]

\[ 4D = 4(0.875) = 3.5'' \]

\[ Z_{RT'} = n_{row} \cdot n_i \cdot F'_v \cdot t_{critical} \]

\[ Z_{RT'} = (2)(8)(150)(3.5)(3.5) = 29,400 \text{ lbs} > 20,000 \text{ lbs} \text{ OK} \]
Local Stresses in Fastener Groups

Solution
Using Appendix E provisions
- Group Tear-out Capacity
  Assume:
  - uniform row spacing
  - edge distance = 3.75 inches
  \[ Z_{GT} = \frac{Z_{RT}}{2} + F_{t} A_{group-net} \]
  \[ = \frac{(29,400)}{2} + 625(3.5) \left[ 11.25 - 2(3.75) - (0.875 + 0.0625) \right] \]
  \[ = 20,850 \text{ lbs} > 20,000 \text{ lbs OK} \]

The design is still acceptable. Net section tension controls.

Alternate: maximum spacing between rows
Using Appendix E provisions:
- Group Tear-out Capacity
  Assume:
  - 5" max between rows
  - edge distance = 3.125"
  \[ Z_{GT} = \frac{Z_{RT}}{2} + F_{t} A_{group-net} \]
  \[ = \frac{(29,400)}{2} + 625(3.5) \left[ 11.25 - 2(3.125) - (0.875 + 0.0625) \right] \]
  \[ = 27,688 \text{ lbs} > 20,000 \text{ lbs OK} \]

The design is still acceptable.

Chapter 10 – Mechanical Connections

Alternate: minimum spacing between rows
Using Appendix E provisions
- Group Tear-out Capacity
  Assume:
  - Spacing between rows 1.5D
  - 1.5D = 1.31 inches
  \[ Z_{GT} = \frac{Z_{RT}}{2} + F_{t} A_{group-net} \]
  \[ = \frac{(29,400)}{2} + 625(3.5) \left[ 1.31 - (0.875 + 0.0625) \right] \]
  \[ = 15,515 \text{ lbs} < 20,000 \text{ lbs NG} \]

The design is unacceptable. Spacing between rows is too tight!
Group Action Factor, $C_g$

Multiple fastener connections
- accounts for load distribution within the connection
- Split rings, shear plates, dowels ≤ 1”
- tabulated values still in the NDS
- can calculate $C_g$ if outside tabulated range

$C_g$ definitions
- row of fasteners
  - 2 or more split ring or shear plate connector units aligned in the direction of load
  - 2 or more bolts of same diameter loaded in direction of load
  - 2 or more lag screws of same type and size loaded in direction of load

\[ C_g = \left[ \frac{m(1 - m^{2n})}{n(1 + R_{EA}m^n)(1 + m) - 1 + m^{2n}} \right] \left[ \frac{1 + R_{EA}}{1 - m} \right] \]

where:
\[ R_{EA} = \text{the lessor of} \quad \frac{E_m A_m}{E_s A_s} \quad \text{or} \quad \frac{E_m A_m}{E_s A_s} \]
\[ m = u - \sqrt{u^2 - 1} \]
\[ u = 1 + \gamma \left[ \frac{1}{E_m A_m} + \frac{1}{E_s A_s} \right] \]

\[ \gamma \text{ (lb/in.)} \]
- Load / slip modulus

- Bolt, lag screws:
  - wood-to-metal connections: (270,000)(D^{1/2})
  - wood-to-wood connections: (180,000)(D^{1/2})

- 2-1/2” split ring & 2-5/8” shear plate: 400,000
- 4” split ring & 4” shear plate: 500,000
Group Action Factor, $C_g$

- **Equation method Example**
  Find $C_g$ for two rows of 1" diameter bolts spaced 4" apart in a
  wood-to-wood double shear splice connection using 2x12's for
  main and side members

  Wood Data
  
  $E_m =$ 1400000 psi  
  $A_m =$ 1.5 in x 11.25 in  
  $A_m = 16.875$ in$^2$

  Fastener Data
  
  $s =$ 4 in  
  $n =$ 10

  Load / Slip
  
  $\gamma =$ 180000 lbf/in  
  $D =$ 1 in 
  $\gamma = 1.8 \times 10^5$ lbf/in

  \[
  u := 1 + \gamma \frac{s}{2 \left( \frac{1}{E_s A_s} + \frac{1}{E_m A_m} \right)} \Rightarrow u = 1.023 \\
  m := u - \sqrt{u^2 - 1} \Rightarrow m = 0.808 \\
  R_{EA} := \min \left( \frac{A_m}{E_m A_m}, \frac{A_s}{E_s A_s} \right) \Rightarrow R_{EA} = 0.5 \\
  C_g := \frac{u}{n} \left[ \left( 1 - m^2 n^2 \right) \left( 1 + R_{EA}^{2 m} \right) \right] \Rightarrow C_g = 0.669
  \]

- **Tabulated values**

  $A_m =$ gross x-sectional area of main member, in$^2$
  
  $A_s =$ sum of gross x-sectional areas of all side members, in$^2$
Group Action Factor, \( C_g \)

Not applicable here - loads acting along the length of the member are unit loads

Chapter 10 – Mechanical Connections

- Wet Service Factor, \( C_M \)

Wet Service Factor, \( C_M \)

<table>
<thead>
<tr>
<th>Saturated</th>
<th>19% MC</th>
<th>Dry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fabrication</td>
<td>1.0</td>
<td>0.7</td>
</tr>
<tr>
<td>In-service</td>
<td>1.0</td>
<td>0.7</td>
</tr>
</tbody>
</table>

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

- Withdrawal load - lag & wood screws only

\( C_M = 1.0 \) if:

- 1 fastener
- 2+ fasteners

- Withdrawal load - nails & spikes

- Lateral load (\( C_M = 0.7 \) for \( D < 1/4'' \))

- Lateral load (\( D > 1/4'' \))

- Split splice plates
Fasteners on Common Splice Plate

Good detailing to allow for shrinkage

Table 11.5.10 Spacing Requirements Between Rows

<table>
<thead>
<tr>
<th>Direction of Loading</th>
<th>Minimum Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parallel to Grain</td>
<td>1.5D</td>
</tr>
<tr>
<td>Perpendicular to Grain</td>
<td></td>
</tr>
<tr>
<td>when 24 × D ≤ 8</td>
<td>2.5D</td>
</tr>
<tr>
<td>when 24 × D &gt; 8</td>
<td>(5/5) × (D/8)</td>
</tr>
</tbody>
</table>

ASD and LRFD accommodated through Table 10.3.1
- Bolts
- Lag screws
- Wood screws
- Nails & spikes

Fastener Values

Included in U.S. design literature

<table>
<thead>
<tr>
<th>Fastener Type</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bolts</td>
<td>NDS or NER</td>
</tr>
<tr>
<td>Lag Screws</td>
<td>NDS or NER</td>
</tr>
<tr>
<td>Wood Screws</td>
<td>NDS or NER</td>
</tr>
<tr>
<td>Nails &amp; Spikes</td>
<td>NDS or NER</td>
</tr>
<tr>
<td>Split Ring Connectors</td>
<td>NDS</td>
</tr>
<tr>
<td>Shear Plate Connectors</td>
<td>NDS</td>
</tr>
<tr>
<td>Drill Bolts &amp; Drill Pins</td>
<td>NDS</td>
</tr>
<tr>
<td>Metal Plate Connectors</td>
<td>NER</td>
</tr>
<tr>
<td>Hangers &amp; Framing Anchors</td>
<td>NER</td>
</tr>
<tr>
<td>Staples</td>
<td>NER</td>
</tr>
</tbody>
</table>

Fastener Bending Yield

<table>
<thead>
<tr>
<th>Fastener Type</th>
<th>F_y (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bolt, lag screw (with D ≥ 3/8&quot;)</td>
<td>45,000</td>
</tr>
<tr>
<td>Common, box, or sinker nail, lag screw, wood screw (low to medium carbon steel)</td>
<td>45,000</td>
</tr>
<tr>
<td>0.099&quot; ≤ D ≤ 0.142&quot;</td>
<td>100,000</td>
</tr>
<tr>
<td>0.142&quot; &lt; D ≤ 0.177&quot;</td>
<td>90,000</td>
</tr>
<tr>
<td>0.177&quot; &lt; D ≤ 0.236&quot;</td>
<td>80,000</td>
</tr>
<tr>
<td>0.236&quot; &lt; D ≤ 0.273&quot;</td>
<td>70,000</td>
</tr>
<tr>
<td>0.273&quot; &lt; D ≤ 0.344&quot;</td>
<td>60,000</td>
</tr>
<tr>
<td>0.344&quot; &lt; D ≤ 0.375&quot;</td>
<td>45,000</td>
</tr>
<tr>
<td>Handened steel nail (medium carbon steel)</td>
<td>130,000</td>
</tr>
<tr>
<td>0.120&quot; ≤ D ≤ 0.142&quot;</td>
<td>115,000</td>
</tr>
<tr>
<td>0.142&quot; &lt; D ≤ 0.192&quot;</td>
<td>110,000</td>
</tr>
<tr>
<td>0.192&quot; &lt; D ≤ 0.207&quot;</td>
<td>100,000</td>
</tr>
</tbody>
</table>

National Evaluation Reports (NER) are developed for proprietary products
Fastener Bending Yield Test

Center-Point Bending Test

Load

Dowel Bearing Strength

Table 11.3.2 Dowel Bearing Strengths

<table>
<thead>
<tr>
<th>Specific Gravity, G</th>
<th>Dowel bearing strength</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D=1/4&quot;</td>
</tr>
<tr>
<td>0.73</td>
<td>9300</td>
</tr>
<tr>
<td>0.72</td>
<td>9050</td>
</tr>
<tr>
<td>0.71</td>
<td>8850</td>
</tr>
<tr>
<td>0.70</td>
<td>8600</td>
</tr>
<tr>
<td>0.69</td>
<td>8400</td>
</tr>
<tr>
<td>0.68</td>
<td>8150</td>
</tr>
</tbody>
</table>

Yield Limit Equations

Table 11.3.1A Yield Limit Equations

<table>
<thead>
<tr>
<th>Yield Mode</th>
<th>Single Shear</th>
</tr>
</thead>
<tbody>
<tr>
<td>I&lt;sub&gt;n&lt;/sub&gt;</td>
<td>( Z = \frac{D_{c} F_{m}}{R_{g}} ) (11.3-1)</td>
</tr>
<tr>
<td>I&lt;sub&gt;1&lt;/sub&gt;</td>
<td>( Z = \frac{D_{c} F_{m}}{R_{g}} ) (11.3-2)</td>
</tr>
<tr>
<td>II</td>
<td>( Z = \frac{k_{2} D_{c} F_{m}}{R_{g}} ) (11.3-3)</td>
</tr>
<tr>
<td>III&lt;sub&gt;n&lt;/sub&gt;</td>
<td>( Z = \frac{k_{3} D_{c} F_{m}}{(1 + 2R_{g}) R_{g}} ) (11.3-4)</td>
</tr>
<tr>
<td>III&lt;sub&gt;e&lt;/sub&gt;</td>
<td>( Z = \frac{k_{3} D_{c} F_{m}}{(2 + R_{g}) R_{g}} ) (11.3-5)</td>
</tr>
<tr>
<td>IV</td>
<td>( Z = \frac{D_{c}^{2} F_{m} F_{p}}{R_{g} \sqrt{3(1 + R_{g})}} ) (11.3-6)</td>
</tr>
</tbody>
</table>

Yield Limit Equations

Table 11.3.1A Yield Limit Equations

<table>
<thead>
<tr>
<th>Yield Mode</th>
<th>Single Shear</th>
</tr>
</thead>
<tbody>
<tr>
<td>I&lt;sub&gt;n&lt;/sub&gt;</td>
<td>( Z = \frac{D_{c} F_{m}}{R_{g}} ) (11.3-1)</td>
</tr>
<tr>
<td>I&lt;sub&gt;1&lt;/sub&gt;</td>
<td>( Z = \frac{D_{c} F_{m}}{R_{g}} ) (11.3-2)</td>
</tr>
<tr>
<td>II</td>
<td>( Z = \frac{k_{2} D_{c} F_{m}}{R_{g}} ) (11.3-3)</td>
</tr>
<tr>
<td>III&lt;sub&gt;n&lt;/sub&gt;</td>
<td>( Z = \frac{k_{3} D_{c} F_{m}}{(1 + 2R_{g}) R_{g}} ) (11.3-4)</td>
</tr>
<tr>
<td>III&lt;sub&gt;e&lt;/sub&gt;</td>
<td>( Z = \frac{k_{3} D_{c} F_{m}}{(2 + R_{g}) R_{g}} ) (11.3-5)</td>
</tr>
<tr>
<td>IV</td>
<td>( Z = \frac{D_{c}^{2} F_{m} F_{p}}{R_{g} \sqrt{3(1 + R_{g})}} ) (11.3-6)</td>
</tr>
</tbody>
</table>

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### Yield Limit Equations

**Table 11.3.1B Reduction Term, R_s**

<table>
<thead>
<tr>
<th>Fasteners Size</th>
<th>Yield Mode</th>
<th>Reduction Term, R_s</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25&quot; ≤ D ≤ 1&quot;</td>
<td>I, I_i, II</td>
<td>4 K_o</td>
</tr>
<tr>
<td></td>
<td>III, III_i, IV</td>
<td>3.6 K_o</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.2 K_o</td>
</tr>
<tr>
<td>D &lt; 0.25&quot;</td>
<td>I, I_i, II, III, III_i, IV</td>
<td>K_D (I)</td>
</tr>
</tbody>
</table>

Notes:
- \( K_o = 1 + 0.25(0/90) \)
- \( \theta \) = maximum angle of load to grain (0 ≤ \( \theta \) ≤ 90°)
  - for any member in a connection
- \( D \) = diameter, in. (see 11.3.6)
- \( K_D = 2.2 \) for \( D ≤ 0.17" \)
- \( K_D = 10D + 0.5 \) for \( 0.17" < D < 0.25" \)

---

### Nail Types and Designations

**Nails and Nomenclature**

- box nail
- ring shank nail
- common nail
- sinker
- pneumatic

**Nail Types described in Appendix L**

**Table L4 - Standard Common, Box, and Sinker Nails**

<table>
<thead>
<tr>
<th>Common or Box</th>
<th>6d</th>
<th>7d</th>
<th>8d</th>
<th>10d</th>
<th>12d</th>
<th>16d</th>
<th>20d</th>
<th>25d</th>
<th>30d</th>
<th>36d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter</td>
<td>2&quot;</td>
<td>2-1/4&quot;</td>
<td>2-1/2&quot;</td>
<td>3&quot;</td>
<td>3-1/4&quot;</td>
<td>3-1/2&quot;</td>
<td>4&quot;</td>
<td>4-1/2&quot;</td>
<td>5&quot;</td>
<td>5-1/2&quot;</td>
</tr>
<tr>
<td>Head Diameter</td>
<td>D</td>
<td>H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td>----</td>
<td>----</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common</td>
<td>0.113&quot;</td>
<td>0.131&quot;</td>
<td>0.148&quot;</td>
<td>0.162&quot;</td>
<td>0.192&quot;</td>
<td>0.209&quot;</td>
<td>0.225&quot;</td>
<td>0.244&quot;</td>
<td>0.263&quot;</td>
<td></td>
</tr>
<tr>
<td>Box</td>
<td>0.099&quot;</td>
<td>0.113&quot;</td>
<td>0.128&quot;</td>
<td>0.135&quot;</td>
<td>0.162&quot;</td>
<td>0.175&quot;</td>
<td>0.206&quot;</td>
<td>0.244&quot;</td>
<td>0.313&quot;</td>
<td></td>
</tr>
<tr>
<td>Sinker</td>
<td>0.092&quot;</td>
<td>0.113&quot;</td>
<td>0.12&quot;</td>
<td>0.135&quot;</td>
<td>0.148&quot;</td>
<td>0.177&quot;</td>
<td>0.192&quot;</td>
<td>0.209&quot;</td>
<td>0.344&quot;</td>
<td></td>
</tr>
</tbody>
</table>

**Table 11N - Common Wire, Box, or Sinker Nails: Refer Values (Z) for Single Shear (two member) Cor**

| Side Member Thickness | Nail Diameter | Common Wire Nail | Box Nail | Sinker Nail | Douglas I, II, III \( A, B, C \) | Douglas I, II, III \( D \) | Douglas I, II, III \( E \) | Douglas I, II, III \( F \) | Douglas I, II, III \( G \) | Dougl ||
|----------------------|---------------|------------------|----------|------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Z                    | Z             | Z                | Z        | Z          | Z                               | Z                               | Z                               | Z                               | Z                               |
| 0.068"               | 0.099"        | 0.121"           | 0.155"   | 0.189"     | 0.224"                          | 0.260"                          | 0.307"                          | 0.353"                          | 0.399"                          |

---

**Figure 5.2**

- (A) common wire nail
- (B) box nail
- (C) zinc-coated (Z) cement-coated (E) helically threaded (F) annularly threaded (G) cut nail (H) double-headed construction nail
Penetration Depth Factor, $C_d$

- Changed in 2001 NDS
- Penetration is built-in to Yield Limit Equations:
  - $\frac{d_m}{2}$ main member dowel bearing length
  - $\frac{d_s}{2}$ side member dowel bearing length
- Tables for lag screws, wood screws, and nails:
  - Based on 8D, 10D, and 10D penetrations, respectively
  - Reduced penetration? Use Table Footnotes
- FAQ available at awc.org

<table>
<thead>
<tr>
<th>Fastener Type</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lag Screws</td>
<td>4D</td>
</tr>
<tr>
<td>Wood Screws</td>
<td>6D</td>
</tr>
<tr>
<td>Nails &amp; Spikes</td>
<td>6D</td>
</tr>
</tbody>
</table>

NDS 11.3.4 “…The length of dowel bearing shall not include the length of the tapered tip of a fastener for fastener penetration lengths less than 10D.”

Penetration - Nails

- $P = 6D$ (NDS 11.1.5.5)

Penetration - Wood Screws

- $P = 6D$ (NDS 11.1.4.6) - includes tip

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Penetration – Lag Screws

- \( P = 4D \) (NDS 11.1.3.6) - does not include tip

Dowel Diameter – Lag Screws

Reduced Body Diameter
- \( D_r \) used to calculate capacity regardless of shear plane location (NDS 11.3.6.1)

Dowel Diameter

- \( D_r \) = root diameter
- \( S \) = unthreaded shank length
- \( T \) = minimum thread length
- \( E \) = length of tapered tip
- \( N \) = number of threads/inch
- \( F \) = width of head across flats
- \( H \) = height of head

Lateral Capacity

Full Body Diameter
- \( D_r \) used to calculate capacity if threads are in or near the shear plane (NDS 11.3.6.2)

Lateral Capacity – Lag Screws

- Why no threads near the shear plane?

Because the induced maximum moment can occur in the threads if the shear plane is not located sufficiently into the shank away from the threads
**Lateral Capacity – Lag Screws**

- Info on where to locate the shear plane

**Lateral Capacity – Wood Screws**

### Rolled Thread

- $D_r$ used to calc capacity if shear plane is anywhere (NDS 11.3.6.1)

  \[
  D = \text{diameter} \\
  D_r = \text{root diameter} \\
  L = \text{thread length} \\
  T = \text{thread length}
  \]

### Cut Thread

- $D_r$ used to calc capacity if shear plane is in or near the threads (NDS 11.3.6.2)

  \[
  D = \text{diameter} \\
  D_r = \text{root diameter} \\
  L = \text{thread length} \\
  T = \text{thread length}
  \]

**Toe nailing**

### Withdrawal

- $C_{tn} = 0.67$

### Lateral

- $C_{tn} = 0.83$
Chapter 11 – Connections

• Capacity definitions
  - $Z_{||}$
  - $Z_{m\perp}$
  - $Z_{s\perp}$
  - $Z_{\perp}$

Spacing, End, & Edge Distances

Nail Capacity Calculations

• Example: Shear Wall Chord Ties with Nails
  - ASD & LRFD

Nailed Tension Tie

How many nails for this connection?

Design connection ties between first and second floor shear wall chords. Walls are 2x6, dry Douglas Fir-Larch studs spaced at 16” oc. The specified wind overturning force is 2.4 kips.
Nailed Tension Tie – LRFD & ASD

Try:
- ASTM A653 Grade metal strap 16 gage x 2.5” wide
- 2 rows staggered 10d common nails

2005 NDS Table 11P

\( Z = 116 \text{ lbs} \)

| Table 11P COMMON WIRE, BOX, or SINKER NAILS: Reference Lateral Design Values (Z) for Single Shear (two member) Connections*1,3 |
|---|---|---|---|---|---|---|
| Panhead weight | lbs | lbs | lbs | lbs |
| 0.005 (40 gage) | 0.115 | 64 | 58 | 60 | 60 |
| 0.010 | 0.175 | 84 | 79 | 80 | 60 |
| 0.015 | 0.275 | 110 | 105 | 105 | 90 |
| 0.020 | 0.475 | 145 | 139 | 140 | 115 |
| 0.025 | 0.725 | 216 | 205 | 205 | 158 |

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2005 NDS Table 11P, Table 10.3.1, and Appendix N

ADJUSTMENT FACTORS

<table>
<thead>
<tr>
<th>ADJUSTMENT FACTORS</th>
<th>LRFD</th>
<th>ASD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time dependent</td>
<td>( \lambda = 1.0 )</td>
<td>( C_D = 1.6 )</td>
</tr>
<tr>
<td>Wet service</td>
<td>( C_M )</td>
<td>1.0</td>
</tr>
<tr>
<td>Temperature</td>
<td>( C_I )</td>
<td>1.0</td>
</tr>
<tr>
<td>Group Action</td>
<td>( C_G )</td>
<td>1.0</td>
</tr>
<tr>
<td>Geometry</td>
<td>( C_A )</td>
<td>1.0</td>
</tr>
<tr>
<td>End grain</td>
<td>( C_{eg} )</td>
<td>1.0</td>
</tr>
<tr>
<td>Diaphragm</td>
<td>( C_{di} )</td>
<td>1.0</td>
</tr>
<tr>
<td>Toe nail</td>
<td>( C_{tn} )</td>
<td>1.0</td>
</tr>
<tr>
<td>Penetration</td>
<td>3” &gt; 10D</td>
<td>1.0</td>
</tr>
</tbody>
</table>

\( K_F = 2.16 / \phi_z = 3.32 \) Table N1

\( \phi_z = 0.65 \) Table N2

DEMAND – Wind Overturning

LRFD

\[ w = \alpha_{ot} W_{ot} \]

\[ w = (1.6)(2,400) = 3,840 \text{ lbs} \]

ASD

\[ w = W_{ot} \]

\[ w = 2,400 \text{ lbs} \]
Nailed Tension Tie – LRFD & ASD

CAPACITY
Safety Limit State

LRFD

\[ Z' = Z \phi \lambda K_F \text{ (all C factors) } \]
\[ = (116)(0.65)(1.0)(3.32)(1.0) \]
\[ = 250 \text{ lbs} \]

ASD

\[ Z' = Z C_D \text{ (all C factors) } \]
\[ = (116)(1.6)(1.0) \]
\[ = 186 \text{ lbs} \]

Nails Needed

\[ n = \frac{w}{Z'} \]
\[ = \frac{(3,840)}{(250)} \]
\[ = 15.4 \rightarrow 16 \text{ nails} \]

\[ n = \frac{w}{Z'} \]
\[ = \frac{(2,400)}{(186)} \]
\[ = 12.9 \rightarrow 13 \text{ nails} \]

Nailed Tension Tie – LRFD & ASD

Why the ASD / LRFD discrepancy?

- 2005 NDS format conversion does not benefit LRFD in the Wind Only case
- Real benefits are realized with combined multiple transient loads (ie. wind + snow + live) – examine load combination cases and LRFD load factors in addition to relative magnitudes of the loads themselves

Connection Calculator

AWC.org
Chapter 12 – Split Rings and Shear Plates

- Capacity tables - unchanged

<table>
<thead>
<tr>
<th>Table 12.2A Split Ring Connector Unit Reference Design Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Split ring diameter</strong></td>
</tr>
<tr>
<td>-------------------------</td>
</tr>
<tr>
<td>0.394</td>
</tr>
<tr>
<td>0.788</td>
</tr>
</tbody>
</table>

Chapter 13 – Timber Rivets

- Capacity tables and details - unchanged

<table>
<thead>
<tr>
<th>Table 13.2A Reference Wood Capacity Values Parallel to Grain, P, for Timber Rivets</th>
</tr>
</thead>
</table>

Chapter 12 – Split Rings and Shear Plates

Availability

- www.clevelandsteel.com

Chapter 13 – Timber Rivets

- Many applications
Chapter 13 – Timber Rivets

Rivets
- Steel AISI 1035
- Rockwell Hardness C32-39
- \( F_u = 145 \text{ ksi} \)
- Hot-dipped galvanized

Plates
- Steel ASTM A36
- Hot-dipped galvanized if in wet service

---

Timber Rivets - Design

- Four strength limit states:
  - Rivet yielding
    - \( P_r \) – parallel to grain
    - \( Q_r \) – perpendicular to grain
  - Wood failure
    - \( P_w \) – parallel to grain
    - \( Q_w \) – perpendicular to grain
  - Plate yielding
    - Enhanced ductility

Lowermost value governs design

QUESTIONS?

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