Design of Bolted Connections per the 2015 NDS (DES335)

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Description

This course will feature a bolt design example utilizing AWC's 2015 National Design Specification® (NDS®) for Wood Construction. Topics will include connection design philosophy and behavior, an overview of 2015 NDS provisions related to bolt design including Appendix E for local stresses in fastener groups, and a detailed design example.
Learning Objectives

At the end of this program, participants will be better able to:

• Understand application of the six yield limit equations for dowel-type connection design
• Know when to utilize applicable adjustment factors for common bolted connections
• Apply spacing, end, and edge distance requirements for wood-to-wood bolted connections
• Determine local stresses in fastener groups

Polling Question

What is your profession?

a) Architect
b) Engineer
c) Code Official
d) Building Designer
e) Other
Basic Concepts

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

**Parallel**

**Perpendicular**

Stronger

Less strong

Connecting Wood - Philosophy

- Wood likes to take on load spread over its surface
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

<table>
<thead>
<tr>
<th>Lateral Loads</th>
<th>ASD Only</th>
<th>ASD and LRFD</th>
<th>LRFD Only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dowel type Fasteners</td>
<td>( P = P \times C_1 \times C_2 \times C_3 \times C_4 \times C_5 \times C_6 \times C_7 \times 0.65 \times 0.65 \times 0.65 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Split ring/shear plate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Timber rivets</td>
<td>( P = P \times C_1 \times C_2 \times C_3 \times C_4 \times C_5 \times C_6 \times C_7 \times 0.65 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spike grids</td>
<td>( P = P \times C_1 \times C_2 \times C_3 \times C_4 \times C_5 \times C_6 \times C_7 \times 0.65 \times 0.65 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nails, screws, wood screws, &amp; drill plugs</td>
<td>( W = W \times C_1 \times C_2 \times C_3 \times C_4 \times C_5 \times C_6 \times C_7 \times 0.65 \times 0.65 \times 0.65 )</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

New chapter numbering for 2015 NDS!

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### 11.2.2 Multiple Fastener Connections

Where 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 evaluated in accordance with principles of engineering mechanics (see 11.1.2).
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

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
Lateral Yield Modes

MODE I
- bearing-dominated yield of wood fibers

MODE II
- pivoting of fastener with localized crushing of wood fibers

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
Yield Limit Equations

- NDS Chapter 12 contains tables with Lateral “Z” values
- Pay attention to assumptions!
  - Faces of connected members must be in contact
  - Load acts perpendicular to axis of dowel

## Table 12A BOLTS: Reference Lateral Design Values, Z, for Single Shear (two member) Connections

<table>
<thead>
<tr>
<th>Thickness</th>
<th>Member</th>
<th>Material</th>
<th>(D_{ss}) in.</th>
<th>(D_{ds}) in.</th>
<th>(Z_{st}) ft</th>
<th>(Z_{dt}) ft</th>
<th>(Z_{sa}) ft</th>
<th>(Z_{da}) ft</th>
<th>(Z_{fa}) ft</th>
<th>(Z_{da}) ft</th>
<th>(Z_{fa}) ft</th>
<th>(Z_{da}) ft</th>
<th>(Z_{fa}) ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1/2</td>
<td>1/4</td>
<td>Red Oak</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>3/4</td>
<td>0.75</td>
<td>Mixed Pine</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>1</td>
<td>1.50</td>
<td>Southern Pine</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
</tr>
</tbody>
</table>

## Table 12.3.1A Yield Limit Equations

<table>
<thead>
<tr>
<th>Yield Mode</th>
<th>Single Shear</th>
<th>Double Shear</th>
</tr>
</thead>
<tbody>
<tr>
<td>(I_{ss})</td>
<td>(Z = \frac{D_{ss} F_{es}}{R_e})</td>
<td>(Z = \frac{D_{ss} F_{es}}{R_e})</td>
</tr>
<tr>
<td>(I_{ds})</td>
<td>(Z = \frac{D_{ds} F_{es}}{R_e})</td>
<td>(Z = \frac{D_{ds} F_{es}}{R_e})</td>
</tr>
<tr>
<td>(II_{es})</td>
<td>(Z = \frac{k_2 D_{es} F_{ce}}{R_e})</td>
<td>(Z = \frac{2 D_{es} F_{ce}}{R_e})</td>
</tr>
<tr>
<td>(III_{es})</td>
<td>(Z = \frac{k_3 D_{es} F_{ce}}{(1+R_e) R_e})</td>
<td>(Z = \frac{2 k_3 D_{es} F_{ce}}{(2+R_e) R_e})</td>
</tr>
<tr>
<td>(IV_{es})</td>
<td>(Z = \frac{F_{ce}}{R_e} \sqrt{3(1+R_e)})</td>
<td>(Z = \frac{2 F_{ce}}{R_e} \sqrt{3(1+R_e)})</td>
</tr>
</tbody>
</table>

**Lowest Yield “Z” value is Connection Capacity**

- 4 Modes of failure
- 6 Yield equations
- Single & double shear
- Wood-to-wood
- Wood-to-steel
- Wood-to-concrete
Yield Limit Equations

\[ D = \text{diameter, in (see 12.3.7)} \]
\[ F_{yb} = \text{dowel bending yield strength, psi} \]
\[ R_d = \text{reduction term (see Table 12.3.1B)} \]
\[ R_t = \frac{R_0}{R_0} \]
\[ \ell_m = \text{main member dowel bearing length, in} \]
\[ \ell_s = \text{side member dowel bearing length, in} \]
\[ F_{m} = \text{main member dowel bearing strength, psi (see Table 12.3.3)} \]
\[ F_{s} = \text{side member dowel bearing strength, psi (see Table 12.3.3)} \]

Table 12.3.3 Dowel Bearing Strengths, \( F_a \), for Dowel-Type Fasteners in Wood Members

<table>
<thead>
<tr>
<th>( G )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.55</td>
</tr>
<tr>
<td>0.65</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>( D )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{D-1/4”} )</td>
</tr>
<tr>
<td>( \text{D-5/32”} )</td>
</tr>
<tr>
<td>( \text{D-7/64”} )</td>
</tr>
<tr>
<td>( \text{D-11/64”} )</td>
</tr>
<tr>
<td>( \text{D-15/64”} )</td>
</tr>
<tr>
<td>( \text{D-19/64”} )</td>
</tr>
<tr>
<td>( \text{D-25/64”} )</td>
</tr>
<tr>
<td>( \text{D-1/4”} )</td>
</tr>
</tbody>
</table>

Dowel bearing strength in pounds per square inch (psi)

Table I1 Fastener Bending Yield Strengths, \( F_{yb} \)

<table>
<thead>
<tr>
<th>Fastener Type</th>
<th>( F_{yb} ) (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bolt, lag screw (with ( D \geq 3/8” )), drift pin (SAE J429 Grade 1 - ( F_y = 36,000 ) psi and ( F_b = 60,000 ) psi)</td>
<td>45,000</td>
</tr>
<tr>
<td>Common, box, or sinker nail, spike, lag screw, wood screw (low to medium carbon steel)</td>
<td></td>
</tr>
<tr>
<td>( 0.099” \leq D \leq 0.142” )</td>
<td>100,000</td>
</tr>
<tr>
<td>( 0.142” &lt; D \leq 0.177” )</td>
<td>90,000</td>
</tr>
<tr>
<td>( 0.177” &lt; D \leq 0.236” )</td>
<td>80,000</td>
</tr>
<tr>
<td>( 0.236” &lt; D \leq 0.273” )</td>
<td>70,000</td>
</tr>
<tr>
<td>( 0.275” &lt; D \leq 0.344” )</td>
<td>60,000</td>
</tr>
<tr>
<td>( 0.344” &lt; D \leq 0.375” )</td>
<td>45,000</td>
</tr>
<tr>
<td>Hardened steel nail (medium carbon steel) including post-frame ring shank nails</td>
<td></td>
</tr>
<tr>
<td>( 0.120” \leq D \leq 0.142” )</td>
<td>130,000</td>
</tr>
<tr>
<td>( 0.142” &lt; D \leq 0.192” )</td>
<td>115,000</td>
</tr>
<tr>
<td>( 0.192” &lt; D \leq 0.207” )</td>
<td>100,000</td>
</tr>
</tbody>
</table>
Dowel Diameters

Dia. Fastener = $D_r$

- $D_r$ when shear plane passes through or near threads
- $D$ when threads are at least $\frac{3}{4} \ell$ away from shear plane
- TR12 can be used for more analytical approach

Dowel Diameters

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

<table>
<thead>
<tr>
<th>Table L1</th>
<th>Standard Hex Bolts[1]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter, $D$</td>
<td>1/4&quot;</td>
</tr>
<tr>
<td>$D_r$</td>
<td>0.189&quot;</td>
</tr>
<tr>
<td>$P$</td>
<td>7/16&quot;</td>
</tr>
<tr>
<td>$H$</td>
<td>11/64&quot;</td>
</tr>
<tr>
<td>$T$</td>
<td>3/16&quot;</td>
</tr>
<tr>
<td>$L$</td>
<td>3/16&quot;</td>
</tr>
</tbody>
</table>

1. Tolerances are specified in ANSI/ASME B18.3. Full-body diameter bolt is shown. Fastener bored in UNC thread series (see ANSI/ASME B1.3).
Polling Question

**NDS yield limit equations consider which of the following conditions?**

a) Wood-to-wood  

b) Wood-to-steel  

c) Wood-to-concrete  

d) All of the above
Example 1: Bolted Splice Joint Check

What can this splice hold in tension?
- Assume 1” diameter x 5” long bolts
- 2x12 No. 2 Southern Pine main and side members
- Dead and construction live load controls
- Normal moisture and temperature

Example 1: Bolted Splice – Bolt Check

Adjustment Factors - ASD
- $C_{eg} = n/a$
- $C_{di} = n/a$
- $C_{tn} = n/a$

Table 11.3.1  Applicability of Adjustment Factors for Connections

Lateral Loads
Dowel-type Fasteners
(e.g. bolts, lag screws, wood screws, nails, spikes, drift bolts, & drift pins)

$Z = Z \times C_D, C_{ld}, C_{w}, C_{x} - C_{w} - C_{x} C_{p}$
Example 1: Bolted Splice – Bolt Check

ASD Adjustment Factor

- **11.3.2 Load Duration Factor**
  - $C_D = 1.25$

### Table 2.3.2
Frequently Used Load Duration Factors, $C_D$

<table>
<thead>
<tr>
<th>Load Duration</th>
<th>$C_D$</th>
<th>Typical Design Loads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permanent</td>
<td>0.9</td>
<td>Dead Load</td>
</tr>
<tr>
<td>Ten years</td>
<td>1.0</td>
<td>Occupancy Live Load</td>
</tr>
<tr>
<td>Ten months</td>
<td>1.15</td>
<td>Snow Load</td>
</tr>
<tr>
<td>Seven days</td>
<td>1.25</td>
<td>Construction Load</td>
</tr>
<tr>
<td>Ten minutes</td>
<td>1.6</td>
<td>Wind-Earthquake Load</td>
</tr>
<tr>
<td>Impact</td>
<td>2.0</td>
<td>Impact Load</td>
</tr>
</tbody>
</table>

1. Load duration factors shall not apply to members subjected to broader ductility levels.
   - $E_0$: reference modulus of elasticity for beams and columns, stability, $E_0$, or to reference compression perpendicular to grain design values.
   - $E_0$: based on a deformation limit.

2. Load duration factors greater than 1.6 shall not apply to structural connections pretreated with waterborne penetrants (see Reference 30) or fire-retardant chemicals. The impact load duration factor shall not apply to connections.

---

Example 1: Bolted Splice – Bolt Check

Adjustment Factors

- **11.3.3 Wet Service Factor**
  - $C_M = 1.0$ lateral dowel

### Table 11.3.3
Wet Service Factors, $C_M$, for Connections

<table>
<thead>
<tr>
<th>Fastener Type</th>
<th>Moisture Content</th>
<th>At Time of Fabrication</th>
<th>In-Service</th>
<th>$C_M$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral Loads</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Split Ring and Shear Plate Connectors $^1$</td>
<td>$\leq 19%$</td>
<td>$\leq 19%$</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>$&gt; 19%$, any</td>
<td>$&gt; 19%$, any</td>
<td>0.8</td>
<td>0.7</td>
</tr>
<tr>
<td>Dowel-type Fasteners (e.g., bolts, lag screws, word screws, nail, spikes, drift bolts, &amp; drift pins)</td>
<td>$\leq 19%$</td>
<td>$\leq 19%$</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$&gt; 19%$, any</td>
<td>$&gt; 19%$, any</td>
<td>0.4</td>
<td>0.7</td>
</tr>
</tbody>
</table>

$^1$: Pretreatment of structural members with waterborne penetrants shall not apply.
Example 1: Bolted Splice – Bolt Check

Adjustment Factors

- 11.3.4 Temperature Factor
  - \( C_t = 1.0 \)

**Table 11.3.4 Temperature Factors, \( C_t \), for Connections**

<table>
<thead>
<tr>
<th>In-Service Moisture Conditions</th>
<th>( C_t )</th>
<th>( 100^\circ F &lt; T \leq 125^\circ F )</th>
<th>( 125^\circ F &lt; T \leq 150^\circ F )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry</td>
<td>1.0</td>
<td>0.8</td>
<td>0.7</td>
</tr>
<tr>
<td>Wet</td>
<td>1.0</td>
<td>0.7</td>
<td>0.5</td>
</tr>
</tbody>
</table>

1. Wet and dry service conditions for connections are specified in 11.3.3.

Example 1: Bolted Splice – Bolt Check

Adjustment Factors

- 11.3.6 Group Action Factor, \( C_g \)
  - Accounts for load distribution within the fastener group
  - **Calculated Method:** \( C_g = 0.97 \)

11.3.6.1 Reference lateral design values for splitting connectors, shear plate connectors, or dowel-type fasteners with \( D \leq 1" \) in a row shall be multiplied by the following group action factor, \( C_g \):

\[
C_g = \left[ \frac{m(1-m^m)}{n(1+R_m)^m(1+m)-1+m^m} \right] \left[ \frac{1+R_m}{1-m} \right] \quad (11.3-1)
\]
Example 1: Bolted Splice – Bolt Check

Adjustment Factors

- **11.3.6 Group Action Factor, \( C_g \)**
- **Tabulated Method**
- **Interpolated** \( C_g = 0.97 \)

\[
\begin{align*}
\text{n} & = 3 \\
E & = 1,400,000 \text{ psi (NDS Supp. Table 4B)} \\
\text{A}_m & = \text{gross } x\text{-sectional area of main member, } \text{in}^2 = 16.875 \text{ in}^2 \\
\text{A}_s & = \text{sum of gross } x\text{-sectional areas of all side members, } \text{in}^2 = 2 \times 16.875 \text{ in}^2 \\
\text{A}_s/\text{A}_m & > 1.0 \text{ and } \text{A}_m/\text{A}_s = 0.5
\end{align*}
\]

Table 11.3.6A  Group Action Factors, \( C_g \) for Bolt or Lag Screw Connections with Wood Side Members

<table>
<thead>
<tr>
<th>( A_s/A_m )</th>
<th>( A_s )</th>
<th>( C_g )</th>
<th>Number of fasteners in a row</th>
<th>Number of fasteners in a row</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>5</td>
<td>0.08</td>
<td>0.99</td>
<td>0.94</td>
</tr>
<tr>
<td>12</td>
<td>0.99</td>
<td>0.99</td>
<td>0.94</td>
<td>0.91</td>
</tr>
<tr>
<td>20</td>
<td>1.00</td>
<td>0.98</td>
<td>0.96</td>
<td>0.92</td>
</tr>
<tr>
<td>40</td>
<td>1.00</td>
<td>0.99</td>
<td>0.97</td>
<td>0.95</td>
</tr>
<tr>
<td>64</td>
<td>1.00</td>
<td>0.99</td>
<td>0.98</td>
<td>0.97</td>
</tr>
</tbody>
</table>

1. Where \( A_s/A_m > 1.0 \), use \( A_s/A_m \) and use \( A_m \) instead of \( A_s \).
2. Tabulated group action factors \( (C_g) \) are conservative for \( D < 1", s < 4", \) or \( E > 1,400,000 \) psi.

Example 1: Bolted Splice – Bolt Check

12.5.1 Geometry Factors, \( C_\Delta \)

- **Edge distance = 3-5/8"**
- **\( \ell/D = \ell_m/D = 1.5"/1" = 1.5 < 6 \)**
- **1.5D minimum = 1.5" < 3-5/8" OK**
- **\( C_\Delta = 1.0 \)**

Table 12.5.10  Edge Distance Requirements

<table>
<thead>
<tr>
<th>Direction of Loading</th>
<th>Minimum Edge Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parallel to Grain:</td>
<td>1.5D or ( \ell/D ) the spacing between rows, whichever is greater</td>
</tr>
<tr>
<td>where ( \ell/D \leq 6 )</td>
<td>1.5D</td>
</tr>
<tr>
<td>where ( \ell/D &gt; 6 )</td>
<td>1.5D or ( \ell/D )</td>
</tr>
<tr>
<td>Perpendicular to Grain:</td>
<td>4D</td>
</tr>
<tr>
<td>loaded edge</td>
<td>1.5D</td>
</tr>
<tr>
<td>unloaded edge</td>
<td>1.5D</td>
</tr>
</tbody>
</table>

1. The \( \ell/D \) ratio used to determine the minimum edge distance shall be the lesser of:
   (a) length of fastener in wood main member/\( D = \ell_m/D \)
   (b) total length of fasteners in wood side member/\( s/D = \ell_s/D \)
Example 1: Bolted Splice – Bolt Check

12.5.1 Geometry Factors, $C_A$

- Spacing between bolts = 4”
- 4D minimum = 4” OK
- $C_A = 1.0$

<table>
<thead>
<tr>
<th>Direction of Loading</th>
<th>Minimum spacing</th>
<th>Spacing for $C_A = 1.0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parallel to Grain</td>
<td>3D</td>
<td>4D</td>
</tr>
<tr>
<td>Perpendicular to</td>
<td>3D</td>
<td>Required spacing for</td>
</tr>
<tr>
<td>Grain</td>
<td></td>
<td>attached members</td>
</tr>
</tbody>
</table>

Table 12.5.1B Spacing Requirements for Fasteners in a Row

Example 1: Bolted Splice – Bolt Check

12.5.1 Geometry Factors, $C_A$

- Spacing between rows = 4”
- 1.5D minimum = 1.5” OK
- $C_A = 1.0$

- Also < 5” maximum
- If not, special detailing needed for shrinkage

Table 12.5.1D 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</td>
<td></td>
</tr>
<tr>
<td>Grain</td>
<td></td>
</tr>
<tr>
<td>where $E/D \leq 2$</td>
<td>2.5D</td>
</tr>
<tr>
<td>where $2 &lt; E/D &lt; 6$</td>
<td>$(5E + 10D) / 8$</td>
</tr>
<tr>
<td>where $E/D \geq 6$</td>
<td>5D</td>
</tr>
</tbody>
</table>

Figure 12H Spacing Between Outer Rows of Bolts
Example 1: Bolted Splice – Bolt Check

12.5.1 Geometry Factors, \( C_D \)
- End distance = 4” (main member)
- \( 3.5D \) absolute minimum = \( 3.5" < 4" \) OK
- \( 7D \) minimum (for \( C_D = 1.0 \)) = 7” NG
- \( C_D = 4" / 7" = 0.57 \)

<table>
<thead>
<tr>
<th>Direction of Loading</th>
<th>Minimum end distance for ( C_D = 0.5 )</th>
<th>Minimum end distance for ( C_D = 1.0 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perpendicular to Grain</td>
<td>2D</td>
<td>4D</td>
</tr>
<tr>
<td>Parallel to Grain, Compression (fastener bearing away from member end)</td>
<td>2D</td>
<td>4D</td>
</tr>
<tr>
<td>Parallel to Grain, Tension (fastener bearing toward member end)</td>
<td>3.5D</td>
<td>7D</td>
</tr>
</tbody>
</table>

For softwoods: 3.5D, 7D
For hardwoods: 2.5D, 5D

Example 1: Bolted Splice – Bolt Check

Calculated Method

\[ I_m = 2306 \text{ lbs} \text{ controls} \]

\[ I_s = 4612 \text{ lbs} \]

\[ III_s = 4307 \text{ lbs} \]

\[ IV = 6003 \text{ lbs} \]

\[ Z = 2306 \text{ lbs} \]

Double Shear

\[ Z = \frac{D \ell_m F_{em}}{R_d} \]

(12.3-7)

\[ Z = \frac{2D \ell_s F_{es}}{R_d} \]

(12.3-8)

\[ Z = \frac{2K_3 U \ell_s F_{em}}{(2 + R_d) R_d} \]

(12.3-9)

\[ Z = \frac{2D^2}{R_d} \sqrt{\frac{2F_{um} F_{ub}}{3(1 + R_c)}} \]

(12.3-10)
Example 1: Bolted Splice – Bolt Check

**Tabulated** Method

- $Z = 2310$ lbs

### Table 12F

| Thickness | $G=0.67$ Red Oak | $G=0.65$ Mixed Species Southern Pine | $G=0.50$ Douglas Fir-Larch | $G=0.49$ Douglas Fir-Larch
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>6 in.</td>
<td>1500</td>
<td>1500</td>
<td>1500</td>
<td>1500</td>
</tr>
<tr>
<td>8 in.</td>
<td>1500</td>
<td>1500</td>
<td>1500</td>
<td>1500</td>
</tr>
<tr>
<td>10 in.</td>
<td>1500</td>
<td>1500</td>
<td>1500</td>
<td>1500</td>
</tr>
</tbody>
</table>

Example 1: Bolted Splice – Bolt Check

**Online Calculator** Method

- $Z = 2306$ lbs
- No adjustments taken for comparison purposes

Example 1: Bolted Splice – Bolt Check

Multiple Bolt Capacity

\[ Z' = n Z C_D C_g C_A \]

\[ = (6)(2306)(1.25)(0.97)(0.57) \]

\[ = 9,562 \text{ lbs} \]

Polling Question

The perp-to-grain distance between outermost fastener rows shall not exceed 5" for sawn lumber under what conditions?

a) Never under any circumstance

b) Unless special detailing is provided to allow cross-grain wood shrinkage

c) When the wood is less than 19% MC

d) None of the above
Example 1: Bolted Splice – Local Stresses

Appendix E – Local Stresses in Fastener Groups

- Groups of closely spaced fasteners loaded parallel to grain
  - Net Section Tension Capacity
  - Row Tear-Out Capacity
  - Group Tear-Out Capacity

Lumber Design Values – NDS Supplement Table 4B

- $F_t = 450$ psi
- $F_v = 175$ psi
- $E = 1,400,000$ psi

<table>
<thead>
<tr>
<th>Species and commercial grade</th>
<th>Size classification</th>
<th>Design values in pounds per square inch (psi)</th>
<th>Specific Gravity</th>
<th>Grading Rules Agency</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOUTHERN PINE</td>
<td>No.2&lt;br&gt; No.3 and Stud&lt;br&gt; No.4&lt;br&gt; Non-Derive</td>
<td>$F_t$ $F_v$ $F_r$ $F_{cp}$ $F_{cp}$</td>
<td>750&lt;br&gt; 450&lt;br&gt; 450&lt;br&gt; 450</td>
<td>1,400,000&lt;br&gt; 450,000&lt;br&gt; 450,000&lt;br&gt; 450,000</td>
</tr>
</tbody>
</table>
### Example 1: Bolted Splice – Local Stresses

#### Lumber Adjustment Factors

- $C_D = 1.25$ for $F_t$ and $F_v$
- $C_M = 1.0$ for $F_t$, $F_v$ and $E$
- $C_t = 1.0$
- $C_i = 1.0$

<table>
<thead>
<tr>
<th>Load Duration</th>
<th>$C_D$</th>
<th>Typical Design Loads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permanent</td>
<td>0.9</td>
<td>Dead Load</td>
</tr>
<tr>
<td>Ten years</td>
<td>1.0</td>
<td>Occupancy Live Load</td>
</tr>
<tr>
<td>Severe damage</td>
<td>1.25</td>
<td>Construction Load</td>
</tr>
<tr>
<td>Ten minutes</td>
<td>1.6</td>
<td>Wind/Earthquake Load</td>
</tr>
<tr>
<td>Impact</td>
<td>2.0</td>
<td>Impact Load</td>
</tr>
</tbody>
</table>

#### Net Section Tension Check

- $Z_{NT}' = F'_t A_{net}$
- $F'_t = 450(1.25) = 562.5$ psi
- $A_{net} = 13.7$ in$^2$
- $Z_{NT}' = 7,706$ lbs

Note: hole size for net area includes 1/16" oversizing per NDS 12.1.3.2
Example 1: Bolted Splice – Local Stresses

Row Tear-Out Check
- $Z_{RT1}' = n_i F_v' t s_{critical}$
- $n_i = 3$
- $F_v' = 175(1.25) = 219$ psi
- $t = 1.5''$
- $s_{critical} = 4''$
- $Z_{RT1}' = 3,938$ lbs for one row
- $Z_{RT2}' = 7,875$ lbs for two rows

Note: $s_{critical}$ is the minimum of the end distance and the in-row bolt spacing = 4''

E.3 Row Tear-Out Capacity

The adjusted tear-out capacity of a row of fasteners can be estimated as follows:

$$Z_{RT}' = \frac{n_i F_v t s_{critical}}{2}$$ (E.3-1)

$$Z_{RT}' = \frac{F_v t}{2} [2 \text{s}_{\text{critical}} \text{ (2 shear lines)]}$$ (E.3-2)

$$= n F_v t s_{critical}$$

Group Tear-Out Check
- $Z_{GT}' = Z_{RT1}'/2 + Z_{RT2}'/2 + F_t' A_{\text{group-net}}$
- $Z_{RT1}' = Z_{RT2}' = 3,938$ lbs
- $F_t' = 450(1.25) = 562.5$ psi
- $A_{\text{group-net}} = 4.41$ in$^2$
- $Z_{GT}' = 6,418$ lbs

Note: hole size for net area includes 1/16'' oversizing per NDS 12.1.3.2

E.4 Group Tear-Out Capacity

The adjusted tear-out capacity of a group of "n" rows of fasteners can be estimated as:

$$Z_{GT}' = \frac{Z_{RT1}'}{2} + \frac{Z_{RT2}'}{2} + F_t' A_{\text{group-net}}$$ (E.4-1)
Example 1: Bolted Splice – Local Stresses

Final Bolt Capacity

\[ Z' = 9,562 \text{ lbs} \]
\[ Z_{NT}' = 7,706 \text{ lbs Controls} \]
\[ Z_{RT}' = 7,875 \text{ lbs} \]
\[ Z_{GT}' = 6,418 \text{ lbs} \]

Polling Question

NDS Appendix E provisions focus on which of the following?

a) Local stresses around fasteners
b) End and edge distance and spacing
c) Group action
d) None of the above
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

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