Wood Connections

Presented by: Karyn Beebe, P.E.
Key to Connections

1. Wood has a strong and weak direction
2. Wood Moves
3. Strive for Consistency
4. Wood and Moisture Don’t Mix
5. Load Path Continuity
Connecting Wood

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
Connecting Wood

Wood likes to take on load spread over its surface
Concentrated at a single fastener – wood is more prone to split and crush
Connection Techniques

Truss plates

- Design metal plate connections using the latest edition of ANSI/TPI 1
Connection Techniques

Steel bolts and plates in heavy trusses
Glulam Connections
Field Notching and Drilling of Glued Laminated Timber Beams

Tech Note EWS S560
Possible Reinforcement for an End Notch

Depth of notch = 0.1d maximum

Lag screw extends past the neutral axis into the upper portion of beam

Neutral axis

Potential crack zone

Use one or more fully threaded lag screws

Washer

Ref. APA Technical Note EWS S560
Vertical Holes

Strength reduction
= 1.5 x Hole diameter/beam width

Example:
• 6” Beam width
• 1” diameter vertical hole
Reduction = (1.5 x 1”)/6”
Reduction = 0.25
Beam is 75% of original strength

Tech Note EWS S560
Hanger to Beam

Load suspended from lower half of beam – another case of tension perpendicular to grain
Hanger to Beam

Load supported in upper half of beam
- Extended plates puts wood in compression when loaded
The Basics - Engineered

Lateral connection strength depends on:

- Crushing (bearing) strength of wood
- Size of wood pieces
- Fastener size and strength
- Plus appropriate end use adjustment factors
- i.e. Wet service, edge distance, end grain, etc.
Withdrawal Connection Strength Depends On:

- Depth of penetration
- Wood density
- Fastener size and type
- Plus appropriate end use adjustment factors
- i.e. wet service, edge distance, end grain, etc.
Connection Techniques

Multi-ply linear members and inter-ply shear/load transfer
Connection Serviceability

Humidity and moisture

- Ambient conditions
- Contact with cementitious materials
Moisture Changes In Wood

Causes dimensional changes perpendicular to grain

Growing tree is filled with water

As wood dries, it shrinks perp. to grain
Connecting Wood

Wood, like other materials, moves in varying environments.
Connection Serviceability

Shrinkage due to moisture loss

- **Solid Sawn**
  - 3½"
  - 3¾"
  - 14½"
  - 15¼"
  - Green 8%

- **Glulam**
  - 5¼"
  - 5½"
  - 5½"
  - 35¼"
  - 36"
  - 12%
  - 8%
Connection Techniques

Gap panels 1/8” to allow for dimensional changes
Beam to Beam

Beam hangers
- Fasteners in top of supported beam
- Wood shrinkage
- May split
- Not recommended
Beam to Beam

Beam hangers

- Fasteners in bottom of supported beam
- Wood shrinkage allowed
- Prevents lateral movement
Beam to Beam

• Concealed
  – kerf must accommodate steel and weld
  – Dowel hole plugged
Beam to Wall

Problem

- shrinkage
- tension perp
Beam to Wall

Solution:
- allows shrinkage

Slotted hardware
Weld bracket

- Bucket-style
- Dapped support beam
Beam to Column

Full-depth side plates

- May cause splitting
- Restrains wood shrinkage
Beam to Column

Smaller side plates

- Transmit force
- Allow wood movement
Before
After
Pre-engineered Connectors

Joist and beam hangers

• Top and face mount
• Product specific
• Use correct nail
• Fill all holes
• Ensure proper fastener penetration
Web Stiffener Detail

1/8" Gap

>1000 lb

>1550 lb
## Nails

### A few 10d nails –

There are even more!

<table>
<thead>
<tr>
<th>Nail Type</th>
<th>Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 x 0.250 Boat Nail</td>
<td>27/8 x 0.120 Sinker Nail</td>
</tr>
<tr>
<td>3 x 0.128 Box Nail</td>
<td>27/8 x 0.135 Corker Nail</td>
</tr>
<tr>
<td>27/8 x 0.113 Box Nail</td>
<td>3 x 0.162 Common Nail</td>
</tr>
<tr>
<td>3 x 0.128 Casing Nail</td>
<td>3 x 0.113 Finish Nail</td>
</tr>
<tr>
<td>27/8 x 0.120 Cooler Nail</td>
<td>3 x 0.135 Flooring Nail, Deformed</td>
</tr>
</tbody>
</table>
There is no control over nail nomenclature!

Manufacturers can and will call fasteners anything that they want.

8d is not a clear specification!
Specifying Nails

Avoid problems by specifying pennyweight, type, diameter and length

- Ex: 10d common
  (0.148” shank dia. X 3” shank length)
Fastener Interchangeability

NER-272 & ESR-1539

- 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)
  - www.isanta.org
  - 708-482-8138
Shear Walls: Box v. Common

- **Box v. common nail performance**
- **Research shows:**
  - Ultimate loads are not significantly affected
  - Stiffness may be reduced about 20%
  - See [www.curee.org](http://www.curee.org) for woodframe project findings
  - APA form TT-087 for more info.
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

Glued floor construction
Minimize squeaks
Increase stiffness
Glued Connections

Gluing is not recommended for bonding wall or roof sheathing to framing.
Glued Structural Connections

Can be difficult to find design values (i.e. no code reports) for adhesives.

Prohibited (shear walls) in Seismic Design Category D, E, or F (per IBC 2305.3.10)
Power Driven Fastener Considerations

Contact:

- 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 over-driven fasteners.
Mechanical Connections

Nail installation

- Overdriving reduces performance
Overdriven nails

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.
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” panel with fasteners overdriven by 1/8” = capacity of ½” panel.) - Adjust nailing schedule accordingly.
CAUTION!

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

Nailing not staggered

Nailing staggered
Material Properties of Wood – Problem Areas

**Splitting** happens because wood is relatively weak perpendicular to grain

- Nails too close (act like a wedge)
Material Properties of Wood

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

Splitting occurs parallel to grain.

Staggering a line of nails parallel to wood grain minimizes splitting.
Material Properties of Wood

Staggered nailing in tightly nailed shear wall helps prevent splitting of framing
Material Properties of Wood
Problem Areas

Large plate washers (3”x3”x0.229”), like a 3x sill plate, prevent cross grain bending-splitting of sill plate (IBC 2305.3.11)

- Required for SDC D, E or F

Wood structural panel

Cross grain bending (tension perp. Stresses)

Plate washer

Sill plate
• Application
  • Bearing plate under beam
  • Prevent contact with masonry

Capillary break
Beam end bearing on concrete

**Notched beam bearing**

- Tension perpendicular
- Differential moisture uptake
- Reseal end grain

[Diagram showing beam end bearing on concrete with a split indicated]
Beam to Masonry

Application
- Need 1/2” air gap between wood and masonry
Column to Base

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

- **Floor slab poured over connection**
  - Can cause decay
  - Not recommended
Column to Base

• Simple steel dowel
  – Bearing plate
  – Shear transfer

Insulating Detail

[ APA ]
Column to Base

- Problem
  - No weep holes in closed shoe
  - Moisture
  - Decay
Column to Base

- Where’s the *plate*?
- Grout substituted
- Moisture may wick into wood
Connection Serviceability

Issue:
- Direct water ingress
- No weep holes
Arch Base to Support

Good connection
- Avoids tension perp
- Avoids decay
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
Preservative treated glulam

end caps and flashing
Continuous Load Path
Connection Techniques

- Shear force transfer
- Uplift force transfer
  (New APA Technical Note E510)
Shear Transfer at Engineered Wood Floors, Data File Y250
Connection Techniques

Hold-down hardware
Strap & Shear Inspection
Strap & Shear Inspection
Connection Techniques
Hold-Down Placement Traditional
Connection Techniques
Hold-Down Placement Perforated
Fasteners and Connections

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:
  - $C_D = \text{Load duration factor}$
  - $C_M = \text{Wet service factor}$
  - $C_g = \text{Group action factor}$
  - $C_\Delta = \text{Geometry factor}$
  - $C_d = \text{Penetration depth factor}$
  - $C_{tn} = \text{Toe-nail factor}$
Load Duration Factor

Wood capacity greater for short time loading

<table>
<thead>
<tr>
<th>LOAD DURATION</th>
<th>Load Duration Factor - $C_d$</th>
<th>Typical 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>Floor live load</td>
</tr>
<tr>
<td>Two 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</td>
</tr>
<tr>
<td>Impact</td>
<td>2.0</td>
<td>Vehicles</td>
</tr>
</tbody>
</table>

These factors are applied to member capacity
2005 NDS Provisions

Wet Service Factor, $C_M$ for connection $Z$ values

- Bolts
- Lag screws
- Wood screws

Saturated  
19% MC  
Dry

$C_M$ | 1.0 | 0.7 | 0.4
---|---|---|---
Lateral Load

fabrication MC
in-service MC
Mechanical Connections

Larger fasteners

- **Group action factor,** $c_g$
  - NDS tables
  - Equation calculation
Mechanical Connections

Consider as 2 rows of 8 fasteners

Consider as 1 row of 5 fasteners and 1 row of 3 fasteners

Consider as 1 row of 8 fasteners and 1 row of 4 fasteners
Calculated –
Group Action Factor, $C_g$

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

where:

$$R_{EA} = \text{the lessor of } \frac{E_s A_s}{E_m A_m} \text{ or } \frac{E_m A_m}{E_s A_s}$$

$$m = u - \sqrt{u^2 - 1}$$

$$u = 1 + \gamma \frac{s}{2} \left[ \frac{1}{E_m A_m} + \frac{1}{E_s A_s} \right]$$
Tabulated – Group Action Factor, $C_g$

**$A_m$** = gross x-sectional area of main member, in$^2$

**$A_s$** = sum of gross x-sectional areas of all side members, in$^2$

<table>
<thead>
<tr>
<th>Number of fasteners in a row</th>
<th>$A_m/A_s$</th>
<th>$A_s$</th>
<th>$A_m$</th>
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<tbody>
<tr>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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<tr>
<td>5</td>
<td>0.97</td>
<td>0.89</td>
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<td>0.85</td>
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<td>16</td>
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<td>0.96</td>
<td>0.92</td>
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<td>0.99</td>
<td>0.97</td>
<td>0.94</td>
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<td>1.00</td>
<td>0.98</td>
<td>0.96</td>
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<tr>
<td>64</td>
<td>1.00</td>
<td>0.99</td>
<td>0.98</td>
</tr>
<tr>
<td>120</td>
<td>1.00</td>
<td>0.99</td>
<td>0.99</td>
</tr>
<tr>
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<tr>
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<td>1.00</td>
<td>0.97</td>
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<th>$A_m$</th>
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</thead>
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<td>0.98</td>
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<td>1.00</td>
<td>0.99</td>
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</tr>
</tbody>
</table>

1. Tabulated group action factors ($C_g$) are conservative for $D < 4''$ or $s < 6''$. 

Table 7.3.6C Group Action Factors, $C_g$ for Bolt or Lag Screw Connections With Steel Side Plates

For $D = 1''$, $s = 4''$, $E_{mod} = 1,400,000$ psi, $E_{vho} = 30,000,000$ psi
Geometry Factor, $C_\Delta$

Spacing, End, & Edge Distances

- Parallel to grain
Local Stresses in Fastener Groups

Appendix E   NDS Expressions

Net tension:

\[ Z'_{NT} = F'_t A_{net} \]

Row tear-out:

\[ Z'_{RTi} = n_i F'_v t s_{min} \]

\[ Z'_{RT} = \sum_{i=1}^{n_{row}} Z'_{RTi} \]
## Fastener Penetration, $C_d$

### Lag screws, wood screws, and nails

<table>
<thead>
<tr>
<th>Fastener Type</th>
<th>Full</th>
<th>Reduced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lag Screws</td>
<td>8D</td>
<td>4D</td>
</tr>
<tr>
<td>Wood Screws</td>
<td>7D</td>
<td>6D</td>
</tr>
<tr>
<td>Nails &amp; Spikes</td>
<td>10D</td>
<td>6D</td>
</tr>
</tbody>
</table>

D = Diameter (in)
Nail installation (11.5.4)

- Correct toe nailing Fig. 11A
- 5/6 adjustment for lateral
- 2/3 adjustment for withdrawal
"Air Nail" Factor, $C_{air}$

$C_{air} = 0.00$
Design software
Eqn’s Easily Solved With a PC

http://www.wwpa.org/_techguide/suite.asp
AWC Connection Calculator

http://www.awc.org/calculators/index.html
Where to get more information
Where to Find Specifics

IBC, IRC, NDS, ICC-ES
Web sites...

www.awc.org
www.apawood.org
www.cwc.ca
www.southernpine.com
For More Information: APA Forms

Go to www.apawood.org and enter the Publications store

The following publications expand on the information given in this presentation and can be downloaded for free using subject, title, or form number
APA Forms (www.apawood.org)

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
APA Forms (www.apawood.org)

- TT-035 – Corrosion resistant fasteners
- TT-036 – Glued floors
- TT-039 – Nail withdrawal
- TT-070 – Nail pull through
- TT-045 – Min. nail penetration
- TT-012 – Overdriven fasteners
- TT-056 – Power driven fasteners
- TT-050/051 – Screw withdrawal
- TT-058 – Slant nailing
- TT-061 – Nailing thin flange I-joist
- TT-020 – Dowel bearing strength
Welcome to APACAD.org, a resource for building designers and construction professionals in search of CAD details for wood-frame construction.

To search for a detail, select "CAD Detail Index" from the column on the left. You'll be able to preview thumbnail images of more than 100 CAD details, sorted by product and construction topics. After selecting the detail that you need, simply follow the on-screen instructions to download the detail in DWF, DXF, or DWG format. If you don't have a CAD program on your computer, you can preview images in CAD format by downloading the Autodesk DWF Viewer software.
www.WoodUniversity.org

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Getting Started

- To Register for a course, click the blue "Register" button to your left.
- For course descriptions, click on "Course Catalog" on the left.
Key to Connections

1. Wood has a strong and weak direction
2. Wood Moves
3. Strive for Consistency
4. Wood and Moisture Don’t Mix
5. Load Path Continuity
Quiz: Is the below a code-conforming connection?
Questions?