Engineered Wood Beams: Spanning the Distance

Structural Engineers Association of Ohio
September 12, 2014

Bob Clark, APA
Non-profit Trade Association representing manufacturers of engineered wood products:

- Structural Panels: Plywood and Oriented Strand Board (OSB)
- Glulam
- I-joists
- Structural Composite Lumber (SCL): Laminated Veneer Lumber (LVL), Oriented Strand Lumber (OSL)
What is an Engineered Wood Product?

Any wood-based building material that has been improved physically by a man-process.
Engineered Wood Products

Machined into pieces…
- Sawing (Glulam)
- Peeling (Plywood/LVL)
- Slicing (OSB/OSL)
Engineered Wood Products

Processed for maximum strength by...

- Drying
- Sorting
- Grading
- Aligning
Engineered Wood Products

 Manufactured by…

- Applying Adhesives
- Pressing
- Curing
- Finishing
Designing panels for performance

Strength, stiffness, durability, and dimensional stability

- Face
- Core
- Center
- Core
- Back
Oriented Strand Board Layup
Laminated Veneer Lumber (LVL)

Veneers bonded together
- Beams, headers, rafters & scaffold planking
- Common thicknesses: 
  \( \frac{3}{4} \)” to 3-1/2”
Parallel Strand Lumber (PSL)

- Manufactured from veneers clipped into long strands in a parallel formation and bonded together
- Strand length-to-thickness ratio is around 300
- Common uses: headers, beams, load-bearing columns
- Published on a proprietary basis by the manufacturer and recognized in evaluation reports.
Other Structural Composite Lumber

Laminated Strand Lumber (LSL):
- Flaked strand length-to-thickness ratio is around 150
- Common uses: studs

Oriented Strand Lumber (OSL):
- Flaked strand length-to-thickness ratio is around 75
- Common uses: studs
Wood I-Joist Shape

Flange
Typically LVL (peeled, dried, aligned, glued, pressed) or MSR lumber (sawn, dried, sorted, graded)

Web
Typically OSB (sliced, dried, aligned, glued, pressed)

Critical Glue Joint

- 46% less than lumber at 16" vs. I-joist at 19.2"
- 36% less when both are at 16"

Placing Wood Fiber Where the Stresses are Greatest
Glulam

- Wood laminations bonded together
- Wood grain runs parallel to the length

Typical Widths:
- 2-1/2" to 10-3/4"

Laminations:
- 1-3/8" for Southern Pine
- 1-1/2" for Douglas Fir
1933 – First Glulam in the U.S.A. Madison, WI
Disney Ice Arena
Anaheim, CA
Disney Ice Arena
Anaheim, CA
Air Terminal
Victoria, BC
Glulam Concept
Engineered Lay-ups

- Compression zone
- Inner zone
- Tension zone

Critical Tension Zone
Unbalanced Layup
(Used for simply supported beams)

24F-V4 Doug Fir (12 Lamination Example)

- 2 - #2 Dense Grade Outer Comp. Lams
- 1 - #2 Grade Inner Comp. Lam
- 6 - #3 Grade Core Lams
- 1 - #2 Grade Inner Ten. Lam
- 2 - #1 Grade Outer Tension Lams
Simple Span
Trademark and “TOP” Stamp for Unbalanced Layup
Balanced Layup

24F-V5 Southern Pine (12 Lamination Example)

2 - #1 Dense Grade Outer Comp. Lams

8 - #2 Medium Grade Core Lams

2 - #1 Dense Grade Outer Tension Lams
Cantilever or Continuous Span
New Technology
High Strength Beams

LVL Hybrid Glulam with LVL Outer Laminations

- Full length with no finger joints required
- LVL has greater tensile strength compared to lumber
- 30F-2.1E stress level achieved
- Direct substitute for many SCL products
Appearance Classifications

- **Framing** – Intended for concealed applications and is typically available in 3-1/2” & 5-1/2” widths to match dimensions of 2x4 and 2x6 framing lumber
- **Industrial** – Intended for concealed applications or where appearance is not of primary importance
- **Architectural** – Used where members are exposed to view and an attractive finish is desired
- **Premium** – Available only as a custom order where appearance is of primary importance

Strength is not impacted by appearance classifications
Versatility of Shapes and Spans
Spans of 100 feet or greater
Oceans Exhibit – Indianapolis Zoo

10-3/4” x 72”
115 ft. clear span
Product Basics
Large Cross Sections Are Possible

21” x 27” x 110’

Note multiple pieces positioned side by side
Field Notching and Drilling of Glulam

ZONES WHERE SMALL HORIZONTAL HOLES ARE PERMITTED IN A UNIFORMLY LOADED, SIMPLY SUPPORTED BEAM

- Moment critical zone
- Shear critical zone
- Bearing critical zone

Zones where horizontal holes are permitted for passage of wires, conduit, etc.
Field Notching and Drilling of Glulam
Interior Applications
Preservative Treatment of Glulam

Untreated glulam in pressure cylinder ready for treatment

Preservative forced into wood cells under pressure

See APA Technical Note S580
Naturally Durable Species

- Port Orford Cedar: 22F-1.8E
- Alaska Yellow Cedar: 20F-1.5E
- Western Red Cedar: 16F-1.3E
- California Redwood: 16F-1.1E
Alaska Yellow Cedar (AYC)
Santa Monica, CA Reservoir Cover
Effects of Moisture

- Seasoning checking
- Is it of structural concern?
Examples of Checking

- Side checks
- Bottom glue line check
- End checks
Glulam: Applications & Features

Fire Resistance
Glulam: Applications & Features
APA Case Study: Cathedral of Christ The Light (Form J140)

- Oakland, California
- Constructed in 2008
- Design Team: SOM, Western Wood Structures
Glulam in Golf Resort Construction (Form EWS G225)

- Riverwalk Golf Club Bridges (San Diego, CA)
- Design Team: William A. Steen & Assoc. and Western Wood Structures
- Span 117 and 170’
- Max loading 10,000 # maintenance vehicles
Wood I-Joists
Roofs
Unique Projects
Panelized Roof Systems
Wood I-Joist Shape

Flange
- Typically LVL (peeled, dried, aligned, glued, pressed) or MSR lumber (sawn, dried, sorted, graded)

Web
- Typically OSB (sliced, dried, aligned, glued, pressed)

Critical Glue Joint

- 46% less than lumber at 16" vs. I-joist at 19.2"
- 36% less when both are at 16"

Placing Wood Fiber Where the Stresses are Greatest
Predictable Performance

- Consistent dimensions
- Straight
- Predictable
- Less Shrinkage
- Less Crowning
- Long Lengths
Lightweight
Wood I-Joists in the Code

- IBC Section 2303.1.2
- IRC Section R502.1.4

Prefabricated wood I-joists.

- Structural Capacities and design provisions for prefabricated wood I-joists shall be established and monitored in accordance with ASTM D 5055.
APA Product Reports

• Report indicates that product meets the intention of the listed codes when used as stated and within the specified limitations.

• Design properties are included.

Available for download at www.apawood.org/publications
Validation Testing
Bending Force in Flanges

Forces are Max. at $L$
Shear Force in Web

Uniform Load

Collected Shear (Vertical) Force is Max. At Support
Holes in Web

Uniform Load

Hole Size in Proportion to Shear Force
Rim Joist Detail

End Bearing Condition shall provide:
- Lateral Bracing
- Vertical Load Transfer

Uniform Vertical Load Transfer not to exceed 2,000 plf

Attach rim joist to floor joist with one nail at top and bottom

8d nails @ 6” o.c. to top plate

Min. 1 3/4” bearing required

Alternative Method (installed as blocking)
One 8d face nail at each side at bearing

Min. 1 3/4” bearing required
Rim Board Detail

End Bearing Condition shall provide:
- Lateral Bracing
- Vertical Load Transfer

Uniform Vertical Load Transfer

<table>
<thead>
<tr>
<th>Rim Board Type</th>
<th>Load Transfer (plf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1/8” Rim Board Plus</td>
<td>4,850</td>
</tr>
<tr>
<td>1 1/8” Rim Board</td>
<td>4,400</td>
</tr>
<tr>
<td>1” Rim Board</td>
<td>3,300</td>
</tr>
</tbody>
</table>

- One 8d face nail at each side at bearing
- Min. 1 3/4” bearing required
- Attach Rim Board to top plate using 8d common or box toenails @ 6” o.c.
- One 8d common or box nail at top and bottom flange
Do Not Mix Dimension Lumber with I-Joists
### Rim Board Over Openings

<table>
<thead>
<tr>
<th>Grade</th>
<th>$F_{be}$</th>
<th>$E_e$</th>
<th>$F_{ve}$</th>
<th>$C_{c,e}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rim Board and Rim Board Plus</td>
<td>600</td>
<td>550,000</td>
<td>140</td>
<td>550</td>
</tr>
</tbody>
</table>

Rim Boards may be used to span up to 4 feet in length, depending on the applied loads on the opening. For greater spans and additional loads, consider other engineered wood products, such as LVL.

Do not cut holes in Rim Board over opening except for 1-1/2” or less in size.
Integrated Rim Board Header

INTEGRATED RIM HEADER FOR 2X6 WALLS

To be designed by engineer

- APA Rim Board® or SCL
- Double APA Rim Board or SCL as required
- Face- or top-mount hanger (typ.)

No Rim Board joints within 12" of opening

- 1-joists - 24"oc
- Double top plate or single plate per designer

- Stud (typ.)
- Cripple stud (typ.)
- Header
- King studs

Note: The number of king studs required to transfer gravity and wind loads may increase with larger opening. Check with designer.

No joints within span of Rim Board header or within 12" of opening. Detail courtesy of NAHB Research Center.
### Rim Board Hole Specifications

<table>
<thead>
<tr>
<th>Rim Board Depth (in.)</th>
<th>Maximum Allowable Hole Size (in.)</th>
<th>Minimum Length of Rim Board Segment for the Maximum Allowable Hole Size (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9-1/2</td>
<td>6-1/4</td>
<td>50</td>
</tr>
<tr>
<td>11-7/8</td>
<td>7-3/4</td>
<td>62</td>
</tr>
<tr>
<td>14</td>
<td>9-1/4</td>
<td>74</td>
</tr>
<tr>
<td>16</td>
<td>10-1/2</td>
<td>84</td>
</tr>
</tbody>
</table>

Hole of 1-1/2” or less in diameter

“All holes shall be cut in a workman-like manner.”
Vertical Load Transfer

Stacking Walls

Wall Load Above

Potential Failure Modes:
- Buckling of web
- Knifing through flange
Interior Block Panel Detail

Blocking provides additional lateral stability of spanning I-Joist flanges

Not necessary to brace webs or notching webs to fit

8d nails at 6” o.c. to top plate

One 8d face nail at each side at bearing

Uniform Vertical Load Transfer not to exceed 2,000 plf
Blocking Panels
Squash Block Detail

Note: Squash Blocks do NOT provide lateral bracing of spanning joists. Provide bracing if required.

Vertical Load Transfer Capacity (lbs.)

<table>
<thead>
<tr>
<th>Pair of Squash Blocks</th>
<th>3-1/2” wide</th>
<th>5-1/2” wide</th>
</tr>
</thead>
<tbody>
<tr>
<td>2x lumber</td>
<td>4,000</td>
<td>7,000</td>
</tr>
<tr>
<td>1-1/8” Rim Board or RSIF 48 oc</td>
<td>3,000</td>
<td>3,500</td>
</tr>
<tr>
<td>1” Rim Board or RSIF 32 oc</td>
<td>2,700</td>
<td>3,500</td>
</tr>
</tbody>
</table>
# Web Stiffener Detail

<table>
<thead>
<tr>
<th>Flange Width</th>
<th>Web Stiffener Size (thickness x min. width)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1/2”</td>
<td>15/32” x 2-5/16”</td>
</tr>
<tr>
<td>1-3/4”</td>
<td>19/32” x 2-5/16”</td>
</tr>
<tr>
<td>2-5/16”</td>
<td>1” x 2-5/16”</td>
</tr>
<tr>
<td>2-1/2”</td>
<td>1” x 2-5/16”</td>
</tr>
<tr>
<td>3-1/2”</td>
<td>1-1/2” x 2-5/16”</td>
</tr>
</tbody>
</table>

- **End Bearing (Bearing Stiffener)**
  - No Gap
  - >1550 lb

- **Concentrated Load (Load Stiffener)**
  - No Gap
  - >1000 lb
Use backer block if hanger load exceeds 250 lbs or if required by hanger manufacturer.

<table>
<thead>
<tr>
<th>Flange Width</th>
<th>Material Thk. Rqd.</th>
<th>Min. Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1/2”</td>
<td>19/32”</td>
<td>5-1/2”</td>
</tr>
<tr>
<td>1-3/4”</td>
<td>23/32”</td>
<td>5-1/2”</td>
</tr>
<tr>
<td>2-5/16”</td>
<td>1”</td>
<td>7-1/4”</td>
</tr>
<tr>
<td>2-1/2”</td>
<td>1”</td>
<td>5-1/2”</td>
</tr>
<tr>
<td>3-1/2”</td>
<td>1-1/2”</td>
<td>7-1/4”</td>
</tr>
</tbody>
</table>
Backer Block
Hanger Selection / Installation
Double I-Joist and Filler Block

Use two rows of 10d nails at 12” o.c. (clinched if possible)

1/8” Gap

Offset nails from opposite face by 6”
Web Holes
Distance – Inside of Support to Center of Hole

<table>
<thead>
<tr>
<th>9-1/2&quot; JOIST</th>
<th>Round Hole Diameter (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td>PRI-20</td>
<td>0'-6&quot;</td>
</tr>
<tr>
<td>PRI-30</td>
<td>1'-0</td>
</tr>
<tr>
<td>PRI-40</td>
<td>1'-0</td>
</tr>
<tr>
<td>PRI-50</td>
<td>1'-6&quot;</td>
</tr>
<tr>
<td>PRI-60</td>
<td>2'-0</td>
</tr>
</tbody>
</table>
# Center Cut Chase Openings

<table>
<thead>
<tr>
<th>I-Joist Designation</th>
<th>Joist Spacing (in.)</th>
<th>Center chase opening length (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>PRI-40</td>
<td>12</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>19.2</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>X</td>
</tr>
</tbody>
</table>

- The center chase opening must ALWAYS be centered at the center of the I-joist span.
- I-joist top and bottom flanges must NEVER be cut, notched, or otherwise modified.
- The maximum depth of the center chase opening must equal the clear distance between the flanges of the I-joist minus ¼ in.
- The edge of additional holes must not be placed any closer to the edge of the center chase opening than two times the length of the center chase opening.
I-Joist Holes

- Limit 3 maximum size holes per span
- A 1-1/2 inch hole can be placed anywhere in the web, provided it has the required distance from adjacent holes
- Keep a minimum 1/8” between top or bottom of a hole and the flanges
- I-Joist top and bottom flanges must never be cut, notched, or otherwise modified
- Whenever possible field-cut holes should be centered on the middle of the web
- The max. size hole that can be cut into an I-joist web shall equal the clear distance between the flanges of the I-joist minus ¼ in
Variable Spacing... Be Careful
Minimizing Floor Vibration in Wood I-Joist Floors

- Removal of vibrating articles
- Soft-spot correction
- Increasing floor stiffness or mass
Floor Joist Reinforcement

19/32” or 23/32” wood structural panel

Glue & nail to I-joist flanges with Minimum nail spacing recommendations

Strength Axis
Additional Floor Sheathing

Additional wood structural panel or hardwood flooring
Ceiling Board Attachment

Glue-nail gypsum to bottom of floor joists
Bridging

Blocking, cross bridging, or bottom strapping shown

I-Joist

Less than 14 ft.

Greater than 14 ft.
2012 IRC

R501.3 Fire protection of floors. Floor assemblies, not required elsewhere in this code to be fire resistance rated, shall be provided with a 1/2 inch gypsum wallboard membrane, 5/8 inch wood structural panel membrane, or equivalent on the underside of the floor framing member.

Pertains to all Floor Joists

- Wood I-Joists
- Dimensional Lumber less than 2x10
- Trusses
- Steel
1-Hour Fire-Rated Assemblies

- Wood I-Joists or Trusses Spaced 24” o.c.
- 23/32” APA T&G Plywood
- Adhesive at Supports and T&G Edges
- Resilient Channels Spaced 16” o.c.
- ½” Proprietary Type X Gypsum Wallboard Ceiling (2 Layers)
LVL Beams in I-Joist Floor Systems
LVL Floor Beams
Side Loaded LVL
Permissible Holes for LVL

Minimum amount of spacing = 2 x diameter of the largest hole

Zone where holes are permitted for passage of wires, conduits, etc.
Field Notching and Drilling of Laminated Veneer Lumber

Tech Note
EWS G535