Structural Fasteners in Wood-to-Wood Connections

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Learning Objectives

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

1. Articulate how wood properties, loading direction and dowel bearing strength affect the strength of wood connections.
2. Understand the features and strength properties of traditional nails, screws, lags and bolts and the newest fastener - Structural Wood Screws.
3. Understand the procedures involved in determining the imposed loads and selection of the appropriate fastener.
4. Locate and understand the code requirements for specific wood-frame structural connections.
Welcome

Introductions

- Mark Guthrie
  - Technical Manager
  - Testing and Code Development

Who's in the Room?

- Inspectors, Plan Review
- Architects, Engineers
- Builders, Contractors, Developers
- Other

Today's Topics

- Critical Wood Properties
- Fastener Basics
- The “Evolution of Fasteners”
- New Category of Structural Wood Screws

Resources Referenced

  - Wood Properties – Strengths, Span Tables, etc
  - Fastener Strengths in Wood (Connection Design)
Resources Referenced
- IRC – Residential Code
- IBC – Commercial Building Code
- Your State Code

Resources Referenced
- AF&PA Wood Frame Construction Manual
  - Code compliant prescriptive method
  - Same authors as NDS

Critical Wood Properties
- Species / Specific Gravity
- Moisture Content
- Loading Direction
- Dowel Bearing Strength

Species / Specific Gravity
- The “floatability” factor
  - Ipe (Brazilian Hardwood) sinks
  - DF Larch floats 50% above
- Higher SG = Denser
- Denser = Stronger Wood
- Specific Gravity is the #1 determinant of connection strength

<table>
<thead>
<tr>
<th>Wood Species</th>
<th>SG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ipe</td>
<td>1.00</td>
</tr>
<tr>
<td>Red Oak</td>
<td>0.67</td>
</tr>
<tr>
<td>Southern Pine</td>
<td>0.55</td>
</tr>
<tr>
<td>Douglas Fir Larch</td>
<td>0.50</td>
</tr>
<tr>
<td>SCL / Engineered</td>
<td>0.50</td>
</tr>
<tr>
<td>Douglas Fir South</td>
<td>0.46</td>
</tr>
<tr>
<td>Hem Fir</td>
<td>0.43</td>
</tr>
<tr>
<td>SPF</td>
<td>0.42</td>
</tr>
</tbody>
</table>
Critical Wood Properties

- **Species / Specific Gravity**
  - How does SG effect connection strength?

<table>
<thead>
<tr>
<th>Species</th>
<th>SG</th>
<th>Lbs./Lag</th>
<th>Strength Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oak</td>
<td>0.67</td>
<td>280</td>
<td>+22%</td>
</tr>
<tr>
<td>SYP</td>
<td>0.55</td>
<td>230</td>
<td></td>
</tr>
<tr>
<td>DFL</td>
<td>0.50</td>
<td>200</td>
<td>-13%</td>
</tr>
<tr>
<td>SPF</td>
<td>0.42</td>
<td>150</td>
<td>-35%</td>
</tr>
</tbody>
</table>

* Assumes a 2x attached to a 4x

**Shear Strength of 1/2” Lag Screw in Different Woods**

- **Wet vs. Dry Wood**
  - Moisture Content
    - If 19% or Less = “DRY” to engineer
    - If above 19% = “WET”
  - The wetter the wood, lower the connection strength
  - Must be compensated for by engineer:
    - Per NDS 10.3.3 “When connections are exposed to wet service conditions in use, reference design values must be multiplied by the wet service factors…”

Design Strengths in SYP

<table>
<thead>
<tr>
<th>Load Type</th>
<th>Fastener Type</th>
<th>Dry (Lbs)</th>
<th>Wet Service Factor</th>
<th>Wet (Lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shear</td>
<td>1/2” Lag</td>
<td>230</td>
<td>.70</td>
<td>161</td>
</tr>
<tr>
<td></td>
<td>16d Nail</td>
<td>154</td>
<td>.70</td>
<td>108</td>
</tr>
<tr>
<td>Withdrawal</td>
<td>1/2” Lag</td>
<td>437</td>
<td>.70</td>
<td>306</td>
</tr>
<tr>
<td></td>
<td>16d Nail</td>
<td>75</td>
<td>.25</td>
<td><strong>19</strong></td>
</tr>
</tbody>
</table>

- **Loading Direction**
  - Parallel to Grain vs. Perpendicular to Grain

Which connection is stronger?
Critical Wood Properties

- **Loading Direction**
  - Parallel to Grain is actually stronger!

  ![Diagram showing load direction and parallel vs. perpendicular to grain loading.](image)

  - **Load Direction**
  - **Grain Direction**

  - **Parallel to Grain Loading**
    - 410 lbs.

  - **Perpendicular to Grain Loading**
    - 230 lbs.

  (Design shear of ½” Lag Screw in SYP)

  **Which one of these holes supports the least weight?**

Critical Wood Properties

- **Dowel Bearing Strength**
  - Ability for the wood above the fastener to support the fastener

  ![Diagram showing dowel bearing strength.](image)

- **Dowel Bearing Strength**
  - 5150 psi
  - 4200 psi
  - 3650 psi
  - 2950 psi

  ![Diagram showing dowel bearing strength values.](image)

  - **Larger the hole, weaker the wood!**

Fastener Facts

- **Anatomy of Nails / Screws**
- **Metal Strength Properties**
- **Design Strength Properties in Wood**
- **Evolution of Fasteners**
### Fastener Facts

#### Anatomy of Nails / Screws

- **Head Style**
- **Shank/Blank Diameter (Gauge)**
- **Point Style**
- **Threads Per Inch (TPI)**
- **Minor Thread & Major Thread Diameter**

### Fastener Facts

#### Metal Strength Properties

- **Shear Strength** – Lbs needed to slice metal
  - Approx 1,500 Lbs * #8 deck screw
- **Tensile Strength** – Lbs to stretch until break metal
  - Approx 2,500 Lbs *
- **Bending Yield** – Lbs to bend metal beyond elastic
  - Approx 125,000 psi *

- Used to compare fasteners only
- Not suitable for designing the connection

### Fastener Facts

#### Design Strength Properties

- **Design Shear Strength**
  - Approx. 150 lbs. * #8 deck screw in SYP
- **Design Withdrawal Strength**
  - Approx 100 lbs. per inch of thread embedded *
- **Design Head Pull-Through Strength**
  - Approx 100 lbs. per inch of wood under head

- Takes into account fastener and wood interaction
- Only value used by designer/engineer
- Include Safety Factor (2.5 – 5 times)

### Fastener Facts

#### Safety factor?

Who cares about a safety factor?
Fastener Facts

Ledger Connection
35 people

Handrail Connections
At least 6 “leaners”

Stair Stringer Connection
1 guy

Guests weigh 6200 lbs. Deck designed to carry 7700 lbs.
Only 1500 lbs. (7 people + 1 keg) away from anticipated live load.
The safety factor creates a buffer for inconsistencies in materials and usage.

Fastener Facts

Quick “Live Load” Analysis

Maximum pounds of shear load that can be safely applied before fastener or wood is displaced

Design Shear Strength

Maximum pounds of withdrawal load that can be safely applied before threads disengaging from the wood

Design Withdrawal Strength
Fastener Facts

- **Design Pull-Through Strength**
  Maximum pounds of withdrawal load that can be safely applied before head begins to pull through side member

Evolution of Fasteners

- Wooden Dowels
- Nails and Spikes
- Wood Screws
- Lag Screws
- Through Bolts
- Structural Wood Screws

Evolution of Fasteners

- Wooden Dowels
  - Ship building
  - Post & beam
  - Timber frame

Evolution of Fasteners

- Nails - Benefits
  - Easy to install – one tool / no special skills needed
  - Contractor familiarity – common nomenclature
  - Pneumatic capability – faster by far
  - Inexpensive – cheapest method
  - Accepted design values in NDS
Evolution of Fasteners

Nails - Drawbacks
- Tough to determine size from head
- Difficult to identify fastening pattern once installed
- Common disregard for fastening patterns

Nails – Biggest Drawbacks
- #1 – Very low withdrawal strength
- #2 – Made worse when exposed to moisture (75% reduction in strength!)

Evolution of Fasteners

- Very low withdrawal strength
- Unacceptable in many code applications

(Ledgers) 2009 IRC: R502.2.2
“where supported by attachment to an exterior wall, decks shall be positively anchored to the primary structure and designed for both vertical and lateral loads. Such attachment shall not be accomplished by the use of toenails or nails subject to withdrawal”.

Evolution of Fasteners

Wood Screws
- Deck screws
- NOT drywall screws!!
Evolution of Fasteners

**Wood Screws - Benefits**
- Easy to install
  - No pre-drilling
  - Cordless drills & impact drivers
- Threads add greater withdrawal strength vs. nails
- Values in NDS
  - Shear & Withdrawal

**Wood Screws - Drawbacks**
- Unknown quality
  - 95% imports
- No strengths printed on box
- Most not ICC vetted (no report)
- Coating claims unchecked
  - “ACQ Approved”?
- QC Process Accountability

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**Lag Screws – Benefits**
- Easy to find. Available in all sizes.
- Greater strength than screws or nails
- Strengths reported in the NDS
- Code allowed / preferred

**Through Hardened**
- Carbon cooked, brittle potential

**Case Hardened**
- Carbon-rich case, ductile core
Evolution of Fasteners

Lag Screws – Drawbacks
- By code, must pre-drill twice
  - 75% of diameter for entire length
  - 100% of diameter for unthreaded portion
- Second pre-drill step commonly ignored by the installer
  - Nearly impossible to inspect!

Evolution of Fasteners

Through Bolts – Benefits
- Best withdrawal strengths of all
- Requires pre-drilling – can’t cheat
- Easy to identify
- Accepted values in NDS

Deck Collapse Injures Scores - Ledger splits from faulty lag screw installation
July 30, 2004. Diamond Horseshoe Casino in Polson, Montana. 34 injured, 3 critically, 4 life threatening
Post-failure inspection found "lag screws were too few and far between, and they were driven through the ledger with a rotary hammer rather than through pre-drilled holes, which induced a splitting force"
Evolution of Fasteners

- Through Bolts – Drawbacks
  - Difficult to install
  - Drilling required
  - Three tools needed for installation
  - Expensive – 4 pieces of hardware

Design Shear Strength Perpendicular to Grain

<table>
<thead>
<tr>
<th>Wood</th>
<th>1/2&quot; Lag</th>
<th>1/2&quot; Bolt</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPF</td>
<td>170</td>
<td>170</td>
</tr>
<tr>
<td>Doug. Fir</td>
<td>200</td>
<td>220</td>
</tr>
<tr>
<td>South. Pine</td>
<td>230</td>
<td>250</td>
</tr>
</tbody>
</table>

Questions?
Comments?
Emotional Outbursts?

Structural Wood Screws

“RSS” by GRK
“SDS” by Simpson
“WS” by USP
TimberLok, LedgerLok, TrussLok by FastenMaster
Structural Wood Screws (SWS)

Benefits
- Strength equal or greater than lag screws
  - Supported by ICC reports
- Versatility of deck screws
  - No predrilling
- Complete Inspectability
  - Head markings
  - Information provided on box / literature

Approved as an Alternative
- As with all non-commodity products, allowable under the Alternative Materials provision R104.11 (IRC & local code).
  - Tested to national standards (ANSI, ASTM)
  - Third party, peer reviewed reports (ICC-ES)
  - Demonstrate equivalency to code

Drawbacks
- New: Contractors need better instruction
- Not a commodity. Small differences between competitors.
- New: Limited familiarity by code officials

What To Look For
- National Code Report (ICC-ES or IAPMO)
  - Documented Metal Strength Properties
  - Shear, Withdrawal, Pull through Values in Wood
  - Lot Traceability via Head Stamp and Packaging
  - QC Audit Process
- Corrosion Statement
  - Hot Dipped Galvanized to ASTM A153
  - Mechanically Galvanized to ASTM B695 Class 55
  - Tested under ICC-ES AC257– Equal to HDG
- Technical Literature
  - Installation Instructions
  - Application-Specific Technical Bulletins
Common SWS Applications

- Multiple Ply Engineered Wood Beams (LVL, LSL, PSL)
- Deck Ledger to Rim
- Rafter & Truss to Top Plate

Multiple Ply EW Beams

- Supported by EW:
  - I-Level (was TrusJoist)
  - Boise, GP, LP
  - Roseburg, Others

- In some Design Software
  - Boise (BC Calc)
  - Keymark
Multiple Ply EW Beams

- Technical Bulletins
  - Code Compliance
  - Proper Installation
  - Limitations

- Fastening Patterns – Top Loaded Beams
- Fastening Patterns – Side Loaded Beams

Deck Ledger to Rim

- Technical Bulletins
  - Proper Size Selection
  - Minimum Edge / End Distances

<table>
<thead>
<tr>
<th>Type of Beam</th>
<th>Number of Rows</th>
<th>Length of Beam</th>
<th>Assembly Size Class</th>
<th>Class A</th>
<th>Class B</th>
<th>Class C</th>
<th>Class D</th>
<th>Class E</th>
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<tr>
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<td>2</td>
<td>34&quot;</td>
<td>504</td>
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<td>504</td>
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<tr>
<td>11</td>
<td>3</td>
<td>34&quot;</td>
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<td>504</td>
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<tr>
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<td>504</td>
<td>504</td>
<td>504</td>
<td>504</td>
<td>504</td>
</tr>
</tbody>
</table>

- Minimum edge distance = 3/4"
**Deck Ledger to Rim**

- **Code History**
  - Prior to 2003 – No direction at all
  - 2003 IRC – Limited nail use
  - 2006 IRC – Same: no nails or toe nails
- **Forced the installer & inspector to become the engineer!**

**Calculating the Load**
- **Live load = 40 psf of deck surface (R301.5)**
- **Dead load = 10 psf (R301.2.2.2.1)**
- **Combined load = 50 psf**
- Take half the distance to the 1st support (5ft)
- Multiply by Combined Load (5ft x 50psi)
- This load (250psf) must be supported at Ledger

**Calculating the Fastening Pattern (w/ 2x SPF Rim)**
- **½" Lag supports 170 lbs per fastener in shear**
  - 170/250 = .68 (1 lag every 8")
- **SWS (LedgerLok) supports 210 lbs**
  - 210/250 = .85 (1 SWS every 10")
- Waaay too much work

**Welcome the 2009 IRC (502.2.2)**
- Requirements and Restriction under one section
- Allows for alternative materials and methods
- Gives actual fastening patterns!!!

**If you’re not there yet – you will be soon.**
Deck Ledger to Rim

- Technical Bulletins
  - Code Compliance
  - Proper Installation
  - Limitations

- Technical Bulletins
  - Code compliance statement
  - ACQ testing to ICC information

- Technical Bulletins
  - Minimum Edge / End Distances
  - PE Approved Fastening Patterns

- Technical Bulletins
  - Installation Requirements & Restrictions

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**General Fastening Guidelines**

- LEDGER Joint is not designed for use in masonry or concrete.
- Ledger fasteners must be properly fastened to prevent water from penetrating the ledger joint.
- Ledger joint shall be minimum thickness 2 and a pressure-resistant metal No. 2 grade finish.
- All ledger connections must be made with through bolts.
- Wood structural fasteners or ground bearing shall be minimum 1" in thickness and permitted provided that the maximum distance between the inner face of the ledger board and the outer face of the ledger board is no greater than 1" and properly fastened to the ledger.
- Ledger cannot be attached to masonry, siding or brick walls.

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**Curriculum Statement**

Ledgers have been tested and is approved for use in above ground 1.25 ft^3 and ground contact 1.40 ft^3 ACQ treated wood applications. Under the recently adopted IFC standards 12/14/17, Informational Text on the Face of the Type of Wood Protection is Required. The proprietary coating on this substrate has been tested and found to exceed the corrosion protection offered by code compliant hot-dipped galvanized (HDG) coating. Under the "Alternative
Evolution of Fasteners

- Very low withdrawal strength
- Unacceptable in many code applications

(Ledgers) 2009 IRC: R502.2.2
"where supported by attachment to an exterior wall, decks shall be positively anchored to the primary structure and designed for both vertical and lateral loads. Such attachment shall not be accomplished by the use of toenails or nails subject to withdrawal".

2007/2009 IRC Code

This section allows Structural wood Screws

R502.2.2.2 Alternate deck ledger connections. Deck ledger connections not conforming to Table R502.2.2.1 shall be designed in accordance with accepted engineering practice. Girders supporting deck joists shall not be supported on deck ledgers or band joists. Deck ledgers shall not be supported on stone or masonry veneer.

R502.2.2.3 Deck lateral load connection. The lateral load connection required by Section R502.2.2 shall be permitted to be in accordance with Figure R502.2.2.3. Hold-down tension devices shall be installed in not less than two locations per deck, and each device shall have an allowable stress design capacity of not less than 1500 pounds (6672 N).
Comments by Glenn Mathewson - Building inspector in Westminster Colorado in an article in November 2009

PROFESSIONAL DECK BUILDER

"As written in the code, the lateral connection detail shall be permitted; it isn’t a requirement.

Throughout the International Codes, the phrase shall be permitted is used only to clarify when a detail seemingly prohibited by a general statement is actually permitted in a specific application.

Section R104.11 of the IRC even states: The provisions of this code are not intended to prevent the installation of any material or to prohibit any design or method of construction not specifically prescribed by this code.

Therefore, it’s not necessary to specifically “permit” a design in the code unless it could be confused as being “prohibited.” That’s obviously not the case for Figure R502.2.2.3, as it’s unlikely that any building official would prohibit a connection like it.
Rafter / Truss to Top Plate

- Rafter - Code Requirements
  - 2-16d toe nailed per IRC Table R602.3(1)
  - Or 3-8d toe nailed per IBC table 2304.9.1

- Truss - Code Requirements
  - Trusses shall be connected to wall plates by the use of approved connectors having a resistance to uplift of not less than 175 pounds and shall be installed in accordance with the manufacturer’s specifications.
  - 3-16d commons will accomplish this, getting 178 pounds of design uplift. (From the Truss Plate Institute & Structural Building Component Association).

<table>
<thead>
<tr>
<th>NDS Withdrawal Value</th>
<th>IRC (2x16d)</th>
<th>IBC (3x8d)</th>
<th>lbs/inch/nail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Embedment Depth</td>
<td>2.5</td>
<td>1.5</td>
<td>inches</td>
</tr>
<tr>
<td>Toe Nail Factor</td>
<td>0.67</td>
<td>0.67</td>
<td></td>
</tr>
<tr>
<td>Wind/Seismic Load Duration</td>
<td>1.6</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>Amount of Nails</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

140 100 lbs/connection
Rafter / Truss to Top Plate

Rafter or Truss to Top Plate Connection
Withdrawal Calculated per ESR-1078

<table>
<thead>
<tr>
<th>Withdrawal Value</th>
<th>131</th>
<th>lbs/inch of thread</th>
</tr>
</thead>
<tbody>
<tr>
<td>Embedment Depth</td>
<td>2.0</td>
<td>inches</td>
</tr>
<tr>
<td>Toe Nail Factor</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Wind/Seismic Load Duration</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>Amount of Screws</td>
<td>1</td>
<td>lbs/connection</td>
</tr>
</tbody>
</table>

**assumes SPF rafter and top plate – weakest wood**

If code requires only nails, why is the de facto method hurricane ties?

- Improper Installation
- High Wind
- Perception

100 140 365 420

100 150 200 250 300 350 400 450 500

Loads in SPF
Four ways to evaluate for substitution:

- In wind zones less than 110 (or 100 in hurricane prone regions), this method exceeds code outright!
- Where stated loads on truss plan are called out, use Table 1
- Where ties specified, compare Table 1 to tie mfr. loads
- Specify using AFPA Wood Frame Construction Manual
Rafter / Truss to Top Plate

**Rafter or Truss to Top Plate Connection**

Withdrawal Calculated per ESR-1078

<table>
<thead>
<tr>
<th>Withdrawal Value</th>
<th>Embedment Depth</th>
<th>Toe Nail Factor</th>
<th>Wind/Seismic Load Duration</th>
<th>Amount of Screws</th>
</tr>
</thead>
<tbody>
<tr>
<td>131 lbs/inch of thread</td>
<td>2.0 inches</td>
<td>0</td>
<td>1.6</td>
<td>1</td>
</tr>
<tr>
<td>420 lbs/connection</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*assumes SPF rafter and top plate – weakest wood

Connection | Design Uplift | Lateral | Shear |
---|---|---|---|
H2.5 | 365 | 130 | 130 |
H3 | 320 | 105 | 140 |
H4 | 235 | 140 | 135 |
H5 | 265 | 100 | 170 |
TimberLok | 420 | 320 | 320 |

SHEAR or BRACED WALLS

You are basically building a two story shear wall!
USE STRUCTURAL WOODSCREWS INSTEAD OF LAGS, THRUBOLTS OR BIG 60d SPIKES

Next Step in the Evolution of Fasteners!

CRAZY SCREW GUYS!

WHAT WILL THEY THINK OF NEXT?

DECK RAIL POST TO RIM BOARD

CONNECTION DETAILS
According to the 2009 International Residential Code for One and Two-Family Dwellings, Table R311.5 (IRC, 2009), guardrails and handrails must be designed to withstand a single concentrated load of 200 pounds in any direction. A critical part of this connection is making a strong connection between the guardrail post and the rim board of the deck. In most cases, a 1/2” through-bolt or carriage bolt is used to make this connection. When installed as instructed in this bulletin, the Thrusk System can replace 1/4” bolts, reducing the 200 pound design load for this part of the connection.

INSTALLATION INSTRUCTIONS

1. Choose the correct length (61/4” or 8”) and framing pattern for each post to pin application based on the illustrated conditions.
2. Mark the surface of the wood with the correct pattern.
3. If a flush mounted head is required, use a 1/8” spade bit to create a 1/8” recess in the surface post.
4. Remove the preassembled Thrusk nut from the screw and using a 1/8” drill or low speed/high torque setting, install the Thrusk screw and washer into the male threads of the application until the screw is 1/16” to 1/4” from being flush.
5. Thread the Thrusk nut onto the exposed threaded end of the fastener. Finally twist on the nut by hand until snug.
Questions?

This concludes The American Institute of Architects Continuing Education Systems Course.

OMG

- Largest Domestic Screw Manufacturer
  - Agawam, MA

Who We Are

OMG / FastenMaster Principles

- Contractor Focused
  - Lower Installed Cost
  - Train the Chain (Contractor, Yard, Inspector, Engineer)
- Code Reliance
  - Clear Installation Instructions, Technical Bulletins
  - Inspectability
  - Tested to Standards (ICC, ASTM, FM)
- Innovation
  - Develop New Products
  - Key to Staying Relevant and in the USA
Thank You!

LOS ANGELES CITY RESEARCH REPORT # 25738
INTERNATIONAL CODE ICC ESR # 1078

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