**Wood Roofs**
Non-Residential Construction

---

**TODAY'S SEMINAR**

- Low Sloped Roofs
- Custom Roofs
- References to:
  1. 2009 IBC (International Building Code)
  2. NDS (National Design Specifications)
  3. APA (American Plywood Association)
  4. AITC (American Institute Timber Construction)
  5. 2010 CBC (California Building Code)
  6. Comments on costs and pros/cons

---

**WOOD 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

---

**CALGreen**
2010 CALGreen
Title 24 Part 11 of CBC

CALGreen

RESIDENTIAL

MANDATORY MEASURES
Appendix A4

TIER 1 Opt electives

TIER 2 Opt electives

VOLUNTARY MEASURES
Chapter 4

TIER 1 Opt electives

TIER 2 Opt electives

Non RESIDENTIAL

MANDATORY MEASURES
Chapter 5

VOLUNTARY MEASURES
Appendix A5

TIER 1 Opt electives

TIER 2 Opt electives

2010 CALGreen
Non-Residential

- Effective January 1, 2011
- Applies to all newly constructed Building
- Excludes small additions, alterations or repairs

MANDATORY
1. Reduce Construction Waste by 50%
2. Sets VOC and formaldehyde limits

TIER 1
1. Reduce Construction waste by 65%
2. Regional mat’ls harvested or mfg within 500 miles of job site

TIER 2
1. Reduce Construction waste by 80%
2. Regional mat’ls harvested or mfg within 500 miles of job site

Sources of Design Properties
Industry Standards / ICC Codes

- 2009 IBC Codes
- Lumber standards are referenced in the IBC Codes
- ICC-ESR Code Reports
- 2012 IBC Codes (now published-to be adopted)

Glulam Design: 2005 NDS

2005
1 General Requirements for Building Design
2 Design Values for Structural Members
3 Design Provisions and Equations
4 Sawn Lumber
5 Structural Glued Laminated Timber
6 Round Timber Poles and Piles
7 Structural Composite Lumber
8 Prefabricated Wood I-Joists
9 Wood Structural Panels
10 Mechanical Connections
11 Dowel-Type Fasteners
12 Split Ring and Shear Plate Connectors
13 Timber Rivets
14 Shear Walls and Diaphragms
15 Special Loading Conditions
16 Fire Design of Wood Members
Sources of Design Properties

2005 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

LOW SLOPED ROOFS

JOISTED ROOFS @ 16”, 24”, 32” OC
1. Solid Sawn Lumber
2. I-Joists
3. SCL (Structural Composite Lumber)
4. Pin Connected Open Web Truss
5. Plated Open Web Truss
6. Glulams

PANELIZED ROOFS
1. Glulams
2. Plated Open Web Truss

SOLID SAWN

2 x 12 Southern Pine (SP)

Adjustments to design values for solid sawn SP

VALUES per 2005 NDS Supplement
SP #1 (visual grade) \( F_b = 1250 \) \( MOE = 1,700,000 \)

PROPOSED NEW VALUES
\( F_b = 1000 \) \( MOE = 1,600,000 \)

ENGINEERED WOOD PRODUCTS
**TYPICAL GLULAM Designs per NDS**

- **24F-V4** Doug Fir unbalanced
- **24F-V8** Doug Fir balanced
- **24F-V1** Southern Pine unbalanced
- **24F-V5** Southern Pine balanced
- **20F-V12** Alaska Yellow Cedar balanced
- **20F-V13** Alaska Yellow Cedar unbalanced

---

**SCL PRODUCTS**

**LVL** Laminated Veneer Lumber
- Sizes: 1 ½ x, 1 ¾ x, 2 ½ x, 3 ½ x
- Grades: 1.7 E, 2.0E

**LSL** Laminated Structural Lumber
- Sizes: 1 ½ x, 1 ¾ x, 3 ½ x
- Grades: 1.35E, 1.55E, 1.75E

**PSL** Parallel Strand Lumber
- Sizes: 3 ½ x, 5 ¼ x 7 x
- Grades: 1.9E

**HYBRID GLULAM WITH LVL LAMINATIONS**
- Sizes: 3 ½ x, 5 ½ x, 7 x
- Grades: 2.0E

---

**Glulam Lay-Ups**

- **Unbalanced Beam**
  - Compression Zone
  - Inner Zone
  - Tension Zone

- **Balanced Beam**
  - Compression Zone
  - Inner Zone
  - Tension Zone

---

**SCL Hybrid Glulam with LVL Outer Laminations**

LVL has greater tensile strength compared to lumber
- Full length (no finger joint)
- LVL outer laminations
- Southern Pine 3000F inner laminations
- Direct substitute for many SCL products
- ICC ES-ESR-1940

---

**LVL Laminations**

- Full length (no finger joint)
- LVL outer laminations
- Southern Pine 3000F inner laminations
- Direct substitute for many SCL products
- ICC ES-ESR-1940
Hybrid Glulam vs. SCL Design Properties

<table>
<thead>
<tr>
<th>Design Property</th>
<th>Hybrid Glulam</th>
<th>PSL</th>
<th>LVL</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_b$</td>
<td>3000</td>
<td>2900</td>
<td>2950</td>
</tr>
<tr>
<td>$MOE$</td>
<td>$2.2 \times 10^6$</td>
<td>$2.0 \times 10^6$</td>
<td>$2.1 \times 10^6$</td>
</tr>
<tr>
<td>$F_v$</td>
<td>300</td>
<td>290</td>
<td>290</td>
</tr>
</tbody>
</table>

Design properties for LVL are assumed to represent typical values for LVL manufacturers holding ICC-ESR reports but may vary between manufacturers.

TYPICAL COMMERCIAL BLDG  
4 Bays @ 20’ Columns @ 40’

GLULAM GIRDERS  
5 x (2400 SP)

ROOF JOISTS  
2 x SP #1 @ 16” oc  
1 ¾ x LVL @ 24” oc  
2 ½” x IJ @ 24” oc

2x and 1 3/4x LVL may not work for roof diaphragm nailing. 2 ½ x or wider may be better.

TYPICAL COMMERCIAL BLDG  
2 Bays @ 40’ Columns at 40’

GLULAM GIRDERS  
6 ¾ x (2400F SP)

Roof Joists-typ  
IJ 3 ½” x @ 24” oc  
IJ 3 ¼” x @32” oc

PANELIZED ROOF  
Purlins at 8’ oc

2 TYPES  
1. ALL Wood  
2. Hybrid – Combination of steel and wood

MATERIALS  
GIRDERS  
Wood --- Glulams  
Hybrid---Steel OWT

PURLINS  
Wood ---Glulams  
I-Joist  
Plated OWT  
Hybrid---Steel OWT

SHEATHING  
Wood ---OSB or Plywood  
Hybrid ---OSB, Plywood, or steel

Panels are assembled on the ground and then lifted into place to the girders. Less construction time, therefore lower costs. Typical roof slopes are ¼” to ½” in 12
PANELIZED ROOF

WOOD PANELIZED
• Most economical on roofs that are 50,000 ft² or smaller
• Column spacing up to 50’ using Glulam girders
• Bay spacing up to 40’ using:
  ----Glulam purlins—typical 3 1/8” (or 3 1/2”) width
  ----I-Joist Purlins—max span of 35 ft for 30” deep IJ
  ----Plated OWT—typical 40” deep at 40’ span

HYBRID
• Economical for large roof areas
• Economical for wide column spacing and long purlin spans

I-JOISTS Non-Residential

SIZES
Flange widths—2 1/2” & 3 1/2” provided as LVL or MSR solid sawn

DEPTHS
9 1/2” to 24” typical east coast up to 32” is available

Typically most economical design
Cambered IJ is not recommended

PIN CONNECTED OPEN WEB TRUSSES

DOUBLE TAPERED

LONG SPAN
PIN CONNECTED OPEN WEB TRUSSES

- Most versatile of all the products
- Available in many profiles---
  1. Parallel Chord
  2. Single Taper
  3. Bowstring
  4. Barrel
  5. Scissor
  6. Parallel Chord Scissor
- Spans up to 80’
- Typical top chord bearing—
- Wood top and bottom chords
- Lightweight

CUSTOM ROOFS

Glulam Arches
1. Tudor Arch
2. Double Pitched and Curved
3. Curved
4. Glulam Truss

Laminated Decking over Glulams

TUDOR ARCH

USED IN
1. Schools-GYMS
2. Churches

ECONOMICAL DESIGN
1. Roof Slope----3/12 to 12/12
2. Radius of 9’-4” (Uses ¾” Laminations)
3. Half Spans 30’ to 45’
4. On Center spacing 20’ to 30’

TUDOR ARCH
GYM-DSA  Pleasanton, Ca

Radius = 9’-4” with Tangent Ends
**CURVED GLULAMS**

**LAM THICKNESS BASED ON RADIUS**

<table>
<thead>
<tr>
<th>Lam Thickness</th>
<th>Tangent Ends</th>
<th>Constant Curve</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4”</td>
<td>4'-0”</td>
<td>4'-0”</td>
</tr>
<tr>
<td>3/8”</td>
<td>5'-6”</td>
<td>6'-4”</td>
</tr>
<tr>
<td>1/2”</td>
<td>6'-0”</td>
<td>7'-8”</td>
</tr>
<tr>
<td>5/8”</td>
<td>7'-6”</td>
<td>9'-8”</td>
</tr>
<tr>
<td>3/4”</td>
<td>9'-4”</td>
<td>12'-6”</td>
</tr>
<tr>
<td>1”</td>
<td>15'-0”</td>
<td>20'-4”</td>
</tr>
<tr>
<td>1 1/4”</td>
<td>20'-0”</td>
<td>28'-0”</td>
</tr>
<tr>
<td>1 1/2”</td>
<td>27'-6”</td>
<td>35'-6”</td>
</tr>
</tbody>
</table>

***Cc factor to modify Fb must be applied***

---

**DOUBLE PITCHED & CURVED GLULAMS**

---

**MECHANICAL REINFORCEMENT**

**CBC Para 2303.1.3.1**

- Mechanical reinforcement is required when the radial tension stress is >15 PSI for Douglas Fir.
- Mechanical reinforcement shall comply with AITC 404.
- Mechanical reinforcement is between tangent points.
- Mechanical reinforcement is provided as lag bolts or rebar in structural epoxy. **Rebar in structural epoxy is most economical**
- Per CBC Para 2303.1.3.1, moisture content at time of gluing is 12%.

---

**Pitched and Curved Beams**

**Mechanically attached haunch**
Raleigh - Durham Airport
550,000 ft²

2010 Olympic Skating Oval
Richmond, B.C.

LeMay American Car Museum
Tacoma, WA

GLULAM TRUSSES
Connections are Hidden (knife plate design)
GILROY HS
Bolted Glulam Truss

SCHOOL LIBRARY

Claim Jumper Restaurant
Fremont, Ca.

LAMINATED DECKING
LAMINATED DECKING

- **SIZES**
  2x, 3x, 4x, 5x

- **SPECIES**
  Doug Fir, Southern Pine, Western Red Cedar, Ponderosa Pine, also Alaska Yellow Cedar

- Most economical installation is “Random Length Continuous” (RCL)

Glulam Manufacturing Standard
ANSI/AITC A190.1

- Specifies product qualification and quality assurance requirements
- Third-party inspection by an approved agency is required on an on-going basis
- Building codes require that all glulam must bear a grademark meeting ANSI/AITC A190.1-07

Specifying Camber

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

**FIGURE 2**

**BEAM CAMBER PARAMETERS**

\[
L = \text{Span (ft.)} \quad R = \text{Radius of curvature (ft.)} \quad \text{Cambor (in.)}
\]
Moisture Content
For Glulams at Time of Fabrication

1. IBC Para 2303.1.3 refers to ANSI/AITC 190.1
2. ANSI/AITC 190.1 Paragraph 4.3.2
   Moisture content shall not exceed 16 percent with a maximum range of 5 percent between adjacent laminations.

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

Horizontal Finger Joint

Adhesive being applied
End joint adhesive is typically melamine or phenol resorcinol

Face Bonding

Glue is phenol resorcinol
No added urea formaldehyde
Southern Pine Glulams

- See NDS Supplement for Design values
- 1 3/8” laminations
- Standard Glulam depths in 1 3/8” multiples (Doug Fir 1 1/2” multiples)
- Gluing to take place within 24 hrs of surfacing laminations
- See APA handout reference possible changes to Southern Pine lumber (does not effect Glulams)

Large Cross Sections Are Possible

- Note multiple pieces positioned side by side
- No reduction in stress values even if pieces are not edge bonded and load is applied perpendicular to the wide face

Edge Layups

Per ANSI/AITC A190.1 Para 4.7.1.2

- Used when 2 or more laminations are side by side
- When 2 side by side laminations are used, they need to be 2 different sizes
- Edge Layups are Required for Glulams 12 1/4” and wider
  ie: 12 1/4 x is made with 2 x 6 and 2 x 8 lams
- Each level of laminations is staggered with at least 2” between each vertical edge joint
  ie: 2 x 6 and 2 x 8 then 2 x 8 and 2 x6
- 14 1/4” x is made with 2 x 6 and 2 x 10 edge layups

Trademark and “TOP” Stamp for “Unbalanced” Layup
Improper Installation

Improper Notching

Possible Reinforcement for an End Notch in Glulam

Field Notching and Drilling of Glulam

APA Form S560

Horizontal Hole Drilling

Note end notch limitation for glulam
GLULAMS EXPOSED TO THE WEATHER

IBC Para 2304.11.3. Laminated Timbers
The portions of glued-laminated timbers that form the structural supports of a building or other structure and are exposed to weather and not fully protected from moisture by a roof, eave or similar covering shall be pressure treated with preservative or be manufactured from naturally durable or preservative-treated wood.

IBC Para 2301.1 Definitions
Naturally Durable Wood—Decay Resistant Cedar, Redwood, Black Locust, or Black Walnut.

CONDITIONS FOR DECAY

CONDITIONS FOR DECAY ARE-

1. Temperature >35 to <100 degrees
2. Moisture content in wood fiber is +20%
3. Presence of Oxygen
4. Eliminate any one of these 3 conditions and there is no decay.

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

IBC 2302.1
NATURALLY DURABLE WOOD
Corner sapwood is permitted if 90% or more is heartwood.

CEDAR GLULAMS

DESIGN VALUES are listed in NDS

<table>
<thead>
<tr>
<th>Alaska Yellow Cedar</th>
<th>Port Orford Cedar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fb Tension</td>
<td>2000</td>
</tr>
<tr>
<td>Fv Shear</td>
<td>265</td>
</tr>
<tr>
<td>MOE</td>
<td>1,500,000</td>
</tr>
</tbody>
</table>

- AYC more readily available –Recommend designing cedar beams to AYC values, a safe design
RETAIL  Santa Rosa, Ca
Top Chord & Webs are Doug Fir
Bottom Chord Alaska Yellow Cedar

Flashing at Glulam Ends

Tasting Room  St Helena, Ca
Alaska Yellow Cedar curved Trellis and roof rafters

Alaska Yellow Cedar (AYC)
Santa Monica, CA Reservoir Cover
Preservative Treatment of Glulam

Untreated glulam in pressure cylinder ready for treatment

Preservative forced into wood cells under pressure

Verify size capability with mfr.

APA S580
Preservative Treatment of Glued Laminated Timber

- Incising is required for Douglas-Fir and other western species.
- Incising is not required for Southern Pine.
- Incising is not considered to have a detrimental effect on the strength of Glulam.

Selecting Preservative Treatments
Preservative Treated Glulam

<table>
<thead>
<tr>
<th>TABLE 2*</th>
<th>TREATMENT TYPE CHARACTERISTICS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creosote</td>
<td>Penta in Oils</td>
</tr>
<tr>
<td>Suitable Applications</td>
<td>Saltwater or fresh water applications, wood block floors, bridges, towers and ground contact.</td>
</tr>
</tbody>
</table>

See APA Technical Note S580

APA does not recommend treating with water preservatives

Fire Rating for Glulam

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

FRT Fire Retardant Treat Flame spread coatings
Glulam Performance During a Fire

- Wood starts charring about 300 degrees F
- Wood ignites about 450-500 degrees F
- Wood chars about 1/40 inch per minute
- After 30 minutes about 3/4” is damaged
- Glulams can perform up to 1650 degrees F
- Unprotected steel can buckle & twist at these high temperatures.

Fire Rated Glulam

<table>
<thead>
<tr>
<th>Table 4</th>
<th>Minimum Depths at Which 9-3/4” and 8-3/4” Wide Beams Can Be Adapted for One-Hour Fire Ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam Width (in)</td>
<td>Depth 3 Sides Exposed (in)</td>
</tr>
<tr>
<td>6-3/4</td>
<td>13-1/2</td>
</tr>
<tr>
<td>8-3/4</td>
<td>7-1/2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 5</th>
<th>Minimum Depths at Which 8-3/4” and 10-3/4” Column Widths Qualify for One-Hour Rating for Given E/D</th>
</tr>
</thead>
<tbody>
<tr>
<td>E/D Criterium</td>
<td>Column Width (in)</td>
</tr>
<tr>
<td>E/D &gt; 11</td>
<td>10-3/4</td>
</tr>
<tr>
<td>E/D ≤ 11</td>
<td>8-3/4</td>
</tr>
<tr>
<td></td>
<td>10-2/4</td>
</tr>
</tbody>
</table>

Cathedral of Light – Oakland, CA

Yountville, Ca Community Center
LEED PLATINUM
QUESTIONS?

CONTACTS

- Structural Resource Group
  Chuck Young
  559-281-0034 cell
  chuck@structuralresourcegroup.com

- Thanks to APA for their support of information and slides
  www.apawood.org

- Visit Woodworks web site for case studies and additional technical support
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

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.

Stock Beam Camber

<table>
<thead>
<tr>
<th>Length</th>
<th>14’</th>
<th>16’</th>
<th>18’</th>
<th>20’</th>
<th>22’</th>
<th>24’</th>
<th>26’</th>
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</thead>
<tbody>
<tr>
<td>2000’</td>
<td>1/8”</td>
<td>1/8”</td>
<td>1/8”</td>
<td>1/4”</td>
<td>3/8”</td>
<td>3/8”</td>
<td>1/2”</td>
</tr>
<tr>
<td>3500’</td>
<td>1/8”</td>
<td>1/8”</td>
<td>1/8”</td>
<td>1/4”</td>
<td>1/4”</td>
<td>1/4”</td>
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</tr>
<tr>
<td>5000’</td>
<td>0</td>
<td>1/8”</td>
<td>1/8”</td>
<td>1/8”</td>
<td>1/8”</td>
<td>1/4”</td>
<td></td>
</tr>
</tbody>
</table>

Standard camber to be noted on structural drawings by EOR.
TYPICAL COMMERCIAL BLDG
Clear Span

OPEN WEB PIN CONNECTED TRUSS

@ 16” oc --- 44” deep

@ 24” oc --- 50” deep

12,000 ft² BUILDING

200’ Wide

ICC 2303.4.1.3 Trusses spanning 60’ or greater. Engineer to design for temporary and permanent bracing.

AT & T PARK  San Francisco
Alaska Yellow Cedar
Shipped fully assembled

Tension Lam Provisions for Fire Rated Glulam

FIGURE 2
SIMPLE SPAN UNBALANCED LAYOUT

SEE APA TECHNICAL NOTE Y245