Connection Solutions for Wood Framed Structures

Bob Clark, APA
Wood Solutions Fair
Chicago, IL May 22, 2014

Course Description

This seminar will feature a discussion of common fastener types, how design values are determined for each, and relevant wood connection philosophies. Topics will include the orthotropic nature of wood, commodity and specialty connectors and the use of small diameter fasteners in portal frames and combined shear and uplift systems. Techniques for designing efficient, durable and structurally safe connections will also be discussed, along with tips for minimizing environmental effects on wood connections and what additional resources are available.

Learning Objectives

• Understand the wide variety of connectors available for wood-framed structures and how they can be used effectively to meet specific design situations.
• Learn how design properties are established for wood connectors and what adjustment factors must be applied to ensure their proper performance in accordance with the 2005 NDS and 2012 NDS.
• Explain how to ensure both the structural performance and long-term durability of wood-framed structures by minimizing environmental impacts on connections.
• Use design and construction examples to illustrate key points and highlight the additional resources available related to wood connection design and detailing.
Wood and compression perpendicular to grain
- Compare wood cells to a bundle of straws
- Bundle crushes under perpendicular load
Connecting Wood

Wood and tension perpendicular to grain
- The evil of wood connections

Initiators
- Notches
- Large diameter fasteners
- Hanging loads

Load spread over its surface increases redundancy and reduces stress concentrations

Mechanical fasteners
- Keep them small
- Use lots of them
- Keep scale of fastener small relative to wood member

Concentrated at a single fastener – Wood is more prone to split and crush
Connecting Wood

Truss plates
- Design metal plate connections using the latest edition of ANSI/TPI 1

Steel bolts and plates in heavy trusses

Connecting Wood

A single large bolt?

Looks can be deceiving...
**Connecting Wood**

**Spike Grid Connectors**

**Hanger to Beam**

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

**Notching**

- **Problem**
  - Tension perpendicular to grain
- **Solution**
Connecting Wood

Notching

Beam to Concrete

Sloped Beam

Potential Splits

Agenda

- Connecting Wood
- Wood Moves
- Wood and Moisture Don’t Mix
- Mechanical Connections
- Glued Connections
- Information Sources
Wood, like other materials, moves in varying environments. Shrinkage due to moisture loss may split and is not recommended. Precautions include fasteners in top of supported beam, wood shrinkage, and prevents lateral movement. Beam hangers are recommended for supported beams.
Wood Moves

Separated Connectors
- shrinkage
- tension perpendicular to grain

Wood Moves

Slotted connections
- Allows for shrinkage and movement under load

Full-depth side plates
- May cause splitting
- Restrains wood shrinkage
Wood Moves

Smaller side plates
- Transmit force
- Allow wood movement

Starlight Theater
Rock Valley Community College – Rockford, IL

Before

Splits
Wood Moves

Back to Basics: 1/8-inch Spacing

- Online Video

Wood Moves

Back to Basics: 1/8-inch Spacing

- Connecting Wood
- Wood Moves
- Wood and Moisture Don’t Mix
- Mechanical Connections
- Glued Connections
- Information Sources
Wood and Moisture Don't Mix

**Application**
- Need 1/2" air gap between wood and masonry

**Beam on shelf**
- Prevent contact with concrete

**Beam on Masonry**
- Bearing plate under beam
- Prevent contact with masonry

**Connectors that trap water:**
- Direct water ingress
- No weep holes
Wood and Moisture Don’t Mix

Arch base to support
- End grain moisture uptake
- Potential for decay

Direct water ingress
- Water is absorbed most quickly through wood end grain

No end caps or flashing

Arch base to support
- Avoids decay

Direct water ingress
- Re-direct the water flow around the connection
- Preservative treated glulam

end caps and flashing
Wood and Moisture Don't Mix

Bearing plate
- Anchor bolts in bearing plate
- Slotted column end

Floor slab poured over connection
- Can cause decay
- Not recommended

Closed Shoe
- No weep holes
- Moisture
- Decay

Elevated Base Plates

Where's the plate?
- Grout substituted
- Moisture may wick into wood

Elevated Base Plates
Agenda

- Connecting Wood
- Wood Moves
- Wood and Moisture Don’t Mix
- Mechanical Connections
- Glued Connections
- Information Sources

Mechanical Connections

Fastener Schedule for Structural Members

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DESCRIPTION OF BUILDING MATERIALS</th>
<th>DESCRIPTION OF FASTENER</th>
<th>SPACING OF FASTENERS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Edges (inches)</td>
</tr>
<tr>
<td>20</td>
<td>3/4&quot; x 1&quot;</td>
<td>6d common (2&quot; x 0.113&quot;) nail (soleway wall)</td>
<td>6</td>
</tr>
<tr>
<td>31</td>
<td>1/2&quot; x 1/2&quot;</td>
<td>6d common (2&quot; x 0.113&quot;) nail (soleway, wall)</td>
<td>6</td>
</tr>
<tr>
<td>32</td>
<td>3/4&quot; x 1/4&quot;</td>
<td>6d common nail (2&quot; x 0.113&quot;)</td>
<td>6</td>
</tr>
<tr>
<td>33</td>
<td>1/2&quot; x 1/4&quot;</td>
<td>10d common (2&quot; x 0.148&quot;) or</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8d 2&quot; x 0.131&quot;) deflected nail</td>
<td></td>
</tr>
</tbody>
</table>

Alternate Attachments

<table>
<thead>
<tr>
<th>NOMINAL MATERIAL THICKNESS</th>
<th>DESCRIPTION &amp; LENGTH</th>
<th>SPACING OF FASTENERS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Edges (inches)</td>
</tr>
<tr>
<td>up to 1/4&quot;</td>
<td>0.060 - 0.099 Nail 2&quot;/</td>
<td>4</td>
</tr>
<tr>
<td>1/8&quot; and 1/6&quot;</td>
<td>0.060 - 0.099 Nail 2&quot;/</td>
<td>3</td>
</tr>
<tr>
<td>1/8&quot; and 1/6&quot;</td>
<td>0.113 Nail 2&quot;/</td>
<td>3</td>
</tr>
<tr>
<td>1/8&quot; and 3/16&quot;</td>
<td>0.060 - 0.099 Nail 2&quot;/</td>
<td>4</td>
</tr>
<tr>
<td>1/8&quot; and 3/16&quot;</td>
<td>0.113 Nail 2&quot;/</td>
<td>3</td>
</tr>
<tr>
<td>3/16&quot; and 3/16&quot;</td>
<td>0.060 - 0.099 Nail 2&quot;/</td>
<td>4</td>
</tr>
<tr>
<td>1/8&quot;</td>
<td>0.113 Nail 2&quot;/</td>
<td>3</td>
</tr>
<tr>
<td>3/16&quot;</td>
<td>0.060 - 0.099 Nail 2&quot;/</td>
<td>4</td>
</tr>
</tbody>
</table>

Alternate Attachments

<table>
<thead>
<tr>
<th>PANEL CATEGORY</th>
<th>SUPPORTED PANEL EDGE</th>
<th>SPACING OF FASTENERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel Category</td>
<td></td>
<td>Edges (inches)</td>
</tr>
<tr>
<td>3/8&quot; - 1/4&quot;</td>
<td>6</td>
<td>6 1/2</td>
</tr>
</tbody>
</table>

Alternate Attachments

<table>
<thead>
<tr>
<th>PENNY SIZE</th>
<th>TYPE</th>
<th>LENGTH (in.)</th>
<th>DIAMETER (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3d</td>
<td>Ring or screw-shank</td>
<td>1 1/4</td>
<td>0.099</td>
</tr>
<tr>
<td>4d</td>
<td>Richelieu or screw-shank</td>
<td>1 1/4</td>
<td>0.099</td>
</tr>
<tr>
<td>6d</td>
<td>Richelieu or screw-shank</td>
<td>1 1/4</td>
<td>0.099</td>
</tr>
<tr>
<td>10d</td>
<td>Box or casing</td>
<td>1 1/4</td>
<td>0.120</td>
</tr>
</tbody>
</table>

Alternate Attachments

**Note:** Fastener schedule may be required for panels with Performance Category 1 or 2. For 1 1/4" Performance Category panels, use 6d or 8d nails. For 2 1/2" Performance Category panels, use 8d nails. Contact the manufacturer for recommendations.
Mechanical Connections

A few 10d nails

There are even more!

- 3 x 0.250 Boat Nail
- 2½ x 0.120 Sinker Nail
- 3 x 0.128 Box Nail
- 2½ x 0.135 Coffin Nail
- 2½ x 0.115 Box Nail
- 3 x 0.162 Common Nail
- 3 x 0.128 Casing Nail
- 3 x 0.113 Finish Nail
- 2½ x 0.120 Cooler Nail
- 3 x 0.135 Flooring Nail, Deformed

Nail Nomenclature

- There is no control over nail nomenclature!
- Manufacturers can and will call fasteners anything that they want.
- 8d is not a clear specification!
- Avoid problems by specifying pennyweight, type, diameter and length
- Example: 10d common (0.148" shank dia. X 3" shank length)

Fastener Interchangeability

ESR-1539 (45 pages)

- Has “conversion” tables for prescriptive requirements
  - For example, if model code requires 8d commons at 6” oc, then what fastener type and spacing is “equivalent”
- Has values for engineered designs for staples and a variety of other power-driven fasteners
- Available from International Staple, Nail and Tool Association (ISANTA)

### Table 40—Allowable Spacing of Alternate Fastenings' Equivalent to the Attachment of ½ Inch and Thinner Wood Structural Panel and Particleboard Sheathing to Wood Framing Members Using an 8d Common Nail

<table>
<thead>
<tr>
<th>FASTENER TYPE (MINIMUM NOMINAL NAIL SHANK DIAMETER, IN INCHES, OR STAPLE GAGE)</th>
<th>MINIMUM NOMINAL LENGTH, INCHES</th>
<th>ED COMMON NAIL SPACED 4&quot; O.C.</th>
<th>ED COMMON NAIL SPACED 5&quot; O.C.</th>
<th>ED COMMON NAIL SPACED 12&quot; O.C.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.133&quot; nail (8d common nail)</td>
<td>2½</td>
<td>4</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>0.092&quot; nail</td>
<td>2½</td>
<td>2</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>0.086&quot; nail</td>
<td>2½</td>
<td>2</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>0.080&quot; deformed shank nail</td>
<td>2½</td>
<td>2</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>0.113&quot; nail</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>0.113&quot; deformed shank nail</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>0.120&quot; nail</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>0.133&quot; deformed shank nail</td>
<td>2½</td>
<td>4</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>16 gauge staple</td>
<td>1½, 2</td>
<td>2</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>15 gauge staple</td>
<td>1½, 2, 2½</td>
<td>2</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>14 gauge staple</td>
<td>2, 2½, 2½, 3</td>
<td>3</td>
<td>4</td>
<td>8</td>
</tr>
</tbody>
</table>
Power Driven Fastener Considerations
- Power driven fasteners rely on velocity to drive fasteners and not mass.
- They do not have the "clamping" action that the last swing of a hammer provides.
- Thin galvanizing - power driven fasteners that are "galvanized" are thinly coated to prevent rusting in the box.
- The protection is scraped off of the fastener during driving.
- Overdriving - if the "gun" is improperly adjusted, overdriven fasteners can be expected.
- Adjusting air pressure is NOT the correct way to prevent overdriven fasteners.

Overdriven Fasteners

APA Recommendations – Prescriptive
- If < 20% fasteners overdriven by <1/8", then they may be ignored.
- If > 20% fasteners overdriven by >1/8", then add 1 additional fastener for every 2 overdriven.

Nail installation
- Overdriving reduces performance

Overdriven nails
**Overdriven nails**

**APA Recommendations – Mechanics Based**
- If < 20% fasteners overdriven by < 1/8", then they may be ignored.
- Otherwise, re-analyze capacity based on average thickness of panel measured from the bottom of the nail head.
  - (i.e. 5/8 CAT panel with fasteners overdriven by 1/8" = capacity of 1/2 CAT panel.) - Adjust nailing schedule accordingly.

**Caution for tight nailing patterns**

If the additional nails violate the minimum spacing requirements (3” o.c. for 2 inch lumber for splitting), use staples and ignore the original nails.

**Staggered Nailing**

- **Framing**
- **Wood Structural Panel**
- **Nail**
- **1/8” Gap Between Panels**

Splitting occurs parallel to grain

Splitting will not occur perpendicular to grain, no matter how close nails are

Staggering a line of nails parallel to wood grain minimizes splitting.
Mechanical Connections

**Tightly nailed shear wall**
Staggered nailing in shear wall helps prevent splitting of framing

Components and Cladding

**Components and Cladding**

Midwest Tornadoes 2003
APA Report SPE-1118

Nail Base for Siding

**Nail Base for Siding**

Siding attachment at energy efficient corners
Attachment base for utility vents, siding trim, etc.
**New Table in 2015 IRC**

Cladding Attachment Schedule for Fasteners into Wood Structural Panel Sheathing (Stud Penetration Not Required)

<table>
<thead>
<tr>
<th>Application</th>
<th>Number and Type of Fastener</th>
<th>Spacing of Fasteners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exterior wall covering (weighing 3 psf or less) attachment to wood structural panel sheathing, either direct or over foam sheathing a maximum of 2 inches thick.</td>
<td>Ring shank roofing nail (0.120” min. dia.)</td>
<td>12” o.c.</td>
</tr>
<tr>
<td></td>
<td>Ring shank nail (0.148” min. dia.)</td>
<td>15” o.c.</td>
</tr>
<tr>
<td></td>
<td>#6 screw (0.138” min. dia.)</td>
<td>12” o.c.</td>
</tr>
<tr>
<td></td>
<td>#8 screw (0.164” min. dia.)</td>
<td>16” o.c.</td>
</tr>
</tbody>
</table>

**Uplift – a Big Challenge**

**Rafter to Top Plate**

- Use connectors
- Very low cost
**Combined Shear & Uplift References**

- SSTD-10 (since early 1990’s) *2006 IRC R301.2.1.1*
- IBHS Guidelines (added by 2006 errata)
- Standard for Residential Construction in High-Wind Regions (ICC 600) *2009 IRC R301.2.1.1*
- Special Design Provisions for Wind and Seismic (SDPWS)

**System Report SR-101**

- APA System Reports are a new series of publications
- Help building officials and design professionals identify innovative design solutions
- Evaluates engineered wood systems that may not be directly prescribed in the codes
- Used as alternatives to the code-prescribed systems for code compliance
Mechanical Connections

- **Step 1** – Design the shear walls
- **Step 2** – Determine required uplift
- **Step 3** – Determine combined shear & uplift nailing

### Uplift Capacity (p/lb)

- **NAILS: SINGLE ROW:**
  - 6d = 84
  - 8d = 168
  - 10d = 216
  - NP = 0
  - 0 = 108
  - 131

- **NAILS: DOUBLE ROW:**
  - 168
  - 336
  - 504
  - 216
  - 432
  - 648
  - 108
  - 324
  - 540
  - 262
  - 524
  - 786

---

**Anchor Bolt & Washer**

- Anchor bolt shall have a steel plate washer under each nut not less than 0.229”x3”x3”

---

**Standard Cut Washer Requirement**

- Diagonally slotted plate washer permitted
- Slot width up to 3/16” larger than bolt diameter
- Slot length not to exceed 1 ¼”
- Provided standard cut washer between steel plate washer & nut

---

**Missing Washer**

- Nut
- Standard cut washer
- Steel plate washer
Anchor Bolts?

Hurricane Katrina
APA Report SPE-1125

System Report SR-103
- New system report
- Method to provide bracing for raised heel trusses

Two design approaches:

Prescriptive
“follow the recipe”
Generally small variables don’t matter. There are no calculations or strength values assigned.

Engineered
“do the calculations”
All variables are accounted for in calculations

Tabulated Values in NDS
- The tabulated values for nails, bolts, lag screws and other connectors are nominal and based on certain assumptions.
- They must be adjusted to account for actual conditions.
Examples:
- $C_D = \text{Load duration factor}$
- $C_M = \text{Wet service factor}$
- $C_g = \text{Group action factor}$
- $C_A = \text{Geometry factor}$
- $C_{tn} = \text{Toe-nail factor}$
**Mechanical Connections**

**LOAD DURATION** | **Load Duration Factor - Cₖ** | **Typical Loads**
--- | --- | ---
Permanent | 0.9 | Dead Load
Ten years | 1.0 | Floor live load
Two months | 1.15 | Snow load
Seven days | 1.25 | Construction load
Ten minutes | 1.6 | Wind/Earthquake
Impact | 2.0 | Vehicles

*These factors are applied to member capacity*

**Spacing, End, & Edge Distances**
- Parallel to grain

**Mechanical Connections**

**Toe-nail Factor, Cₜₙ**
- Correct toe nailing Fig. 11A
- 5/6 adjustment for lateral
- 2/3 adjustment for withdrawal

**“Air Nail” Factor, Cₐᵢʳ**
- Cₐᵢʳ = 0.00
Agenda

- Connecting Wood
- Wood Moves
- Wood and Moisture Don’t Mix
- Mechanical Connections
- Glued Connections
- Information Sources

Glued Connections

Adhesive applications

1. Manufactured components
2. Field construction – floors
3. Repair – epoxy*
   - Glued joints are the most unpredictable
   - Difficult to mix glued and mechanical connections

* McGraw-hill handbook of engineered wood construction

Glued Connections

The APA Glued Nailed Floor System

Continuous Bead
Glue Everything!

Lay Panel in Fresh Adhesive

Fully Fasten with Clamping Force
### Glued Connections

<table>
<thead>
<tr>
<th>Supported Panel Edges</th>
<th>Intermediate Supports</th>
</tr>
</thead>
<tbody>
<tr>
<td>6&quot; o.c.</td>
<td>12&quot; o.c.</td>
</tr>
</tbody>
</table>

- Fasteners maximum 3/8" from panel edges
- Check local codes for increased nail schedules
- High wind areas may require increased nail schedules

---

**Gluing is not recommended for bonding wall or roof sheathing to framing**
- Difficult to find design values for adhesives
- Prohibited in SDC D, E, or F (IBC 2305.3010)

**How about composite action?**
- Theoretically possible!
- True composite action requires rigid structural adhesives. (Construction adhesives creep under load and do not give 100% composite action.)
- Structural adhesives are very hard-to-impossible to do successfully in the field.
- They also are dangerous to apply.
Agenda

- Connecting Wood
- Wood Moves
- Wood and Moisture Don’t Mix
- Mechanical Connections
- Glued Connections
- Information Sources

Information Sources

Connection Calculator

http://www.awc.org/calculators

Information Sources

APA Publications

T300 – Glulam connection details
E830 – Screw and plywood connections
E825 - Bolt and plywood connections
T325 – Roof fastening for wind uplift
Y250 – Shear transfer at engineered floors
A410 – Roof retrofit for wind uplift
D485 – Corrosion resistant fasteners
It's easy to create strong durable wood connections
- Avoid the use of details which induce tension perpendicular to grain stresses in the wood
- Allow for dimensional changes in the wood due to potential in-service moisture cycling
- Minimize exposure of end grain
- Avoid moisture entrapment in connections
- Use smaller multiple fastener connections