Learning Objectives

At the end of this program, participants will be knowledgeable of:

1. Identify basic wood material properties and learn how to avoid splits, notching, and checking in connection solutions.
3. Describe effects of moisture on wood connections and implement proper flashing to avoid problems.
4. Identify proper fastener selection in size, scope, and pattern.
Outline

- wood connection design philosophy
- connection behavior
- serviceability issues
- connection hardware and fastening systems
- glues and adhesive-based connections
- connection techniques
- design software
- where to get more information

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

- but…wait a minute…
Connecting Wood - Philosophy

- *looks* can be deceiving...

- wood and tension perpendicular to grain
  - Not recommended

initiators:
- notches
- large diameter fasteners
- hanging loads

Notching

Problem

Solution

Hanger to Beam

Problem: May cause splits
- not recommended

Exception: light load
- <100 lbs
- >24” o.c.
**Hanger to Beam**

- **Full wrap sling option**

**Upper half of beam**
- extended plates puts more wood in compression when loaded

---

**Beam to Concrete**

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

---

**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**
Beam to Concrete

Sloped Beam
- notched concrete wall
- alternate to beam notch

Connecting Wood - Philosophy

- wood, like other hygroscopic materials, moves in varying environments

Connecting Wood - Philosophy

- fastener selection is key to connection ductility, strength, performance

Connecting Wood - Philosophy

- mechanical fasteners
  - keep them small
  - use lots of them

issue is scale of fastener relative to wood member size
Connecting Wood - Philosophy

Quick summary
- Wood likes compression parallel to grain
- Wood likes to take on load spread over its surface
- Avoid tension perpendicular to grain
- Wood, like other materials, moves in varying environments
- Fastener selection is key to connection ductility, strength, performance

Connection Behavior

Balance
- strength
- ductility

Next...
- wood connection design philosophy
- connection behavior
- serviceability issues
- connection hardware and fastening systems
- glues and adhesive-based connections
- connection techniques
- design software
- where to get more information
Connection Serviceability

Moisture Effects

Issue: direct water ingress
• water is absorbed most quickly through wood end grain

Connection Serviceability

Issue: direct water ingress
• re-direct the water flow around the connection

Connection Serviceability

No end caps or flashing

Connection Serviceability

Issue: direct water ingress
• or, let water out if it gets in...

end caps and flashing

Moisture trap - No weep holes
**Wet Service Factor, $C_M$**

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

<table>
<thead>
<tr>
<th>Saturated</th>
<th>19% MC</th>
<th>Dry</th>
<th>Fabrication MC</th>
<th>In-service MC</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_M$</td>
<td>1.0</td>
<td>0.7</td>
<td>0.4*</td>
<td></td>
</tr>
<tr>
<td>Lateral load</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(D&lt;1/4”)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Withdrawal load</td>
<td>1.0</td>
<td>0.7</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>- lag &amp; wood</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>screws only</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$C_M$</td>
<td>1.0</td>
<td>0.25</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>Withdrawal load</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- nails &amp; spikes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Fasteners on Common Splice Plate**

Good detailing to allow for shrinkage

**Beam to Column**

Full-depth side plates
- may cause splitting
- wood 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 $2x &lt; D $</td>
<td>2.5D</td>
</tr>
<tr>
<td>when $2x &lt; D &lt; 5$</td>
<td>$5 + 1D)/8$</td>
</tr>
<tr>
<td>when $2x &gt; D$</td>
<td>$5 + D)/8$</td>
</tr>
</tbody>
</table>

1. The $D/x$ ratio used to determine the minimum spacing between rows shall be in the tenor or
   the length of fastener in wood main member $D + l/x$.

2. The spacing between outer rows of bolts shall not exceed $2D$ (see Figure 11.8).
**Beam to Column**

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

**Problem**
- shrinkage
- tension perp

**Beam to Wall**

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

**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
Column to Base

Where’s the *plate*?

Hidden Column Base

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

Column to Base

Floor slab poured below connection

Arch Base to Support

Problem
- end grain sitting in puddle
- moisture uptake
- decay
Arch Base to Support

Next...

- wood connection design philosophy
- connection behavior
- serviceability issues
- **connection hardware and fastening systems**
- glues and adhesive-based connections
- connection techniques
- design software
- where to get more information

Arch Base to Support

**Good connection**
- avoids tension perp
- avoids decay

Mechanical Connectors
Traditional Connectors

All-wood solution
• time tested
• practical
• extreme efficiencies available with CNC machining

www.tfguild.org
www.timberframe.org


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>Drift Bolts &amp; Drift 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>

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

Center-Point Bending Test

Load

\[ F_{el} = 112000 \text{G} \]
\[ F_{el} = 61000 \frac{G^{1.5}}{D} \]
\[ F_e \text{ for } D < 1/4" = 16600 G^{1.5} \]

Yield Limit Equations

<table>
<thead>
<tr>
<th>Table 11.3.1A</th>
<th>Yield Limit Equations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield Mode</td>
<td>Single Shear</td>
</tr>
<tr>
<td>Ia</td>
<td>[ Z = D_{r}/R_g ]</td>
</tr>
<tr>
<td>I</td>
<td>[ Z = D_{l}/R_g ]</td>
</tr>
<tr>
<td>II</td>
<td>[ Z = k_2 D_{r}/R_g ]</td>
</tr>
<tr>
<td>IIIa</td>
<td>[ Z = k_2 D_{r}/R_g ]</td>
</tr>
<tr>
<td>III</td>
<td>[ Z = k_2 D_{r}/(2+R_g)R_g ]</td>
</tr>
<tr>
<td>IV</td>
<td>[ Z = D^2 \frac{2F_{em} F_p}{R_g \sqrt{3(1+R_g)}} ]</td>
</tr>
</tbody>
</table>

Yield Limit Equations

Table 11.3.2 Dowel Bearing Strengths

<table>
<thead>
<tr>
<th>Table 11.3.2B Dowel Bearing Strengths for Wood Structural Panels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood Structural Panel</td>
</tr>
<tr>
<td>-----------------------</td>
</tr>
<tr>
<td>Plywood Structural 1, Marine</td>
</tr>
<tr>
<td>Other Grades</td>
</tr>
<tr>
<td>Oriented Strand Board</td>
</tr>
</tbody>
</table>
Nail Types and Designations

Nail types described in Appendix L

<table>
<thead>
<tr>
<th>Type</th>
<th>Pennyweight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common</td>
<td>6d 7d 8d 10d 12d 14d 16d 18d 20d 22d 24d 26d 28d 30d 32d 34d 36d 38d 40d 42d 44d 46d 48d 50d 52d 54d 56d 58d 60d</td>
</tr>
<tr>
<td>L</td>
<td>2&quot; 2 1/4&quot; 2 1/2&quot; 3&quot; 3 1/4&quot; 3 1/2&quot; 4&quot; 4 1/2&quot; 5&quot; 5 1/2&quot; 6&quot;</td>
</tr>
<tr>
<td>D</td>
<td>0.113&quot; 0.113&quot; 0.131&quot; 0.148&quot; 0.162&quot; 0.192&quot; 0.207&quot; 0.225&quot; 0.244&quot; 0.263&quot; 0.281&quot;</td>
</tr>
<tr>
<td>H</td>
<td>0.266&quot; 0.266&quot; 0.281&quot; 0.312&quot; 0.344&quot; 0.406&quot; 0.438&quot; 0.469&quot; 0.5&quot; 0.531&quot;</td>
</tr>
<tr>
<td>Box</td>
<td>2&quot; 2 1/2&quot; 3&quot; 3 1/4&quot; 3 1/2&quot; 4&quot; 4 1/2&quot; 5&quot;</td>
</tr>
<tr>
<td>D</td>
<td>0.099&quot; 0.099&quot; 0.113&quot; 0.128&quot; 0.148&quot; 0.162&quot;</td>
</tr>
<tr>
<td>H</td>
<td>0.266&quot; 0.266&quot; 0.297&quot; 0.312&quot; 0.344&quot; 0.375&quot; 0.406&quot;</td>
</tr>
<tr>
<td>Sinker</td>
<td>1.7/8&quot; 2 1/8&quot; 2 3/8&quot; 3 7/8&quot; 3 1/2&quot; 3 3/4&quot; 4 1/4&quot; 4 3/4&quot; 4&quot;</td>
</tr>
<tr>
<td>D</td>
<td>0.092&quot; 0.099&quot; 0.113&quot; 0.12&quot; 0.135&quot; 0.148&quot; 0.177&quot; 0.192&quot; 0.207&quot;</td>
</tr>
<tr>
<td>H</td>
<td>0.234&quot; 0.250&quot; 0.266&quot; 0.281&quot; 0.312&quot; 0.344&quot; 0.375&quot; 0.406&quot; 0.438&quot;</td>
</tr>
</tbody>
</table>

1. Tolerances specified in ASIM F 1667. Typical shape of common, box, and sinker nails shown. See ASIM F 1667 for other nail types.

Nail capacity tables in 2005 NDS

Connection Calculator

Fastener Penetration

<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 Depth Factor, $C_d$

- Changed in 2001 NDS
- Penetration is built-in to Yield Limit Equations:
  - $l_m$, main member dowel bearing length
  - $l_s$, 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>$0.218$</th>
<th>$0.242$</th>
<th>$0.12$</th>
<th>$0.133$</th>
<th>$0.137$</th>
<th>$0.14$</th>
<th>$0.144$</th>
<th>$0.148$</th>
<th>$0.151$</th>
</tr>
</thead>
</table>

1. Tabulated lateral design values ($Z$) shall be multiplied by all applicable adjustment factor
2. Tabulated lateral design values ($Z$) are for rolled thread wood screws (see Appendix L) into the main member equal to $100$; and screw bending yield strength $F_y = 60,000$ psi for $0.142'' < D < 0.177''$, $F_y = 80,000$ psi for $0.177'' < D < 0.236''$, $F_y = 3$. When $6D < p < 10D$, tabulated lateral design values ($Z$) shall be multiplied by $p/10D$.

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)

Dowel Diameter – Lag Screws

Reduced Body Diameter

- $D_r$ used to calculate capacity regardless of shear plane location (NDS 11.3.6.1)

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

Chapter 11 – Connections

- Capacity definitions
  - $Z_{ll}$
  - $Z_{mll}$
  - $Z_{sll}$
  - $Z_{ll}$

Spacing, End, & Edge Distances

Group Action Factor, $C_g$

Multiple fastener connections
- accounts for load distribution within the connection
- Split rings, shear plates, dowels $\leq 1''$
- tabulated values still in the *NDS*
- can calculate $C_g$ if outside tabulated range
Group Action Factor, $C_g$

- Equation method

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

where:

\[
R_{EA} = \text{the lesser of } \frac{E_s A_s}{E_m A_m} \text{ or } \frac{E_m A_m}{E_s A_s}
\]

\[
m = u - \sqrt{u^2 - 1}
\]

\[
u = 1 + \frac{s}{2} \left[\frac{1}{E_m A_m} + \frac{1}{E_s A_s}\right]
\]

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

<table>
<thead>
<tr>
<th>$A_m/A_s$</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.97</td>
<td>0.89</td>
<td>0.80</td>
<td>0.70</td>
<td>0.62</td>
<td>0.55</td>
<td>0.49</td>
<td>0.44</td>
<td>0.40</td>
<td>0.37</td>
<td>0.34</td>
</tr>
<tr>
<td>8</td>
<td>0.98</td>
<td>0.93</td>
<td>0.85</td>
<td>0.77</td>
<td>0.70</td>
<td>0.63</td>
<td>0.57</td>
<td>0.52</td>
<td>0.47</td>
<td>0.43</td>
<td>0.40</td>
</tr>
<tr>
<td>16</td>
<td>0.99</td>
<td>0.96</td>
<td>0.92</td>
<td>0.86</td>
<td>0.80</td>
<td>0.75</td>
<td>0.69</td>
<td>0.64</td>
<td>0.60</td>
<td>0.55</td>
<td>0.52</td>
</tr>
<tr>
<td>24</td>
<td>0.99</td>
<td>0.97</td>
<td>0.94</td>
<td>0.90</td>
<td>0.85</td>
<td>0.81</td>
<td>0.76</td>
<td>0.71</td>
<td>0.67</td>
<td>0.63</td>
<td>0.59</td>
</tr>
<tr>
<td>40</td>
<td>1.00</td>
<td>0.98</td>
<td>0.96</td>
<td>0.94</td>
<td>0.90</td>
<td>0.87</td>
<td>0.83</td>
<td>0.79</td>
<td>0.76</td>
<td>0.72</td>
<td>0.69</td>
</tr>
<tr>
<td>64</td>
<td>1.00</td>
<td>0.99</td>
<td>0.98</td>
<td>0.96</td>
<td>0.94</td>
<td>0.91</td>
<td>0.88</td>
<td>0.86</td>
<td>0.83</td>
<td>0.80</td>
<td>0.77</td>
</tr>
<tr>
<td>120</td>
<td>1.00</td>
<td>0.99</td>
<td>0.99</td>
<td>0.98</td>
<td>0.96</td>
<td>0.95</td>
<td>0.93</td>
<td>0.91</td>
<td>0.90</td>
<td>0.87</td>
<td>0.85</td>
</tr>
<tr>
<td>200</td>
<td>1.00</td>
<td>1.00</td>
<td>0.99</td>
<td>0.99</td>
<td>0.98</td>
<td>0.97</td>
<td>0.96</td>
<td>0.95</td>
<td>0.93</td>
<td>0.92</td>
<td>0.90</td>
</tr>
</tbody>
</table>

--

Mechanical Connections

D ≤ 1”

Anchor Bolts and Washers as required
Appendix E - Local Stresses in Fastener Groups

E.1 General

When 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 following equation.

\[ Z_{\text{net}} = F \cdot A_{\text{net}} \]

where:

- **F** = cyclic force
- **A** = net area

Note: The equation above is for evaluating local stresses around fastener groups. The actual setup and calculations may vary depending on the specific design and loading conditions.
Local Stresses in Fastener Groups

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

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

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

Specialized Connectors

- Shear plates

NDS Chapter 12 – Split Rings & Shear Plates

- Capacity tables - unchanged

**Table 12.2A Split Ring Connector Unit Reference Design Values**

<table>
<thead>
<tr>
<th>Split ring diameter</th>
<th>Bolt diameter</th>
<th>Number of faces of member with connector on same bolt</th>
<th>Design values at 0° connector unit and bolt, Lbs.</th>
<th>Design values at 90° connector unit and bolt, Lbs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>in.</td>
<td>in.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 (\frac{1}{2})</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.5</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.5</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.5</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.5</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.5</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.5</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.5</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.5</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.5</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.5</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13.5</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14.5</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15.5</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16.5</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.5</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18.5</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19.5</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>1/2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NDS Chapter 12 – Split Rings & Shear Plates**

Availability

- www.clevelandsteel.com
**NDS Chapter 13 – Timber Rivets**

- Many applications

**Chapter 13 – Timber Rivets**

**Rivets**
- Steel AISI 1035
- Rockwell Hardness C32-39
- $F_u = 145$ 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

*Lowest value governs design*
Concealed Connectors

SFS Intec

Fixed column base plate
Framework joint
Framework joint
Assembly joint

Concealed Connectors

BVD Connector

BVD connector

Concealed Connectors

Stavebolt®

Tie Bolt Washer
3/4" Grade 8 Tie Bolt (10" Thread)
5/8" Grade 8 Stitch Bolts (11/16" Hole)
Pipe Assembly (2" Hole)

Concealed Connectors

Timberlinx

Tension
Glued Connections

Bond-based connectors
- some adhesives are sensitive to changing environmental conditions (temperature and moisture)
  - epoxies lose strength above 150 deg F
  - some adhesives are not moisture resistant
- adhesives must be carefully chosen to suit expected conditions
- glued joints are probably the most unpredictable

Glued Connections

Adhesives classed based on application:
- manufactured components
- field construction
- repair

for complete discussion on adhesives and uses, see:
Wood Engineering and Construction Handbook,
McGraw-Hill, Chapter 12.

Connection Techniques

- glued floor construction
Glued Connections

- Gluing is not recommended for bonding siding or roof sheathing to framing
- APA glued floor system

Next...

- wood connection design philosophy
- connection behavior
- serviceability issues
- connection hardware and fastening systems
- glues and adhesive-based connections
- connection techniques
- design software
- where to get more information

Connection Techniques

- must evaluate:
  - forces present
  - environmental effects
  - material effects
  - aesthetics

Connection Techniques

wood bolts in all-wood structure
Connection Techniques

steel bolts in columns

Connection Techniques

bolts in heavy trusses

Pre-engineered Connectors

Post to Beam
Beam to Beam

Pre-engineered Connectors

Joist to Beam (Hanger)
Pre-engineered Connectors
Truss hardware

Custom Hardware
Multiple beam connector with slotted holes

Custom Hardware
Difficult situations made easy

Custom Hardware
A blend of art and technology
Pre-engineered Connectors

Panelized roof connectors

Beam to Beam

cantilever hinge connector

Beam to Beam

cantilever hinge connector with tension tie

Connection Techniques

- connecting other frame materials: Steel
Connection Techniques

- connecting other frame materials: Concrete

Connection Techniques

- connecting other frame materials: Masonry

Connection Techniques

- connecting other frame materials: Dead Trees

Next...

- wood connection design philosophy
- connection behavior
- serviceability issues
- connection hardware and fastening systems
- glues and adhesive-based connections
- connection techniques
- design software
- where to get more information
Software solutions exist

Connections design software

Next...

• wood connection design philosophy
• connection behavior
• serviceability issues
• connection hardware and fastening systems
• glues and adhesive-based connections
• connection techniques
• design software
• where to get more information

DES110: Connection Design

• www.awc.org
• More comprehensive
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 perpendicular 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

Murphy’s Law

No matter how well it is designed...

Connections

...and you thought connecting wood was complicated!

Questions?

This concludes The American Institute of Architects Continuing Education Systems Course

www.awc.org
info@awc.org