Beam Me Up!

Exploring the Worlds of Engineered Wood Beams

Robert A. Kuserk, PE

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

Beam Me Up!

Exploring the Worlds of Engineered Wood Beams

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Course Description

This program will present the different types of Engineered Wood Beam products available including Glulam, and Structural Composite lumber including the proper design, and specification in accordance with the International Building Code. New technologies, streamlined design options, and sustainability issues will be address, as well the constructability benefits of engineered wood beams.

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Learning Objectives

1. Understand Engineered Lumber Product Basics
2. Review the different characteristics of the Various Structural Composite Lumber and Glulam materials available to be used as beams
3. Understand the various constructability aspects of these different beam materials
4. Understand the proper design and specification of SCL and Glulam beams products

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Beam Me Up!
Exploring the Worlds of Engineered Wood Beams

Agenda

- Sustainability
- Product Basics
- New technology
- Constructability
- Proper Design & Specification

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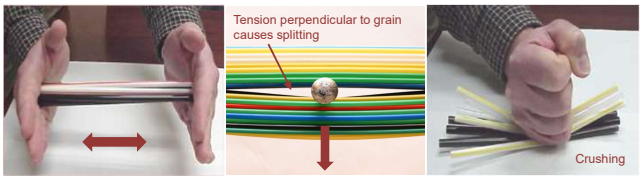
Product Basics
Wood's Strength Direction

1. Wood has different strength directions

Load parallel to grain | Loads perpendicular to grain



Stronger | Weaker

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Product Basics
What Are Engineered Wood Beam Products?

Structural Wood Beam Products

- Glulam – Glued Laminated Timber
- SCL – Structural Composite Lumber
  - Laminated Veneer Lumber (LVL), Oriented Strand Lumber (OSL), Laminated Strand Lumber (LSL), Parallel Strand Lumber (PSL)

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Product Basics
Why Engineered Wood Products?

- Predictable performance
- Uniform, consistent weight, strength and quality
- Systems are quick and easy to install
- Dimensionally stable
- Efficient use of the wood fiber in manufacturing

Product Basics

Structural Composite Lumber (SCL):

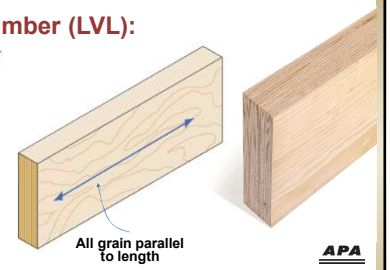
- Wood grain is primarily oriented in the same direction
- Excellent performance when face- or edge-loaded
- Consistent sizes
- Proprietary strength properties

Product Basics

Laminated Veneer Lumber (LVL):

- Veneers bonded together
- Beams, headers, rafters, scaffold planking
- Common thicknesses*: 1-1/2", 1-3/4", 3-1/2", 5-1/4"

*Thickness availability varies by manufacturer



Product Basics

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
- Common thicknesses: 3-1/2", 5-1/4", 7"
- Published on a proprietary basis

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Product Basics

Laminated Strand Lumber (LSL):

- Flaked strand length-to-thickness ratio is around 150
- Common uses: beams, headers, studs, Rim Board®, stair stringers
- Common Thicknesses: 1-1/2", 1-3/4", and 3-1/2"

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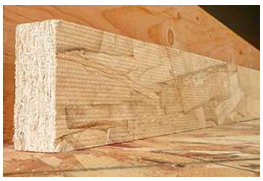
Product Basics

Oriented Strand Lumber (OSL):

- Flaked strand length-to-thickness ratio is around 75
- Common uses: beams, headers, studs, Rim Board®, millwork



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Product Basics
Glulam

- Wood laminations bonded together
- Wood grain runs parallel to the length
- Common uses: purlins, ridge beams, floor beams, headers, arches, bridges

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

Typical Laminations:
- 1-3/8" for Southern Pine
- 1-1/2" for Douglas-fir

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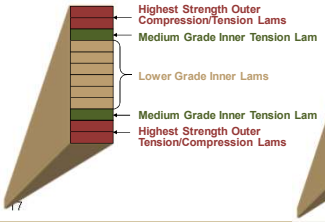
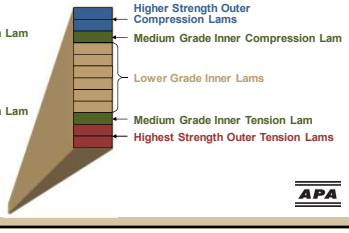
Product Basics
Glulam Beam Layups

Balanced Layup



Unbalanced Layup



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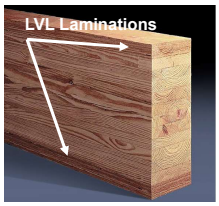
High Strength Glulam Beams

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



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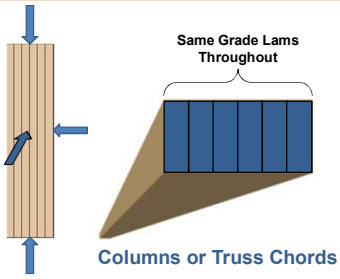
Product Basics
Glulam Column and Truss Chord Layups



Columns or Truss Chords

Glulam Product Basics

Appearance Classifications (APA Form Y110)

- **Framing** – Intended for concealed applications and is typically available in 3-1/2" and 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

Glulam Product Basics
Versatility of Shapes and Spans

Glulam Product Basics
Spans of 100 feet or greater

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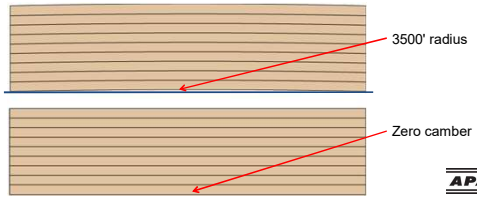
Glulam Product Basics

Stock Beams – Camber is not an issue

Camber in stock beams is usually zero or based on a 3500' or 5000' radius where a 20' beam has a curvature of 1/8" or less



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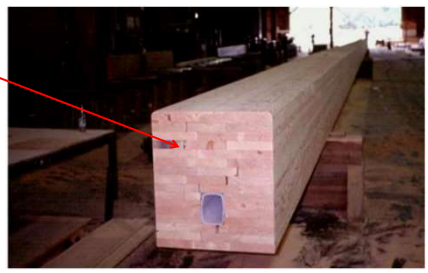
Glulam Product Basics
Large Cross Sections Are Possible

Note multiple pieces positioned side by side



Product Basics

Beams and Headers

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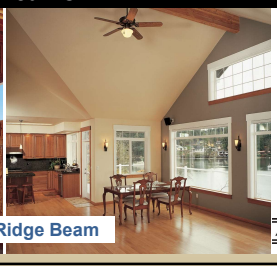
Product Basics

Roof Beams



Exposed Ridge Beam

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Product Basics

Continuous Span Floor Beams

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Product Basics

Beams and Headers

Garage Door Header/Exposed Floor Beam

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Product Basics

Columns

Glulam and LVL Columns for Floor Supports

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Product Basics

I-Joist Compatible Beams and Headers

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Product Basics

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New Technology

Cross Laminated Timber (CLT)

- Application: long span walls, floors, roof panels
- Typical Sizing: 2-10' wide, ≤ 60' lengths, ≤ 20" thicknesses
- Publications: 2015 IBC, 2015 NDS, ANSI/APA PRG 320-2019

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New Technology

Cross Laminated Timber (CLT)

- Typically board layers stacked in alternating directions
- Bonded with structural adhesives
- Pressed to form a solid, straight, rectangular panel
- May be sanded or prefinished
- Precut window and door openings

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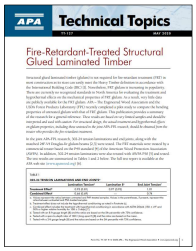
New Technology

Fire-Retardant-Treated (FRT) Structural Glued Laminated Timber

- APA Technical Topic TT-127
- Joint pilot study
  - APA – The Engineered Wood Association
  - USDA Forest Products Laboratory
- Comparison of the bending properties of untreated glulam and FRT glulam
- Use in Type III and Type IV construction
- Research in progress for FRT LVL


APA Technical Topics

Fire-Retardant-Treated Structural Glued Laminated Timber

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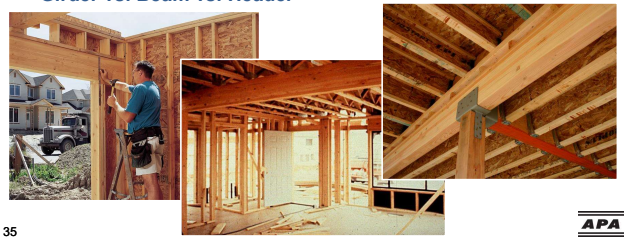
Constructability

- Girder vs. Beam vs. Header



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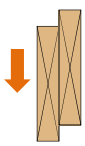
Constructability

- Ease of installation
- Connect built-up members
- Nails, screws, bolts
- Side or uniform loading



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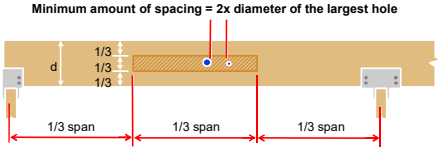
Constructability

Field notching and drilling LVL (APA Form G535)

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



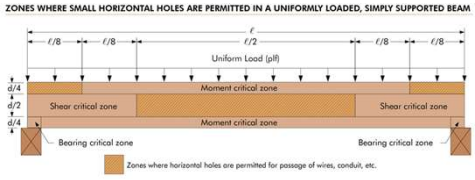
Zone where holes are permitted for passage of wires, conduits, etc.

No holes greater than 2" in diameter. No more than 3 holes per span.

Notching and Drilling

Hole Drilling

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

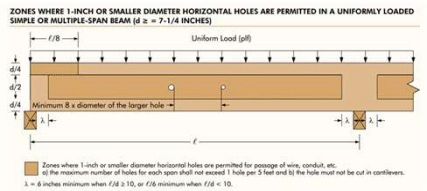


 ****APA Technical Note: Field Notching and Drilling of Glued Laminated Timber Beams*, Form S560**

Notching and Drilling

Hole Drilling

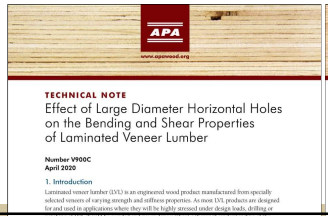
ZONES WHERE 1-INCH OR SMALLER DIAMETER HORIZONTAL HOLES ARE PERMITTED IN A UNIFORMLY LOADED SIMPLE OR MULTIPLE-SPAN BEAM (d ≥ = 7-1/4 INCHES)



 ****APA Technical Note: Field Notching and Drilling of Glued Laminated Timber Beams*, Form S560**

Constructability

Large Diameter Holes in LVL and Glulam Beams (Forms V900, V700)



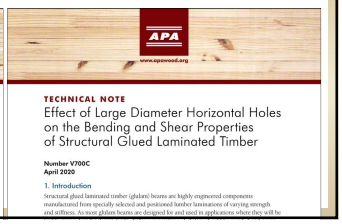
TECHNICAL NOTE

Effect of Large Diameter Horizontal Holes on the Bending and Shear Properties of Laminated Veneer Lumber

Number V900C
April 2020

1. Introduction

Laminated veneer lumber (LVL) is an engineered wood product manufactured from specially selected veneers of varying strength and stiffness properties. As most LVL products are designed for and used in applications where they will be highly stressed under design loads, drilling or



TECHNICAL NOTE

Effect of Large Diameter Horizontal Holes on the Bending and Shear Properties of Structural Glued Laminated Timber

Number V700C
April 2020

1. Introduction

Structural glued laminated timber (glulam) beams are highly engineered components manufactured from specially selected and positioned lumber laminations of varying strength and stiffness. As most glulam beams are designed for and used in applications where they will be

Constructability
Effects of Vertical Holes

Effects of Drilling

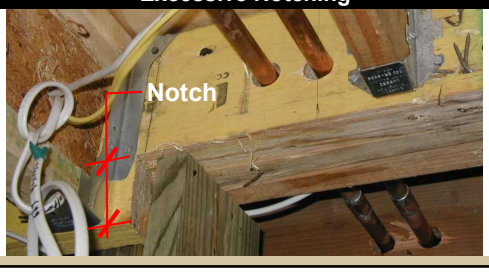
Strength reduction
= 1.5 x hole diameter/beam width

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

Constructability

Excessive Notching



SCL
Overview/APA Recommendations

Excessive Notching

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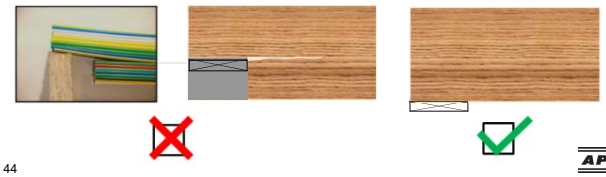
Constructability

Problem

Tension perpendicular to grain stresses induced

Solution

Provide full end grain bearing



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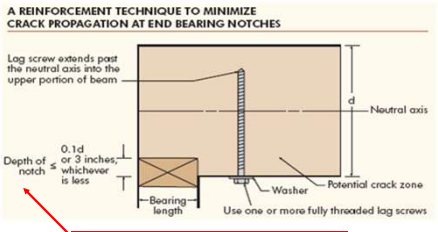
Constructability



Note end notch limitation for glulam

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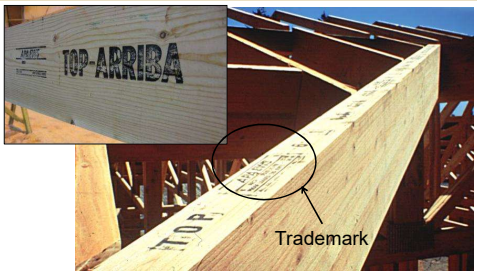
Constructability



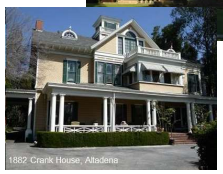
Constructability

Constructability

Strategies for durable construction

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

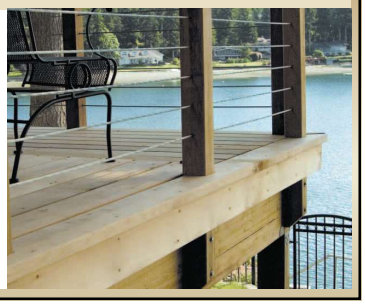

1909 Blacker House, Pasadena
Photo courtesy of LA Magazine


1882 Crank House, Altadena

Constructability

Exposed Conditions

- Naturally durable wood species
- Preservative treated



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Constructability
Treated Glulam and SCL

- Building code requires treated or naturally durable wood under these conditions:
  - Contact with ground or water
  - Contact with concrete
  - Within 12" (beams) and 16" (joists) of ground

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Constructability
Treated Glulam and SCL

- Building code requires treated or naturally durable wood under these conditions:
  - Floor framing in termite zones (or other means of protection)
  - When used below Design Flood Elevation
  - When in-service drying isn't readily available and over 19%

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Constructability
Treated Glulam and SCL

- UC1 Interior/Dry
- UC2 Interior/Damp
- UC3 Above Ground Exterior
  - UC3A Above Ground Protected
  - UC3B Above Ground Exposed
- UC4 Ground Contact
  - UC4A Ground Contact General Use
  - UC4B Ground Contact Heavy
  - UC4C Ground Extreme Duty

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Constructability
Treated Glulam and SCL

- UC2 Interior/Damp
  - Wood products not in contact with the ground but may be subject to dampness.
  - Examples:
    - Interior beams
    - Timbers
    - Flooring
    - Framing
    - Millwork
    - Sill plates

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Constructability
Treated Glulam and SCL

- UC3 Above Ground Exterior
  - UC3A Above Ground Protected
  - UC3B Above Ground Exposed
- UC4 Ground Contact
  - UC4A Ground Contact General Use
  - UC4B Ground Contact Heavy
  - UC4C Ground Extreme Duty
- Additional Information
  - *Technical Note: Preservative Treatment of Glued Laminated Timber*, Form S580

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Constructability
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

Constructability

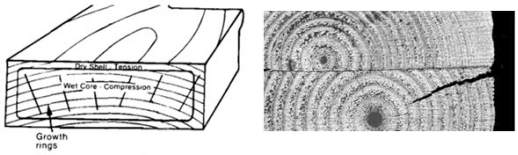
- Alaskan Yellow Cedar (AYC)
- Santa Maria, California, Reservoir Cover

Constructability
Effects of Moisture

- Seasoning checking
- Is it of structural concern?

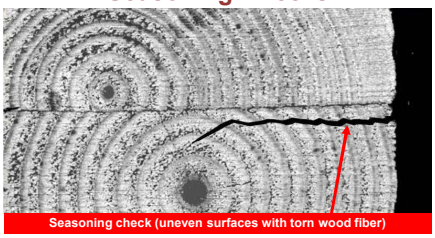
Wood Properties

Seasoning Checks



Wood Properties

Seasoning Checks



Seasoning check (uneven surfaces with torn wood fiber)

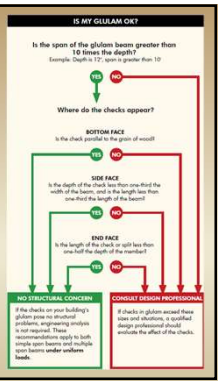
Constructability
Checking vs. Delamination

- Checking is a natural phenomenon associated with natural drying of the glulam
- Delamination is a deterioration of the glue bond when exposed to moisture
- The introduction of wet-use (durable) adhesives in the mid 1940's virtually eliminated delamination in the U.S.
- This is assured by requiring adhesives to meet D2559 and by conducting daily quality control checks using a cyclic delamination test

Wood Properties

Checking Evaluation

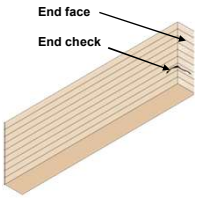
- Guidelines established for what size checks are okay without an engineering analysis
- Published in *Owner's Guide to Understanding Checks in Glued Laminated Timber*, APA Form F450

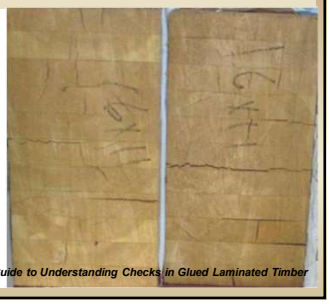


61 *See APA Technical Note: Evaluation of Check Size in Glued Laminated Timber Beams*, Form R475

Wood Properties

Seasoning Checks

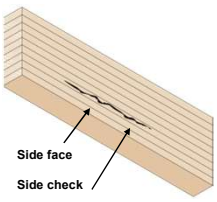




62 * Form F450, *Owner's Guide to Understanding Checks in Glued Laminated Timber*

Wood Properties

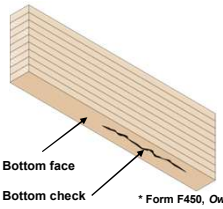
Seasoning Checks



63 * Form F450, *Owner's Guide to Understanding Checks in Glued Laminated Timber*

Wood Properties

Seasoning Checks



* Form F450, *Owner's Guide to Understanding Checks in Glued Laminated Timber*

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Proper Design & Specification

Basic Beam Design Concepts

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

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Proper Design & Specification

Basic Beam Design Concepts

- Proprietary
  - Structural Composite Lumber
    - LVL, LSL, OSL, PSL
- Non-Proprietary
  - Glulam Beams
    - 24F – V4/DF, 30F – E2/SP
- Dimension Lumber
  - 2x4, 4x6, 8x8

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Proper Design & Specification

Type of Member

Stiffness Ranges	LVL	LSL	PSL	Glulam	Select Structural
Low	2250/1.3 2250/1.5	1700/1.3 1750/1.35 2200/1.5 2325/1.55 2360/1.55	N/A	2000/1.6	SPF 1250/1.1 HF 1400/1.6
Mid	2400/1.7 2600/1.9 2650/1.7 2650/1.9	2400/1.6 2600/1.7	N/A	2400/1.8	DF-Larch 1350/1.9 SP Dense 1950/1.9
High	2800/2.0 2900/2.0 2950/2.0 3100/2.0	N/A	2900/2.0	3000/2.1	N/A

Proper Design & Specification
Glulam

Glulam Beam Combination Symbols

1. Allowable Design Stress
2. Appearance Classification
3. Grading = Visual (V) or Mechanical (E)
4. Assigned combination number of lumber used to assign the design stresses
   - Shear, Modulus of Elasticity, etc.
5. Wood Species: Commonly DF or SP

Common Beam Combinations:

- 24F-V4/DF – F_b=2400, Framing Class, Visual Grade, Combination #4, Doug Fir
- 30F-E2/SP – F_b=3000, Framing Class, Mechanical Grade, Combination #2, Southern Pine

Q: What is important to specify from above?

A: Allowable Design Stress

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Proper Design & Specification
Glulam

Simplify Design

- NDS provides > 8 stress classes
- Readily available products: 24F-1.8E and 30F-2.1E

TABLE 3

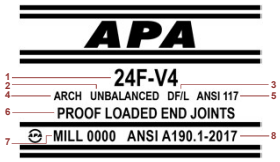
STRESS CLASSES

Stress Class	F_{bx}^{+} (psi)	$F_{bx}^{-(1)}$ (psi)	$F_{c\perp}$ (psi)	$F_{vx}^{(3)}$ (psi)	E_x (10^6 psi)
16F-1.3E	1600	925	315	195	1.3
20F-1.5E	2000	1100	425	210	1.5[5]
24F-1.7E	2400	1450	500	210	1.7
24F-1.8E	2400	1450[2]	650	265[4]	1.8
26F-1.8E	2600	1950	650	265[4]	1.9
28F-1.8E	2800	2300	740	300	2.1[6]
30F-2.1E SP[7]	3000	2400	740	300	2.1[6]
30F-2.1E LVL[8]	3000	3000	650[9]	300	2.1

APA

Specifying

Glulam Trademark

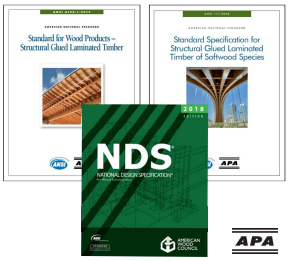


1. Combination symbol
2. Unbalanced layup
3. The species or species group of lumber used
4. Designation of appearance classification
5. Applicable design and manufacturing specification
6. Indicates the member has the required laminations proof loaded
7. Mill number
8. Identification of *ANSI A190.1, Standard for Wood Products – Structural Glued Laminated Timber.*

Proper Design & Specification
Glulam

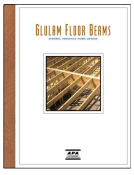
The *National Design Specification (NDS)* Section 5 provides direction for design of Structural Glued Laminated Timber.

Design values are produced in ANSI A190.1, published in ANSI 117 and included in the *NDS* supplement.



Proper Design & Specification
Glulam

APA or Manufacturer's Literature



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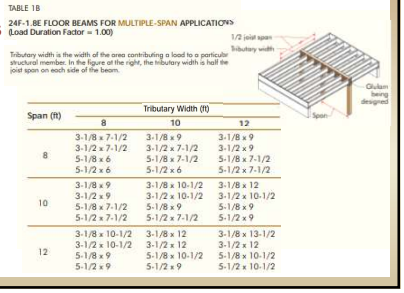

TABLE 1B

24F-1.8E FLOOR BEAMS FOR MULTIPLE-SPAN APPLICATIONS
(Load Duration Factor = 1.00)

Tributary width is the width of the area contributing a load to a particular structural member. In the figure at the right, the tributary width is half the joist span on each side of the beam.

1/2 joist span
Tributary width
Span
Glulam being designed

Span (ft)	Tributary Width (ft) 8	10	12
8	3-1/8 x 7-1/2 3-1/2 x 7-1/2 5-1/8 x 6 5-1/2 x 6	3-1/8 x 9 3-1/2 x 7-1/2 5-1/8 x 7-1/2 5-1/2 x 6	3-1/8 x 9 3-1/2 x 9 5-1/8 x 7-1/2 5-1/2 x 7-1/2
10	3-1/8 x 9 3-1/2 x 9 5-1/8 x 7-1/2 5-1/2 x 7-1/2	3-1/8 x 10-1/2 3-1/2 x 10-1/2 5-1/8 x 9 5-1/2 x 7-1/2	3-1/8 x 12 3-1/2 x 10-1/2 5-1/8 x 9 5-1/2 x 9
12	3-1/8 x 10-1/2 3-1/2 x 10-1/2 5-1/8 x 9 5-1/2 x 9	3-1/8 x 12 3-1/2 x 12 5-1/8 x 10-1/2 5-1/2 x 9	3-1/8 x 13-1/2 3-1/2 x 12 5-1/8 x 10-1/2 5-1/2 x 10-1/2

Proper Design & Specification
Glulam

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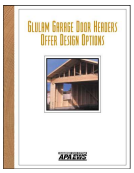
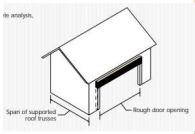


APA Form C410

TABLE 2

APA EWS 24F-1.8E GRADE, GLULAM GARAGE DOOR HEADERS FOR SINGLE-STORY APPLICATIONS
Rough Door Opening = 16 ft 3 in. (Beam depths based on 1-1/2" laminations.)

	Span of supported roof trusses (ft)	
	22	24
Non-Snow Load 15 psf Dead 20 psf Live	3-1/8 x 12 3-1/2 x 12 5-1/8 x 10-1/2 5-1/2 x 10-1/2	3-1/8 x 12 3-1/2 x 12 5-1/8 x 10-1/2 5-1/2 x 10-1/2
Snow Load 15 psf Dead 25 psf Snow	3-1/8 x 13-1/2 3-1/2 x 12 5-1/8 x 10-1/2 5-1/2 x 10-1/2	3-1/8 x 13-1/2 3-1/2 x 13-1/2 5-1/8 x 12 5-1/2 x 10-1/2
Snow Load 15 psf Dead 30 psf Snow	3-1/8 x 13-1/2 3-1/2 x 13-1/2 5-1/8 x 12 5-1/2 x 10-1/2	3-1/8 x 15 3-1/2 x 13-1/2 5-1/8 x 12 5-1/2 x 12



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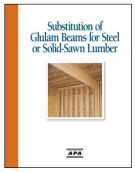
Proper Design & Specification
Glulam

APA or Manufacturer's Literature



APA Form S570

24F-1.8E GLULAM EQUIVALENT TO STEEL ROOF BEAMS FOR MULTIPLE-SPAN APPLICATIONS – NON-SNOW LOADS
Load Duration Factor for Glulam = 1.25

Span (ft)	Glulam Species	W6x9	W8x10
		Glulam Equivalent (in.)	
10	Douglas-fir	3-1/8 x 10-1/2 5-1/8 x 7-1/2 6-3/4 x 7-1/2	3-1/8 x 12 5-1/8 x 9 6-3/4 x 7-1/2
	Southern Pine	3 x 9-5/8 5 x 8-1/4 6-3/4 x 6-7/8	3 x 12-3/8 5 x 9-5/8 6-3/4 x 8-1/4
12	Douglas-fir	3-1/8 x 10-1/2 5-1/8 x 7-1/2 6-3/4 x 7-1/2	3-1/8 x 12 5-1/8 x 9 6-3/4 x 7-1/2
	Southern Pine	3 x 9-5/8 5 x 8-1/4 6-3/4 x 6-7/8	3 x 12-3/8 5 x 9-5/8 6-3/4 x 8-1/4

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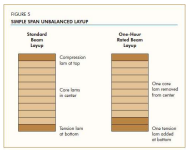
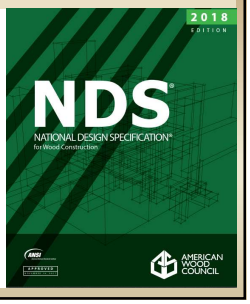
Proper Design & Specification
Fire Rating for Glulam

- **2018 NDS**
  - **Section 16.2 Design Procedure for Exposed Wood Members**
    - **Provides procedure for designing glulam member for fire resistance**





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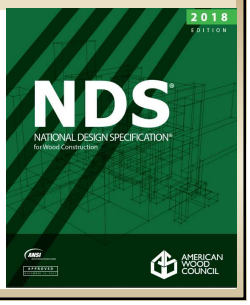
Proper Design & Specification
SCL

- Similar to Glued Laminated Timber
- *National Design Specification* Section 8 provides direction for design of Structural Composite Lumber
- Use design values as provided by the SCL manufacturer



Proper Design & Specification
SCL

Apparent or True (Shear-Free) E

$$Total\ deflection\ (\delta_T) = Bending\ deflection\ (\delta_b) + Shear\ deflection\ (\delta_s)$$

$$\delta_T = \frac{5wl^4}{384E_{True}I} + \frac{wl^2}{K} \qquad Equation\ 1$$

vs

$$\delta_T = \frac{5wl^4}{384E_{apparent}I} \qquad Equation\ 2$$

Proper Design & Specification
SCL

Apparent or True (Shear-Free) E

Table 1. Equivalent $E_{apparent}$ and $E_{shear\text{-}free}$ [a]

$E_{apparent}$ (10^6 psi) [b]	Equivalent $E_{shear\text{-}free}$ (10^6 psi)
1.5	1.6
1.6	1.7
1.7	1.8
1.8	1.9
1.9	2.0
2.0	2.1
2.1	2.2

a) Refer to APA Technical Topics TT-082 for detailed information
b) As published for glulam

$$E_{apparent} \approx 0.95^{*}\ x\ E_{true}$$

* SCL needs to be qualified to use 0.95 factor

Proper Design & Specification
SCL

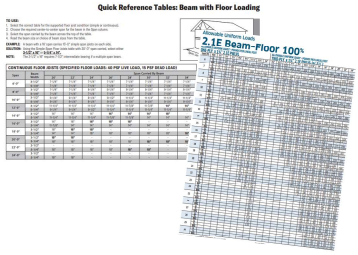
Structural Composite Lumber (SCL) are proprietary products

- Often specified by manufacturer name, E value, and F_b
- 7 Manufacturers
  - One manufacturer provides different values for east and west coasts
- All publish 2.0E
  - True E published by 4 manufacturers
  - Apparent E by 3 manufacturers
- F_b range: 2600 psi – 3300 psi
- F_v range: 285 psi – 290 psi
- F_c(perp) range: 575 psi – 850 psi
- F_c(para) range: 2200 psi – 3200 psi

Proper Design & Specification
SCL

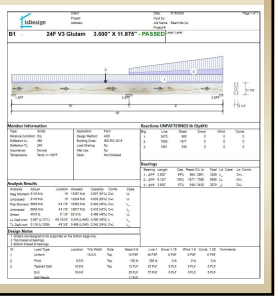
Design Tools

- Manufacturer's Literature
  - PLF Tables
    - Span, total load, live load, minimum required bearing, beam width and depth, load duration factor



Proper Design & Specification
Glulam and SCL

- Manufacturer Software
- Third Party Software



Proper Design & Specification

3rd Party Software Design Tools

- Enercalc
  http://www.enercalc.com/
- RAM Elements
  http://www.bentley.com/en-US/Products/RAM+Elements/
- RISA Technologies (2D, 3D, Floor)
  http://www.risa.com/products.html

Proper Design & Specification

Lead Time

- Many retailers stock common SCL and glulam beams
- If not, local distribution yards also stock common sizes
- Custom products like curved glulam arches are special order and require additional lead times

Proper Design & Specification

Materials Selection

- Soft costs
  - Don't overdesign
  - Consider constructability
    - Working with wood vs. steel
    - Built up member vs. solid
  - Specify what is readily available
  - Save on review time for potential substitutions

Beam Me Up!
Exploring the Worlds of Engineered Wood Beams

Agenda

- Sustainability
- Product Basics
- New technology
- Constructability
- Proper Design & Specification

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Beam Me Up!
Exploring the Worlds of Engineered Wood Beams

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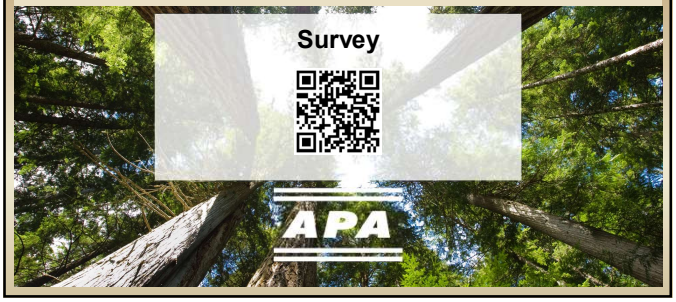

Survey

APA

APA Update Newsletter
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April 2020

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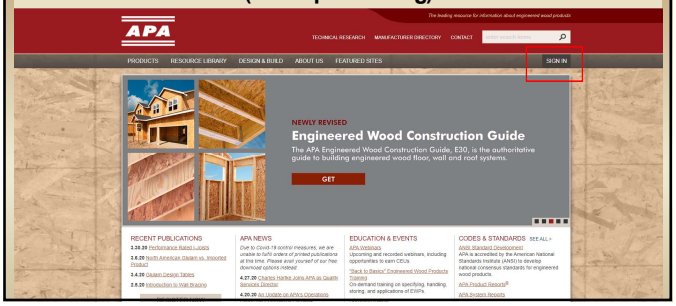

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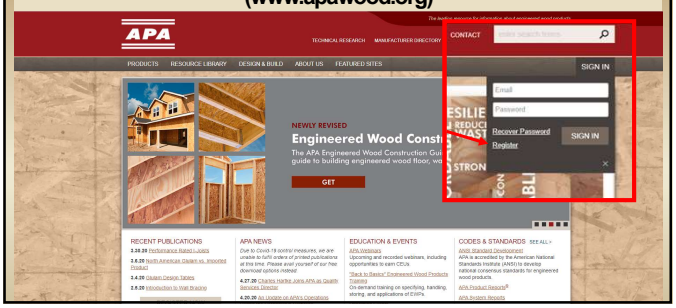

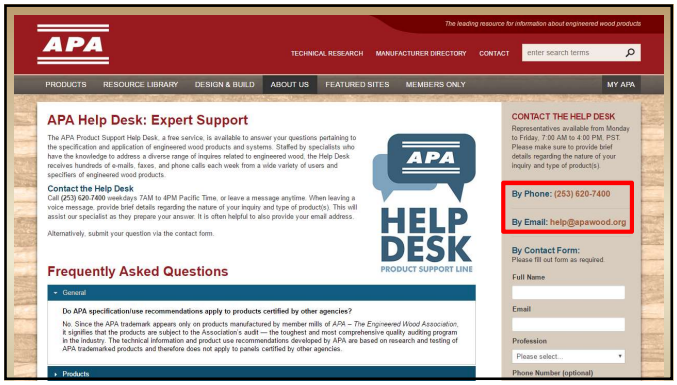

Field Services Division Territories

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Thank you!