Engineered Wood Beams
What Today’s Designers Need to Know

Presenters: Bruce Lindsey / Bryan Readling, P.E.

Learning Objectives

- Compare an array of generic and proprietary engineered wood beams and select the best product for a given application.
- Understand common mistakes made when specifying engineered wood beams, which can affect performance with regard to strength.
- Examine both proper and improper connection details for transferring loads within Engineered Wood Beam systems.
- Determine proper comparison and specification of Engineered Wood Beam products in unique structural applications, using completed structural examples.

Agenda:

- **Products & Applications**
  - Glulam, LVL, PSL, LSL, I-Joist (as a beam)
- **Applications**
  - Exposure Types and Use Treatments
- **Connections**
  - Mechanical Connections
  - Pre-Engineered Connections
- **Case Studies**
- **Environmental Benefits**

Glulam: Features & Applications

- 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
Dispersal of Strength Reducing Characteristics

Stock Beam

Camber

Zero Camber

Glulam Camber

Glulam Manufacturing

L = Span (ft)

\[ \Delta = \text{Camber (in)} \]

Radius of Curvature (ft)

Stock Manufactured Radius

- Douglas Fir: 3500' radius
- Southern Pine: 2000' radius

CAMBER FOR 3500-FOOT RADIUS

<table>
<thead>
<tr>
<th>Span in feet</th>
<th>10</th>
<th>12</th>
<th>14</th>
<th>16</th>
<th>18</th>
<th>20</th>
<th>22</th>
<th>24</th>
<th>26</th>
<th>28</th>
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<tr>
<td>Camber in inches</td>
<td>.04</td>
<td>.06</td>
<td>.08</td>
<td>.11</td>
<td>.14</td>
<td>.17</td>
<td>.21</td>
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Custom Glulam Beam Manufacturing

Engineered Lay-ups

Tennis Courts, Aurora, CO

Compression zone

Inner zone

Tension zone

Critical Tension Zone
Glulam Manufacturing

Engineered Layups

Unbalanced
Simple Spans

Balanced
Continuous Spans or Cantilevered

TOP

No. 2
No. 1
No. 3
No. 2
No. 1
No. 3
No. 2
TL

TL = Tension Lamination

www.woodworks.org

Cantilever or Continuous Span

“TOP” or “Arriba” Stamp

Improperly Installed Unbalanced Glulam

www.woodworks.org
Common Species:
Douglas Fir or Southern Pine

Stock Glulam Properties:
2400 Fb  1.8E

High Strength Glulam Properties:
3000 Fb  2.1E

Both Agencies adhere to the ANSI-A190 standards.
Additional information at:
www.aic-glulam.org
and
www.apawood.org
**Strength**

Glulam Highway Bridge – Hiroshima, Japan
Glulam trusses are 10’ deep with 200+ spans

**Dimensional Stability**

Waterproof adhesives eliminate glue line degradation in exposed structures

**Custom Laminated Glulams**

Disney Ice Center – Anaheim, CA

**High Strength of Glulam**

Glulams are spaced 22’ o.c. and span 116’

**Laminated Veneer Lumber (LVL)**

Uniform, consistent beam that can be field connected to achieve desired width and load capacities.

Common lengths available up to 48” in depths ranging from 5-1/2” to 24”.

**LVL Features & Applications**

Laminated Veneer Lumber (LVL):
- Produced by bonding thin veneers together
- Used for studs, beams, headers, rafters & scaffold planking

The grain of all veneers is parallel to the long direction
Logs are peeled into veneer sheets which are sorted by grade then laminated together to form homogeneous billet of laminated veneers.

Billets are cut to length then rip cut to desired plank width.

- Commonly available up to 48’ in length
- Depending upon thickness, up to four separate pieces may be nailed, bolted or screwed together to achieve desired width or load capacity. (always follow manufacturer’s connection guidelines).

Common Thicknesses:
- 3/4” to 3-1/2”
- Typical width 1-3/4”

Common Depths:
- 3-1/2” to 24”

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
- Strand construction allows for better raw material utilization and the use of various wood species.
**PSL Features & Benefits**

**Parallel Strand Lumber (PSL):**
- Single piece install without field connections to establish width.
- Use of stranded veneer instead of full sheet veneers allows the use of smaller diameter trees and/or different wood species in manufacturing.
- Open grain composition allows for unique face finish options when visually exposed.

**LSL Features & Benefits**

**Laminated Strand Lumber (LSL):**
- Dimensionally stable replacement for most lumber framing
- Cost effective alternative to expensive light-gauge framing.
- Can be manufactured in a variety of sizes and shapes.
- One piece LSL headers offer simplified framing and reduced labor costs in field.

**PSL Sizes & Specifications**

**Parallel Strand Lumber (PSL):**
- High Strength, uniformly constructed beam typically used for beam, header, or column material.
- Stock widths: 2-11/16", 3-1/2", 5-1/4", and 7".
- 2.0E (beams) & 1.8E (columns)
- Lengths up to 48'

**LSL Sizes & Specifications**

**Laminated Strand Lumber (LSL):**
- Common widths: 1-1/2", 3-1/2", 5-1/4"
- Common Depths 3-1/2", 5-1/2", 7-1/4", 9-1/2"
- Design Properties vary by manufacturer
- Common Lengths up to 24'
I-Joist (used as a beam or header)

Manufacturing

I-Joist:
• Commonly used for floor and roof framing
• Long lengths readily available

Flange:
• Lumber
• LVL
• LSL

Web:
• OSB
• Plywood

Flange Widths:
• 1-1/2" to 3-1/2"

Common Depths:
• 9-1/2"
• 11-7/8"
• 14"
• 16"

Bending Force in Flanges

Uniform Load

Compression
Tension

Forces are Max. at

Engineering 101

Shear Force in Web

Uniform Load

Collected Shear (Vertical) Force is Max. At Support

Engineering 101

Double I-Joist Detail

Consult with the I-Joist manufacturer’s specifications for proper blocking materials and nailing patterns

Typical 1/8" Gap between blocking and flange

ALL Double I-Joists must be properly sistered with solid blocking in between the webs.

Additional details and information available on APA Form Z725.

Fire Considerations
IBC Section 602.4 – Type IV Construction (Heavy Timber)

Solid or Glue Laminated Timber Minimum Cross Section (nominal)

Floor Column - 8” minimum in any direction
Roof Column - 6” x 8” minimum
Floor Beam – 6” wide x 10” deep minimum
Floor Arch/Truss Components – 8” minimum in any direction
Roof Arch / Truss / Beams – Consult with IBC Section 602.4.3

Sizes from 4”x6” to 6”x 8” depending upon bearing height and shape of component / beam.

Wet use Exposure

Pressure Treated PSL

- Provides resistance to both decay and insects.
- Cost effective alternative to high cost steel members for exterior deck or roof support.
- Allows longer spans within design when replacing built-up treated lumber beams, reducing foundation costs and expanding design options.

Manufacturing

- Wood Species mix is adapted in manufacturing to ensure treatment penetration and retention
- Pre-treatment manufactured size adjusted to allow for expansion of product after treatment.
- Kiln Dried after treatment to ensure dimensional stability.
**Treated PSL Sizes and Specifications**

Common Beam Widths: 3-1/2", 5-1/4"

Common Beam Depths: 9-1/4", 11-7/8", 14", 16"

Common Column Sizes: 3-1/2" x 5-1/4"

5-1/4" x 5-1/4"

7" x 7"

Consult manufacturer for proper wet use factors and structural design properties.

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**Preservative Treated Glulam**

**Manufacturing**

- Wet-use adhesives are utilized during lamination process.
- Pressure Treatment occurs after laminating and machining of product at mill.
- Some western species such as Douglas Fir require incising (see photo) to ensure proper penetration of treatment.
- Kiln Drying after treatment varies by manufacturer.

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**Preservative Treated Glulam Sizes and Specifications**

Common Sizes: Varies by manufacturer – Cross sectional size is typical to that of untreated glulam but length is usually limited to contracted treatment facility capacity.

Design Properties: Vary by species and level of treatment. Consult with manufacturer’s specifications.

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**Glulam – Decay Resistant Species**

Alternatives to Preservative Treatment:
- Alaska Yellow Cedar
- Western Red Cedar
- Port Orford Cedar

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**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

Connecting Wood

Mechanical fasteners
  – Keep ‘em small
  – Use lots of them
  – Keep scale of fastener small relative to wood member

Tension Perpendicular to Grain

Wood splits from:
  • notches
  • hanging loads
  • restraint by connector

Notching

Problem
  Tension perpendicular to grain

Solution

Connecting Wood

Wood, like other materials, moves in varying environments

Design Considerations

• End restraint conditions:
  – Simple span has 2 supports
  – Continuous has 3 or more supports
  – Cantilevered has 1 support
  – Supports may be beams, columns, walls...

  Simple
  Continuous
  Cantilevered
Field Notching and Drilling of Laminated Veneer Lumber (Tech Note EWS G535)

Permissible Holes for LVL

- 2" max. hole diameter
- 3 holes max.
Minimum amount of spacing = 2 x diameter of the largest hole

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Zone where holes are permitted for passage of wires, conduits, etc.

Excessive Notching

Field Notching and Drilling of Glued Laminated Timber Beams
- Tech Note EWS S560

Notching Creates Tension Perpendicular to the grain
Max. LVL end notch = 0.10d

Pre-engineered Connectors

- Joist and beam hangers
  - Top and face mount
  - Product specific
  - Use correct nail
  - Fill all holes
  - Ensure proper fastener penetration

Generic NDS Connectors

- Timber rivets

Source: ClevelandSteel.com
Timber Rivet System

Timber rivet cross section

Generic NDS Connectors

Split rings & Shear Plates

Source: ClevelandSteel.com

Specialized Connectors

Shear plates
- Loosely fitting in groove
- Easy connection to steel
- Used in pairs for wood-to-wood connections
- Bolt assists in load transfer

Specialized Connectors

Split rings
- Tightly fitting in groove
- More prone to shrinkage splits
- Bolt does not assist in load transfer

Top-Loaded LVL

Side-Loaded LVL
Proprietary Connections

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

www.woodworks.org

Mechanical Connections

Larger fasteners
Bolts in wood bearing are limited to 1 inch diameter or less

www.woodworks.org

Mechanical Connections – Group Action

Geometry Factor, $C_\Delta$

Spacing, End, & Edge Distances
Parallel to grain

www.woodworks.org

Restraint by Connector

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

www.woodworks.org

Starlight Theater
Rockford, IL
Before Splits

Beam to Concrete
- Beam on shelf
- Prevent contact with concrete

Beam to Masonry
Application
- Bearing plate under beam to prevent contact with masonry
- Need 1/2" air gap between wood and masonry

Connection Serviceability
- Protect end-grain and connection
- Preservative treated or decay-resistant species
- end caps and flashing
For More Information... on I-joists and Laminated Beams

- Go to: www.apawood.org
- Click: publications
- Search for:
  - Builder Tips: Storage, Handling & Safety Recommendations for APA Performance Rated I-Joists
  - Builder Tips: Stairwell Openings Parallel to I-Joist Floor Framing
  - APA Performance Rated I-Joists
  - EWS Data File: Shear Transfer at Engineered Wood Floors

Arched Glulams
- 24F-VS
- 8-3/4" x 50-7/8" section
- 75-foot radius
- 22 feet on center
- 116 foot spans
- Moment splices used to allow for transportation

Disney Ice
- 26-foot tall Glulam Trees
  - 3/4" DF laminations
  - 28 feet on center
  - "Branches" support 5-1/8"x 12" glulam purlins

Beaverton, OR Library
- Glued Laminated Decking Roof
- Solid Purlins
- Diagonal Glulams
- Glulam Purlins @ 14 feet o.c.
- Building Size: 69,000 sqft
- Cost: $175/sf

Wisconsin Visitors Information Center

Welcoming Arch
SYP Glulam Trusses span 32 feet
100 feet 5-1/2” x 11-1/2” Glulam Beams
450 feet
5-1/2” x 7-1/2” Glulam Purlins
Cost - $100 / sf

Showcasing Engineered Wood Products

REI Flagship Store - Seattle

Environmentally Conscious Building Materials
Glulams:
- Roof Trusses & Purlins
- Floor Beams
- External Columns & Beams
- Stair Treads
Plywood:
- Roof, Floor & Wall Sheathing
- OSB:
- Wall finish material w/ stain
Investco Financial Corporation
- 22-foot tall interior shear walls
- Birch Veneer Plywood
- Cost Effective: $16.28/sf (interior build out)
- 2/3 less than avg.

Engineered Wood In School Design
- Cost Competitive
- Construction Cost Savings
- Roof Insulation
- Life-Cycle Value
- Durability
- $115/sf – Liberty HS

Dining Hall & Admin. Bldg.
Eleanor Roosevelt College, UCSD

UCSD Dining Hall

2010 Vancouver Olympics
Richmond Olympic Oval completed 2008
Richmond Olympic Oval

330’ Arches – Wood/Steel Composite

www.woodworks.org

Richmond Olympic Oval


www.woodworks.org

Case Studies

Unique Applications

Reservoir Cover

Van Norman Bypass Reservoir Cover:
- Protecting the water supply for the City of LA
- 665,000 sq ft roof covering 15 acres
- Completed in 10 weeks

Unique Applications

• Alaskan Yellow Cedar Glulams—naturally decay resistant
• No chemical treatments
• Concrete columns on a 60’x60’ grid

Unique Applications

Corrosive Mineral Storage

www.woodworks.org
One of Oregon’s Largest Wood Buildings:
- Choices – stainless steel / 3-step epoxy painted steel
- 100 glulam arch members – 8-3/4” x 55-1/2” x 115’
- Erection crew never exceeded 20 persons

Oakland, CA

In North America we plant about 3 million trees - every day *
Growth now exceeds harvest by more than 25% *
* Source: U.S. Forest Service

From 1953 to 1997
- Forest inventories grew 36% *
- Over 50 million wood-frame homes were built

* Source: U.S. Forest Service
Questions?
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