Glued Laminated Timber – An Innovative and Versatile Engineered Wood Composite Product

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Learning Objectives

1. To illustrate how the flexibility of glulam sizes and shapes can help designers meet their most demanding architectural and structural requirements using numerous innovative design examples.

2. To familiarize designers with how to properly select and specify glulam incorporating relevant industry standards and codes.

3. To provide design professionals with an overview of key design considerations that must be considered to ensure both the structural performance and long-term durability of glulam structures.

4. To acquaint designers with the unique fire resistive characteristics of glulam as it influences the use of wood in commercial building construction.

Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.
What is Glulam?

Glulam = a structural composite of lumber and adhesives

Anatomy of Glued Laminated Timber

Lumber Laminations

Glue Lines

Natural Wood Characteristics

End Joints

Glulam – One of the Original Glued Engineered Wood Composites

Switzerland

Laminated Beams, originated in 1893

St. Gallen, Switzerland

120 years of use worldwide

Original U.S. Glulam Structures Constructed in 1934

USDA Forest Products Lab

High School in Wisconsin
Inherent Attributes of Glulam

- High degree of engineering efficiency compared to sawn timber

Engineering Efficiency

![Graph comparing material property values of Glulam, MSR lumber, and visually graded lumber.]

Dispersal of Strength Reducing Characteristics

- Single Lamination
- Glued Laminated Timber

Inherent Attributes of Glulam

- High degree of engineering efficiency compared to sawn timber
- Highly efficient use of wood resource from managed forests
### Inherent Attributes of Glulam

- High degree of engineering efficiency compared to sawn timber
- Highly efficient use of wood resource compared to sawn timber
- Large dimensions possible

### Spans of 100 feet or greater

### Large Cross Sections Are Possible

Note multiple pieces positioned side by side

These pieces are not typically edge bonded but there is no reduction in stress values when the load is applied perpendicular to the wide face
### Inherent Attributes of Glulam

- High degree of engineering efficiency compared to sawn timber
- Highly efficient use of wood resource compared to sawn timber
- Large dimensions possible
- Virtually unlimited versatility in shapes and spans

### Natural Aesthetics of Glulam

- Natural aesthetic appearance of wood

### Unmatched Versatility of Shapes and Spans
Inherent Attributes of Glulam

- High degree of engineering efficiency compared to sawn timber
- Highly efficient use of wood resource compared to sawn timber
- Large dimensions possible
- Virtually unlimited versatility in shapes and spans
- Natural aesthetic appearance of wood
- Environmentally friendly (green)

Glulam is Environmentally Friendly Sustainable and Green

- Produced from small dimension lumber harvested from managed and sustainable forests
- Timber resource utilization optimized using a wide range of lumber grades
- Uses a wide variety of species
- Smaller sections required due to higher strengths
- Manufacturing involves low energy use process
- Uses low formaldehyde emitting adhesives

Formaldehyde: CARB

<table>
<thead>
<tr>
<th>Composite Wood Products</th>
<th>Exempt Products (CARB definition)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardwood plywood</td>
<td>Structural plywood (PS1)</td>
</tr>
<tr>
<td>Particleboard</td>
<td>Structural panels (PS2)</td>
</tr>
<tr>
<td>Medium density fiberboard</td>
<td>Structural composite lumber (ASTM D5456)</td>
</tr>
<tr>
<td></td>
<td>Oriented strand board (PS2)</td>
</tr>
<tr>
<td></td>
<td>Prefabricated wood I-joists (ASTM D5055)</td>
</tr>
<tr>
<td></td>
<td>Structural glued laminated timber (ANSI A190.1)</td>
</tr>
</tbody>
</table>

Must meet threshold emission standards based on ASTM E1333

Glulam Manufacturing Process

- Material Preparation
- End Joint Bonding
- Pre-glue Layup
- Finish Marking Shipping
- Quality Verification
- Face Bonding and Curing
Lumber Species Used

- **Traditional softwoods**
  - Douglas Fir & Southern Pine
- **Other softwoods**
  - Spruce/Pine/Fir and Hem-Fir
- **Naturally durable softwoods**
  - Alaska Yellow Cedar
  - Port Orford Cedar
- **Hardwoods**
- **Mixed species layups**

Visual Lumber Grades

E-Rated Lumber Grades

Southern Pine Glulam Design Values

- Recent changes have resulted in a reduction of Southern pine dimension lumber design values for No. 2 Dense and lower grades
- Questions raised about this affecting the design values for glulam using Southern pine lumber
- Due to the unique grading provisions applied to lumber used in glulam manufacturing these changes have not affected the glulam values
- Information provided in a white paper on the APA web site
### Glulam Adhesive Specifications

**Adhesives used for glulam must meet:**

- **ASTM D2559 for Exterior-Use**
  - Standard Specification for Adhesives for Structural Laminated Wood Products for Use Under Exterior (Wet Use) Exposure Conditions
- **ASTM D7247 for heat durability**
  - Standard Test Method for Evaluating the Shear Strength of Adhesive Bonds in Laminated Wood Products at Elevated Temperatures

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### Finishing for Visual Appearance

**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

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### Glulam Manufacturing Standard

**ANSI A190.1–2012**

- Specifies product qualification and quality assurance requirements
- Third-party inspection by an approved agency is required on an on-going basis
- Building codes require all glulam to bear a trademark meeting ANSI A190.1-2012

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### Quality Trademarks

- **APA**
  - UNBALANCED ARCH
  - Plant 0000 ANSI A190.1-2012

- **AITC**
  - SOUTHERN PINE BEAM
  - QUALITY INSPECTED 117-2010 24F-V4
  - ANSI A190.1-2012

- **IND WCLB**
  - 24F-1.7E UNBAL

- **PLANT 0000**
  - ANSI A190.1-2012
Basic Glulam Design Considerations

- **Type of member / load application**

Member Type

- Column
- Truss member
- Arch
- Simple span beam
- Cantilever span beam

Glulam Lay-Ups

<table>
<thead>
<tr>
<th>24F Bending Members</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balanced</td>
</tr>
<tr>
<td>302-24 T.L.</td>
</tr>
<tr>
<td>No. 1</td>
</tr>
<tr>
<td>No. 2</td>
</tr>
<tr>
<td>No. 3</td>
</tr>
<tr>
<td>No. 2</td>
</tr>
<tr>
<td>No. 2</td>
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<tr>
<td>302-24 T.L.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>24F Bending Members</th>
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<tbody>
<tr>
<td>Unbalanced</td>
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<tr>
<td>302-24 T.L.</td>
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<td>No. 1</td>
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</tr>
<tr>
<td>No. 2</td>
</tr>
<tr>
<td>302-24 T.L.</td>
</tr>
</tbody>
</table>

Glulam layup

Axial stress distribution

- **Same lumber grade and species used throughout**
- **Primarily for use in axially loaded members, such as columns and truss chords**

Single Grade Layup
### Loading Orientations

- Typical use:
  - X-X major axis

![Diagram showing loading orientations](image)

### Importance of Axis Orientation

#### Design Properties for 24F-V4 layup

<table>
<thead>
<tr>
<th>Major Axis (X-X)</th>
<th>Minor Axis (Y-Y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_b = 2,400$ psi</td>
<td>$F_b = 1,500$ psi</td>
</tr>
<tr>
<td>$E = 1,800,000$ psi</td>
<td>$E = 1,600,000$ psi</td>
</tr>
</tbody>
</table>

### Basic Glulam Design Considerations

- Type of member / load application
- Determination of allowable design stresses / layup selection

### ASTM D3737

- Analytical procedure based on the growth characteristics of lumber (knots, slope of grain and density)
- Standardized analysis procedures to generate all major design properties
- Allows manufacturers to use computer models developed by AITC and APA to optimize available resources to achieve high end performance
Empirical method based on full-scale glulam performance tests in combination with or without modeling.

The U.S. has the largest combined full scale glulam beam database in the world.

8-3/4" x 48" x 64 ft

Sources of Design Properties
NDS Supplement

1. Sawn Lumber Grading Agencies
2. Species Combinations
3. Section Properties
4. Design Values
   - Lumber and Timber
   - Non-North American Sawn Lumber
   - Structural Glued Laminated Timber
   - MSR and MEL

NDS Stress Classes

<table>
<thead>
<tr>
<th>Stress Classes</th>
<th>$F_{pm}$ (ksi)</th>
<th>$F_{lt}$ (ksi)</th>
<th>$F_{ul}$ (ksi)</th>
<th>$F_{ur}$ (ksi)</th>
<th>$E$ ($10^7$ psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16F-1.3E</td>
<td>1600</td>
<td>925</td>
<td>315</td>
<td>195</td>
<td>1.3</td>
</tr>
<tr>
<td>20F-1.5E</td>
<td>2000</td>
<td>1100</td>
<td>425</td>
<td>210</td>
<td>1.5</td>
</tr>
<tr>
<td>24F-1.7E</td>
<td>2400</td>
<td>1450</td>
<td>500</td>
<td>210</td>
<td>1.7</td>
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<tr>
<td>24F-1.8E</td>
<td>2400</td>
<td>1450</td>
<td>500</td>
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<tr>
<td>26F-1.8E</td>
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<td>1950</td>
<td>650</td>
<td>265</td>
<td>1.9</td>
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<td>28F-1.8E</td>
<td>2800</td>
<td>2300</td>
<td>740</td>
<td>300</td>
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<tr>
<td>30F-2.1E 3p^a</td>
<td>3000</td>
<td>2400</td>
<td>740</td>
<td>300</td>
<td>2.1</td>
</tr>
<tr>
<td>30F-2.1E LVLR^b</td>
<td>3000</td>
<td>3000</td>
<td>650</td>
<td>300</td>
<td>2.1</td>
</tr>
</tbody>
</table>
### Sources of Design Values

**Industry Standards / ICC Codes**

- ANSI 117 Design Specification
- APA ICC-ESR Code Report 1940
- Glulam standards are referenced in the IBC and IRC codes

### Glulam Design Stresses

- Most common glulam beams are rated at:
  
  \[ F_b = 2,400 \text{ psi} \quad E = 1.8 \times 10^6 \text{ psi} \]

- Higher design stresses also possible:

  - **Southern Pine**
    
    \[ F_b = 3,000 \text{ psi} \quad E = 2.1 \times 10^6 \text{ psi} \]

  - **LVL hybrid**
    
    \[ F_b = 3,000 \text{ psi} \quad E = 2.1 \times 10^6 \text{ psi} \]

  Note: E values for glulam are apparent E and include allowance for shear deflection to simplify deflection calculations. Other products may publish shear free E values which are 5% higher.

### E-Rated Southern Pine Layup

**30F – E2 Balanced Stress Grade**

- **5% No. 1D 2.3E**
  - \( F_b = 3000 \text{ psi} \)
  - \( F_v = 300 \text{ psi} \)
  - \( E = 2,100,000 \text{ psi} \)

**Limited to nominal 6 inch width or less unless manufacturer qualifies for wider widths based on full scale testing**

### US Glulam Standards

**Combination Symbols**

- **24F-V8/DF balanced**
  - Allowable Design Stress:
    - \( 24F = 2,400 \text{ psi} \)
    - \( 30F = 3,000 \text{ psi} \)
  - \( V = \text{visually graded} \)
  - \( E = \text{mechanically graded} \)
  - Assigned combination number
  - Wood species

- **30F-E2/SP**
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 products such as LVL and PSL

Basic Glulam Design Considerations

- Type of member / load application
- Determination of allowable design stresses / layup selection
- Structural analysis

Glulam Design: NDS

Includes both Allowable Stress Design (ASD) and Load and Resistance Factor Design (LRFD)
LRFD vs. ASD

LRFD and ASD presentation formats are different

Example equations for bending moment:

Simple span beam with uniform load

**ASD**

- Applied stress $\leq$ Allowable stress
  
  $f_b \leq F_b'$
  
  $M / S_x \leq F_b C_D$

**LRFD**

- Factored Load $\leq$ Factored Resistance
  
  $M_u \leq M_u'$
  
  $M_u \leq F_b K_F \lambda S_x$

End result will be approximately the same member size for glulam

Additional Glulam Design References

**AITC “Timber Construction Manual”**


Basic Glulam Design Considerations

- Type of member / load application
- Determination of allowable design stresses / layup selection
- Structural analysis
- Stress modification factors

Adjustments for Basic Design Values

- $F_b' = F_b C_D C_M C_t (C_L \text{ or } C_V) C_C$
- $F_v' = F_v C_D C_M C_t$
- $E' = E C_M C_t$

- $C_D$ = load duration factor
- $C_M$ = wet-use factor (16% or greater)
- $C_t$ = temperature factor
- $C_L$ = beam stability factor
- $C_V$ = volume effect factor
- $C_C$ = curvature factor
**Curvature Factor for Bending Strength**

\[ C_C = 1 - 2000 \left( \frac{t}{R} \right)^2 \]

- \( t \) = thickness of lamination (in)
- \( R \) = radius of curvature of the lamination (in)
- \( R_{rec} = 27' - 6'' \) for all species with \( t = 1.5'' \)
- \( R_{rec} = 9' - 4'' \) for Western species with \( t = 0.75'' \)
- \( R_{rec} = 7' - 0'' \) for Southern pine with \( t = 0.75'' \)

Tighter radius can be achieved by using thinner laminations but \( t/R \) cannot exceed 1/100 for S.P and 1/125 for other softwood species

**Volume Factor for Bending Strength**

\[ C_v = \left( \frac{21}{L} \right)^{1/x} \left( \frac{12}{d} \right)^{1/x} \left( \frac{5.125}{b} \right)^{1/x} \leq 1.0 \]

- \( L \) = beam length (ft)
- \( d \) = beam depth (inches)
- \( b \) = beam width (inches)
- \( x = 20 \) for Southern pine
- \( x = 10 \) for all other species

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**Impact of Volume Effect Factor**

Size: 8-3/4” x 72” x 100’

- \( C_v = 0.82 \) for S.P.
- \( C_v = 0.68 \) for other species
- \( F_b' = 2400 \times 0.68 = 1632 \) psi for DF

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**Basic Glulam Design Considerations**

- Type of member / load application
- Determination of allowable design stresses / layup selection
- Stress modification factors
- Structural analysis
- Special design provisions
Typical Glulam Beam Layup

24F-V4 DF Unbalanced (12 Lamination Example)

- 2 - L2 Dense Grade Outer Comp. Lams
- 1 - L2 Grade Inner Comp. Lam
- 6 - L3 Grade Core Lams
- 1 - L2 Grade Inner Tension Lam
- 1 - L1 Grade Inner Tension Lam
- 1 - 302-24 Outer Tension Lam

Trademark and “TOP” Stamp for Unbalanced Layup

Trademark

Improper Installation

Unbalanced Layups “Upside Down” Bending Stresses

Based on full-size beam tests conducted at APA, the “upside down” bending stress is 75% of the normal bending capacity
Specifying Camber

- Glulam can be manufactured with camber to offset the anticipated dead load deflection
- Very important for long span members

**FIGURE 2**

**BEAM CAMBER PARAMETERS**

![Diagram of cambered beam with parameters](image)

**Camber can be specified in inches or as a radius of curvature**

\[ R = \frac{3L^2}{2\Delta} \]

Where:

- \( R \) = approximate radius of curvature (ft)
- \( L \) = span (ft)
- \( \Delta \) = desired camber (in.)

See Figure 1 for a graphic representation of beam camber parameters.

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Importance of Camber

12-1/4” x 84”
140 ft. clear span
Camber = 8”

Spans of 80-100 feet or more are common for glulam

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Field Notching and Drilling of Glued Laminated Timber Beams

**EWS S560F**
**Notching and Drilling**

**Problem**
Tension perpendicular to grain stresses induced

**Solution**
Provide full end grain bearing

**End Notches in Glulam**

A REINFORCEMENT TECHNIQUE TO MINIMIZE CRACK PROPAGATION AT END BEARING NOTCHES

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

Depth of notch 0.1d or 3 inches, whichever is less

Use one or more fully threaded lag screws

Note end notch limitation for glulam

**Improper Notching**

**Effects of Vertical Holes**

Strength reduction
= 1.5 x hole diameter/beam width

Example:
- 6-3/4" beam width
- 1" diameter vertical hole
Reduction = (1.5 x 1.0/6.75)
Reduction = 0.22
Beam has 78% of original strength
Effects of Vertical Holes

3” hole in 6-3/4” wide glulam
Only 1/3rd of strength retained

Notching and Drilling

Horizontal Hole Drilling

Basic Glulam Design Concepts

- Type of member / load application
- Determination of allowable design stresses / layup selection
- Stress modification factors
- Structural analysis
- Special design provisions
- Connection design /detailing

Glulam Connection Design
Connection Design

The NDS provides nominal lateral and withdrawal values for dowel type connectors and specialty connectors such as shear plates, split rings and timber rivets.

Allowable = nominal × adjustment factors

Adjustment factors account for a wide range of different end use applications.

All design information is applicable to glulam.

Durability and Long Term Performance

Strategies for durable glulam construction

- Keep glulam dry
- Focus on design and construction details
- Focus on moisture management
- Use appropriate preservative treatments when exposed to the elements or
- Specify naturally durable and decay resistive wood species
- Numerous examples of glulam structures 50-100 years old worldwide

Interior Applications

Durability Not Typically An Issue

Original U.S. Glulam Structure

USDA Forest Products Laboratory

2009

1934

75 years of continuous use
Glulam Arch Highway Bridge
Elevated Deck – Michigan

Glulam Girder Bridge
Northern California

10-3/4" x 60" x 80 ft center span girders
Erected in 1973
40 years of in-service use

Tri-Level Highway Bridge
Keystone Wye – S.D.

Original installation 1968
Over 45 years of in-service use

Over 45 years of in-service use

Glulam Electric Utility Structures

Some in service since 1970
Preservative Treatment of Glulam

U.S. Standards

- American Wood Protection Association (AWPA U1-13)
  - UC1 Interior, dry Insects
  - UC2 Interior, wet Decay and insects
  - UC3 Exterior, above ground Decay and insects
  - UC4 Ground contact Decay and insects
  - UC5 Salt water Salt water organisms

- American Association of State Highway and Transportation Officials (AASHTO)
  - Above ground
  - Ground contact, fresh water
  - Ground contact, salt water

U.S. building codes require treatment of exposed glulam

Selecting Preservative Treatments

Table 3: Recommended Preservative Treatments for Glulam

Applicable treatments are a function of species and whether treatment is before or after gluing

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
Van Norman Reservoir Cover in Los Angeles Using AYC Glulam

650,000 sq. ft.
15 acres

Serviceability Issues

- Temperature – not of major importance
- Humidity and moisture – can be a major concern
  - exposed end grain
  - contact with concrete or masonry
  - moisture entrapment
  - ambient conditions / dimensional changes

End Grain Exposure

Issue: direct water ingress into the wood
- Water is absorbed rapidly through the end grain of wood
- Project is in Palm Springs, CA
- Heavy checking and deterioration

End Grain Exposure

Issue: direct water ingress
- Minimal roof overhang, no end caps and no flashing used

End caps and flashing used
- Re-direct the water flow around the ends of the glulam
- Use preservative treated glulam or durable species when exposed to the weather

Project is in Palm Springs, CA
Heavy checking and deterioration

Re-direct the water flow around the ends of the glulam
Use preservative treated glulam or durable species when exposed to the weather
**End Grain Exposure**

- Minimal roof overhang
- No flashing
- Checking occurred in 1st year
- Decay may follow

- Roof overhang
- End grain flashing
- No future moisture related problems anticipated

**Glulam Beam to Concrete or Masonry**

- Prevent contact with concrete or masonry
- Use bearing plate under glulam member
- Maintain minimum of ½” air gap at end

- Note steel bearing plate
- Note gap at end

**Glulam Beam to Masonry**

- Grout used at bearing
- No air space

- Need ½” air gap between wood and masonry

**Column Base**

- Problem
  - No provision for moisture to escape
  - Potential for decay to develop
  - Adding a drainage slot at bottom would alleviate problem
Exposed glulam
A-frame with no
flashing and a
closed shoe

No provision
such as weep
holes or slots to
allow moisture to
drain

Note flashing on
top of glulam

Closely
spaced fasteners

Note open shoe
allowing water to drain
After 25 years in service

Ends covered
Closed shoe
### Effects of Moisture Changes on Connections

<table>
<thead>
<tr>
<th>Sawn timber</th>
<th>Glulam</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4&quot;</td>
<td>1/4&quot;</td>
</tr>
<tr>
<td>15-1/4&quot;</td>
<td></td>
</tr>
</tbody>
</table>

| Green | 8% |

#### Glulam Beam End Bearing

**Solution:** allow shrinkage to occur without inducing tension perp stresses by keeping bolts at bottom or use slotted holes.

**Note:** bearing angle and slight gap at wood.

### Beam to Beam Semi-Concealed Kerf Plate
Effects of Moisture

- Seasoning checking
- Is it of structural concern?

Examples of Checking

- Side checks
- End checks
- Bottom glue line check

Checking vs. Delamination

- Checking is a natural phenomena associated with moisture cycling of wood
- Delamination is a deterioration of the glue bond when exposed to moisture
- The requirement for using wet-use (durable) adhesives and ongoing quality assurance during the manufacture of glulam eliminates delamination as a concern
- Checking can be unsightly and be a visual concern but is seldom of structural significance

Testing conducted by APA to evaluate impact of checking

- Guidelines established for what size checks are OK without an engineering analysis
- Published in an Owners Guide to Checking
- One of the industry’s most widely distributed publications
Lessons Learned to Ensure Durable and Long Life Glulam Structures

- Keep glulam dry whenever possible
- Account for moisture effects
  - High moisture = mold, decay, insect attack
    - Protect from direct exposure to elements
    - Use preservative treatments
    - Use naturally durable species
- Design connections for long term performance
  - Allow for movement due to moisture changes
  - Design to avoid moisture entrapment
  - Avoid direct contact with masonry and concrete

Characteristics of Glulam in Fire

- Wood is an excellent heat insulator
- Develops a char layer after fire exposure
- Self-extinguishing after fire source removed
- Retains significant residual strength after being exposed to fire

Glulam vs. Unprotected Steel
ASTM E119 Fire Test

Glulam After ASTM E119 Fire Test

Char rate = 1/40” per minute
or
1-1/2” per hour
Fire Rating for Glulam

Two accepted fire rating methods recognized in the U.S.
- IBC Empirical Method
- NDS Mechanics Based Model

FRT

Flame spread coatings

IBC Methodology
Section 722.6.3

- Empirical calculation protocol
- Based on extensive testing in the U.S. and other countries using the ASTM E119 (ISO 834) fire test protocol
- Beams – 3 or 4 sides exposed
- Columns – 3 or 4 sides exposed
- One hour ratings can be calculated

IBC Methodology for Beams

- Beams exposed on 3 sides
  \[ t = 2.54ZB \left[ 4 - \frac{B}{D} \right] \]
- Beams exposed on 4 sides
  \[ t = 2.54ZB \left[ 4 - 2\frac{B}{D} \right] \]
- B = beam width
- D = beam depth
- t = fire resistance in minutes
- Z = load compensation factor
  = applied load / design capacity

NDS Methodology

- Chapter 16
- Mechanics based model
- Supported by empirical data
- 1, 1-1/2 and 2 hour ratings can be determined
2005 NDS Methodology

\[ \beta_{\text{eff}} = \frac{1.2 \beta_n}{t^{0.187}} \]

<table>
<thead>
<tr>
<th>t</th>
<th>( \beta_{\text{eff}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 hr</td>
<td>1.8 in./hr (45.7 mm/hr)</td>
</tr>
<tr>
<td>2 hr</td>
<td>1.58 in./hr (40.1 mm/hr)</td>
</tr>
</tbody>
</table>

Where:
- \( \beta_{\text{eff}} \) = Effective char rate (in./hr), adjusted for exposure time, \( t \)
- \( \beta_n \) = Nominal char rate (1.5 in./hr)
- \( t \) = Exposure time (hr)

Fire Rated Glulam

**Table 4**

<table>
<thead>
<tr>
<th>Beam Width (in.)</th>
<th>Depth 3 Sides Exposed (in.)</th>
<th>Depth 4 Sides Exposed (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-3/4</td>
<td>13-1/2</td>
<td>13-1/2</td>
</tr>
<tr>
<td>8-3/4</td>
<td>7-1/2</td>
<td>13-1/2</td>
</tr>
</tbody>
</table>

**Table 5**

<table>
<thead>
<tr>
<th>Column Width (in.)</th>
<th>Depth 3 Sides Exposed (in.)</th>
<th>Depth 4 Sides Exposed (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/8 &gt; 11</td>
<td>10-3/4</td>
<td>13-1/2</td>
</tr>
<tr>
<td>6/8 ≤ 11</td>
<td>6-3/4</td>
<td>7-1/2</td>
</tr>
</tbody>
</table>

Typical Glulam Beam Layup

24F-V4 DF Unbalanced (12 Lamination Example)

- 2 - L2 Dense Grade Outer Comp. Lam
- 1 - L2 Grade Inner Comp. Lam
- 6 - L3 Grade Core Lam
- 1 - L2 Grade Inner Tension Lam
- 1 - L1 Grade Inner Tension Lam
- 1 - 302-24 Outer Tension Lam

For 1-hour fire rated beam: substitute additional 302-24 tension lam for core lam

Glulam stock beams often used in residential and light commercial construction
Stock Beam Manufacturing

- Manufactured in long lengths, varying cross-sections, usually unbalanced, minimal camber

Glulam Beams Stored at Distribution Yards

Glulam Beams Shipped to Job Site

Proper handling

Proper storage

Stock Beams - Typical Uses

Roof Beams
Stock Beams - Typical Uses

Garage Door Headers

Simple Span Floor Beams

Continuous Span Floor Beams

IJC Beams and Headers
### I-Joist Compatible (IJC) Glulam

<table>
<thead>
<tr>
<th>Depth</th>
<th>Widths</th>
</tr>
</thead>
<tbody>
<tr>
<td>9-1/2&quot;, 11-7/8&quot;, 14&quot; &amp; 16&quot;</td>
<td>3-1/2&quot;, 5-1/2&quot; &amp; 7&quot;</td>
</tr>
<tr>
<td>Camber: zero, 3500 ft or 5000 ft radius</td>
<td></td>
</tr>
</tbody>
</table>

Lay-up combinations:
- Typically 24F - 1.8E
- Unbalanced DF & SP
- 30F - 2.1E may also be available in some markets

### Column Applications

- Tall wall framing with glulam columns

### Stock Beams – Light Commercial

- Stock Beams – Light Commercial
  - Construction site images
Custom Beams and Arches

Finn Hill Jr. High
Kirkland, WA

Bullitt Center
Seattle, WA

Oceans Exhibit – Indianapolis Zoo
Airport Terminal
Victoria, B.C.

Terminal Two
Raleigh Durham Airport

Kingsway Bridge
Burnaby, B.C.

2010 Olympic Skating Oval
Richmond, B.C.
Twin Rink Ice Arena
Anaheim, CA.

Chicago’s Lincoln Park Zoo
South Pond Pavilion

AT&T PARK in San Francisco
Alaska Yellow Cedar

This is all glulam

Shipped fully assembled

“Life Cycle”
Wood Products

* Non-structural composite panels
Additional Glulam Information

**www.apawood.org**
Glulam Product Guide

Case Studies
Technical Notes
Beam and Column Tables
Manufacturer Product Reports
And much more

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Questions?

This concludes The American Institute of Architects Continuing Education Systems Course

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WoodWorks