

## 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

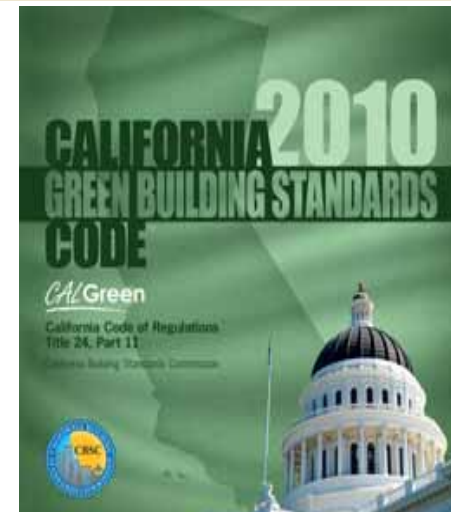


## WOOD is Environmentally Friendly Sustainable and Green

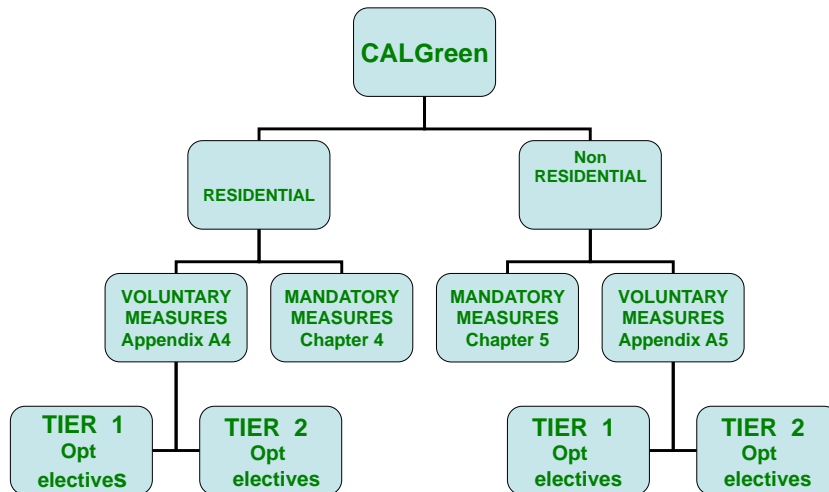
- Produced from small dimension lumber harvested from managed and sustainable forests
- Timber resource utilization optimized using a wide range of lumber grades
- Uses a wide variety of species
- Smaller sections required due to higher strengths
- Manufacturing involves low energy use process
- Uses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



## CALGreen



## 2010 CALGreen Title 24 Part 11 of CBC



## 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

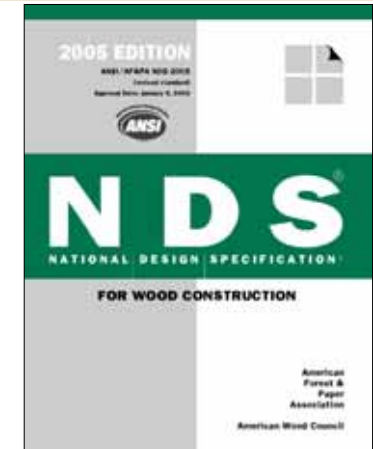
- 2009 IBC Codes
- Lumber standards are referenced in the IBC Codes
- ICC-ESR Code Reports
- 2012 IBC Codes (now published-to be adopted)



## Glulam Design: 2005 NDS

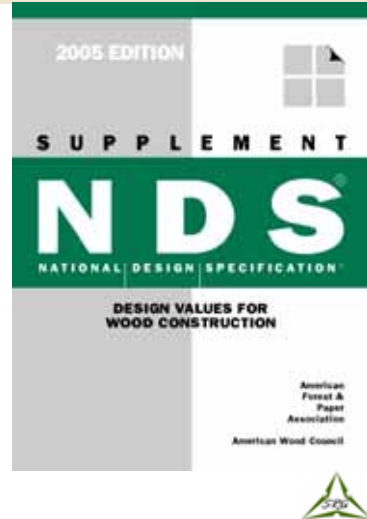
2005

- 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

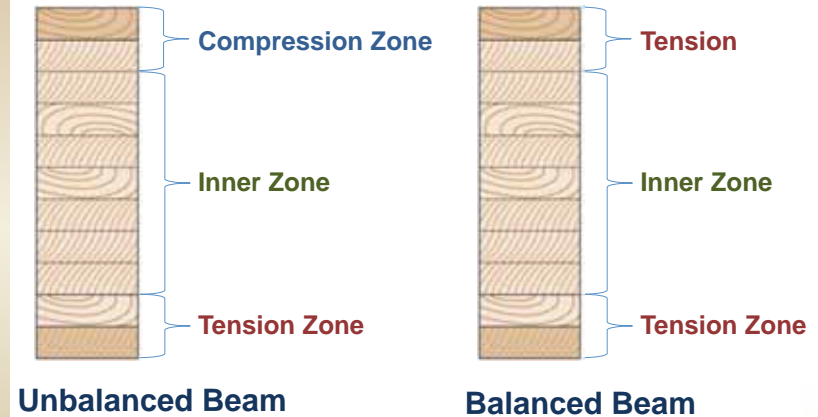


## TYPICAL GLULAM Designs per NDS

- 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



## Glulam Lay-Ups



## 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



## 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



## Hybrid Glulam vs. SCL Design Properties

Design Property	Hybrid Glulam	PSL	LVL
Fb	3000	2900	2950
MOE	$2.2 \times 10^6$	$2.0 \times 10^6$	$2.1 \times 10^6$
Fv	300	290	290

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



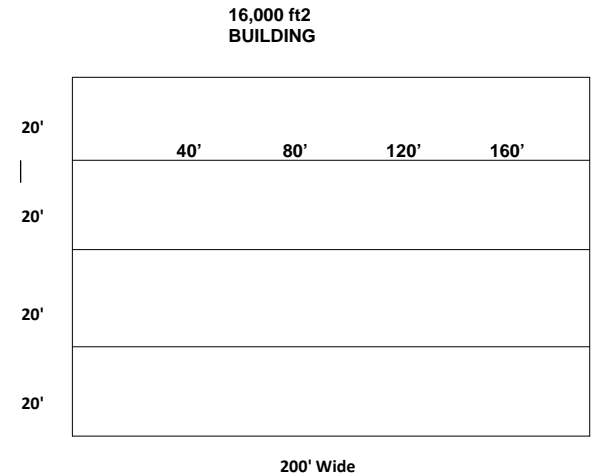
## TYPICAL COMMERCIAL BLDG

4 Bays @ 20' Columns @ 40'

**GLULAM GIRDER**  
5 x (2400 SP)

**ROOF JOISTS**  
2 x SP #1 @ 16" oc  
1 3/4 x LVL @ 24" oc  
2 1/2" x IJ @ 24" oc

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

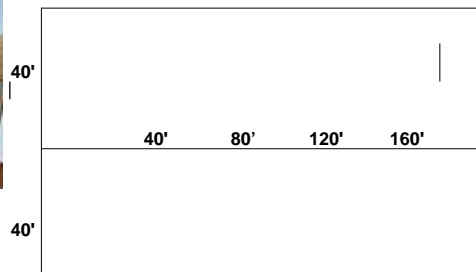


## TYPICAL COMMERCIAL BLDG

2 Bays @ 40' Columns at 40'



16,000 ft2  
BUILDING



**GLULAM GIRDERS**  
6 3/4 x (2400F SP)

**Roof Joists-ty**  
IJ 3 1/2" x @ 24" oc  
IJ 3 1/2" x @ 32" oc

200' Wide



## 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



Hybrid with I-Purlins

Panels are assembled on the ground and then lifted into place to the girders.

Less construction time, therefore lower costs.

Typical roof slopes are 1/4" to 1/2" in 12

## PANELIZED ROOF

### WOOD PANELIZED

- Most economical on roofs that are 50,000 ft<sup>2</sup> 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



I-Joists for shorter spans and Open Web Pin Connected Truss for longer spans



I-Joists used on sloped roofs



## PIN CONNECTED OPEN WEB TRUSSES

### DOUBLE TAPERED



### LONG SPAN



## PIN CONNECTED OPEN WEB TRUSSES



## 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 3/4" 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

Lam Thickness	Tangent Ends	Constant Curve
1/4"	4'-0"	4'-0"
3/8"	5'-6"	6'-4"
1/2"	6'-0"	7'-8"
5/8"	7'-6"	9'-8"
3/4"	9'-4"	12'-6"
1"	15'-0"	20'-4"
1 1/4"	20'-0"	28'-0"
1 1/2"	27'-6"	35'-6"

\*\*\*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 ft<sup>2</sup>



156' Span  
11" x 54" Glulam



## 2010 Olympic Skating Oval Richmond, B.C.

320' Span



LEED  
SILVER



## LeMay American Car Museum Tacoma, WA



4 Story  
Structure



## GLULAM TRUSSES Connections are Hidden (knife plate design)



## GILROY HS

Bolted Glulam Truss



## SCHOOL LIBRARY



## Claim Jumper Restaurant Fremont, Ca.

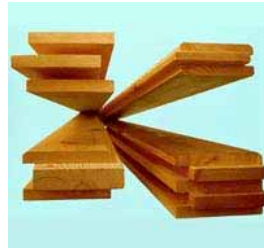


## LAMINATED DECKING



## 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)



## LAMINATED DECKING



Laminated decking can combine with exposed to view Glulams to provide the “All Wood” look .

LIBRARY



## 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

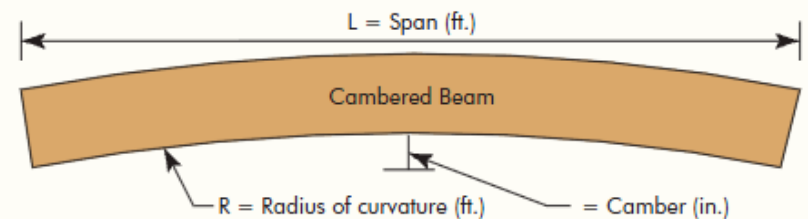


## Specifying Camber

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

FIGURE 2

### BEAM CAMBER PARAMETERS



## 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)

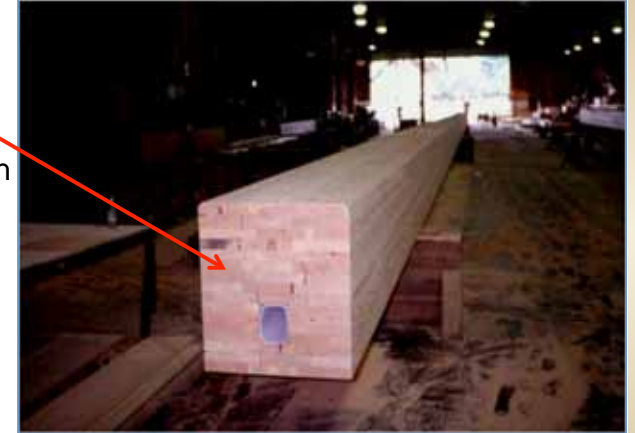


## Large Cross Sections Are Possible

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

21" x 27" x 110'



## 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 x 6
- 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

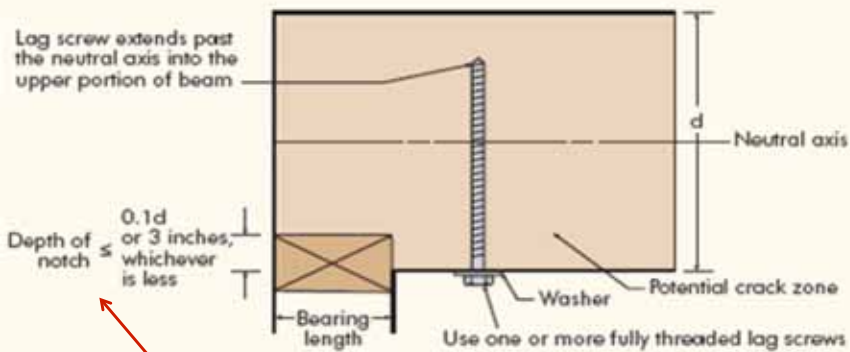


## Improper Notching



## Possible Reinforcement for an End Notch in Glulam

### A REINFORCEMENT TECHNIQUE TO MINIMIZE CRACK PROPAGATION AT END BEARING NOTCHES



Note end notch limitation for glulam



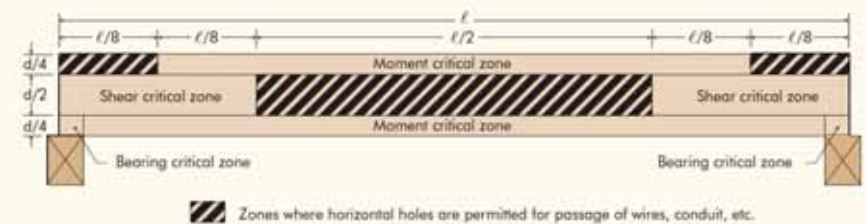
## Field Notching and Drilling of Glulam

APA Form S560

### Horizontal Hole Drilling

FIGURE 3

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



## 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
- 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

	Alaska Yellow Cedar AYC	Port Orford Cedar POC
▪ Fb Tension	2000	2200
▪ Fv Shear	265	265
▪ MOE	1,500,000	1,800,000

▪ 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**



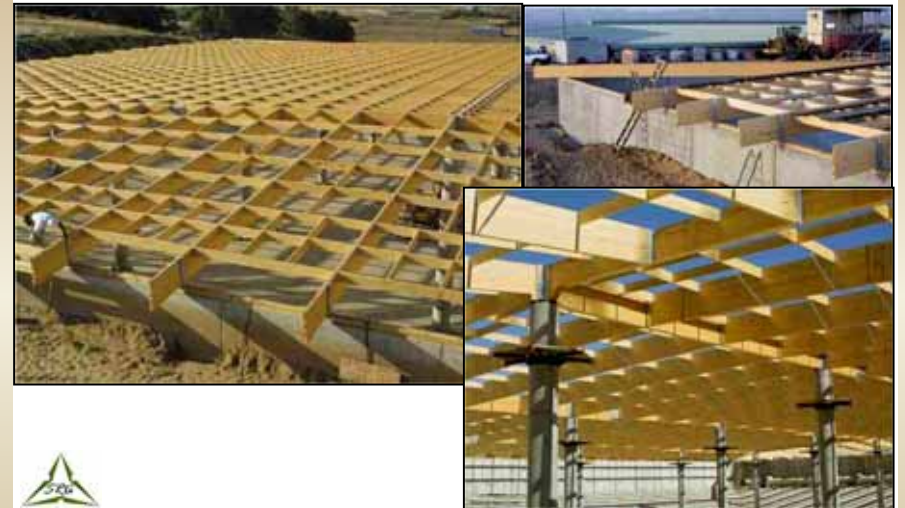
**Tasting Room St Helena, Ca**



Alaska Yellow Cedar curved Trellis and roof rafters



**Alaska Yellow Cedar (AYC)  
Santa Monica, CA Reservoir Cover**





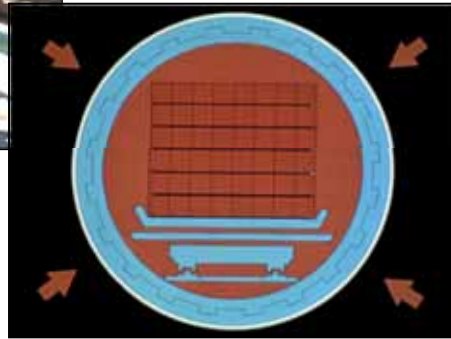
## Preservative Treatment of Glulam



Untreated glulam in pressure cylinder ready for treatment

Verify size capability with mfr.

Preservative forced into wood cells under pressure



## INCISING

### 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 2\*

TREATMENT TYPE CHARACTERISTICS

	Creosote	Penta in Oils	Penta in Light Solvents	Copper Naphthenate	Oxine Copper (Cu-8-Q)	Waterborne Preservatives
<b>Suitable Applications</b>	Saltwater or fresh water applications, wood block floors, bridges, towers and ground contact.	Fresh water, ground contact, above-ground uses, including docks, bridges, towers and beams.		Ground contact and above-ground uses. Should not be used in direct contact with water.	Above-ground use only.	Fresh water applications and ground contact. May be used indoors provided sawdust and construction debris are cleaned up and disposed by ordinary trash collection.

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

Page 21 Glulam Brochure Form No X440D

TABLE 4  
MINIMUM DEPTHS AT WHICH 6-3/4" AND 8-3/4" WIDE BEAMS CAN BE ADAPTED FOR ONE-HOUR FIRE RATINGS

Beam Width (in.)	Depth	
	3 Sides Exposed (in.)	4 Sides Exposed (in.)
6-3/4	13-1/2	27
8-3/4	7-1/2	13-1/2

TABLE 5  
MINIMUM DEPTHS AT WHICH 8-3/4" AND 10-3/4" COLUMN WIDTHS QUALIFY FOR ONE-HOUR RATING FOR GIVEN  $\ell/d$

$\ell/d$ Criteria	Column Width (in.)	Depth	
		3 Sides Exposed (in.)	4 Sides Exposed (in.)
$\ell/d > 11$	10-3/4	10-1/2	13-1/2
	8-3/4	7-1/2	12
$\ell/d \leq 11$	10-3/4	7-1/2	10-1/2

## Cathedral of Light – Oakland, CA



## Yountville, Ca Community Center LEED PLATINUM



## Airport Terminal Victoria, B.C.



## QUESTIONS? CONTACTS

- **Structural Resource Group**  
Chuck Young  
559-281-0034 cell  
[chuck@structuralresourcegroup.com](mailto:chuck@structuralresourcegroup.com)
- **Thanks to APA for their support of information and slides**  
[www.apawood.org](http://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

$$R = \frac{3L^2}{2\Delta}$$

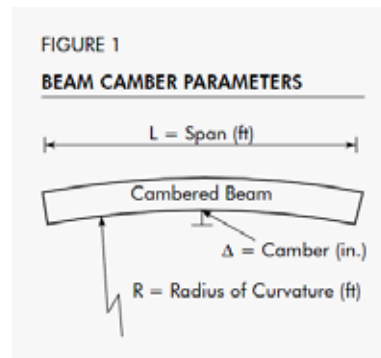
Where:

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

Length	14'	16'	18'	20'	22'	24'	26'
2000' radius	1/8"	1/4"	1/4"	1/4"	3/8"	3/8"	1/2"
3500' radius	1/8"	1/8"	1/8"	1/8"	1/4"	1/4"	1/4"
5000' radius	0	1/8"	1/8"	1/8"	1/8"	1/8"	1/4"

Standard camber to noted on structural drawings by EOR

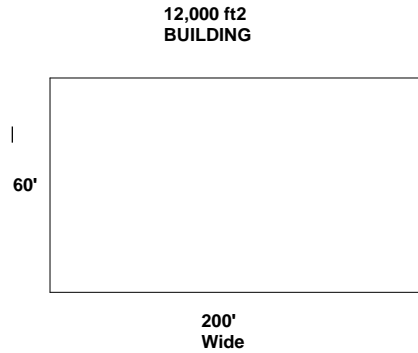
# TYPICAL COMMERCIAL BLDG

## Clear Span

### OPEN WEB PIN CONNECTED TRUSS

@ 16" oc--- 44" deep

@ 24" oc--- 50" deep



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



# AT & T PARK San Francisco

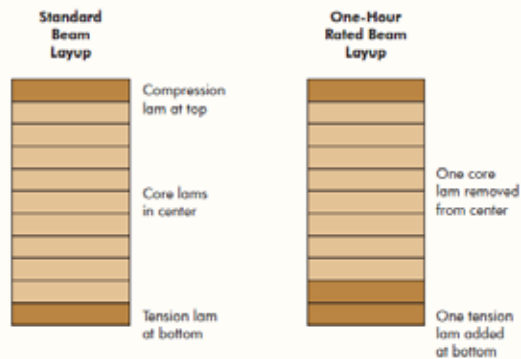
Alaska Yellow Cedar



Shipped fully assembled

# Tension Lam Provisions for Fire Rated Glulam

FIGURE 5  
SIMPLE SPAN UNBALANCED LAYUP



SEE APA TECHNICAL NOTE Y245