Glulam Design Specification

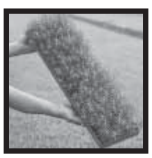
APA

WOOD
The Natural Choice

Engineered wood products are a good choice for the environment. They are manufactured for years of trouble-free, dependable use. They help reduce waste by decreasing disposal costs and product damage. Wood is a renewable, recyclable, biodegradable resource that is easily manufactured into a variety of viable products.

A few facts about wood.

- ***We're growing more wood every day.*** Forests fully cover one-third of the United States' and one-half of Canada's land mass. American landowners plant more than two billion trees every year. In addition, millions of trees seed naturally. The forest products industry, which comprises about 15 percent of forestland ownership, is responsible for 41 percent of replanted forest acreage. That works out to more than one billion trees a year, or about three million trees planted every day. This high rate of replanting accounts for the fact that each year, 27 percent more timber is grown than is harvested. Canada's replanting record shows a fourfold increase in the number of trees planted between 1975 and 1990.



- ***Life Cycle Assessment shows wood is the greenest building product.*** A 2004 Consortium for Research on Renewable Industrial Materials (CORRIM) study gave scientific validation to the strength of wood as a green building product. In examining building products' life cycles – from extraction of the raw material to demolition of the building at the end of its long lifespan – CORRIM found that wood was better for the environment than steel or concrete in terms of embodied energy, global warming potential, air emissions, water emissions and solid waste production. For the complete details of the report, visit www.CORRIM.org.

- ***Manufacturing wood is energy efficient.*** Wood products made up 47 percent of all industrial raw materials manufactured in the United States, yet consumed only 4 percent of the energy needed to manufacture all industrial raw materials, according to a 1987 study.

Material	Percent of Production	Percent of Energy Use
Wood	47	4
Steel	23	48
Aluminum	2	8

- ***Good news for a healthy planet.*** For every ton of wood grown, a young forest produces 1.07 tons of oxygen and absorbs 1.47 tons of carbon dioxide.

Wood: It's the natural choice for the environment, for design and for strong, lasting construction.

NOTICE:
The recommendations in this report apply only to glulam that bears the APA-EWS trademark. Only glulam bearing the APA-EWS trademark is subject to the Association's quality auditing program.

APA EWS
EWS Y117
SP
B IND
EWS 24F-V3
ANSI/AITC A190.1-07
MILL 0000

Introduction

Glued laminated timbers (glulam) are manufactured by end joining individual pieces of dimension lumber or boards together with structural adhesives to create long-length laminations. These long-length laminations are then face bonded together with adhesives to create the desired glulam shape. Through the laminating process, a variety of shapes can be created ranging from straight rectangular cross-sections to complex curved shapes with varying cross-sections. Thus, glulam is one of the most versatile of the family of glued engineered wood products and is used in applications ranging from concealed beams and headers in residential construction to soaring domed stadiums.

Glulam Layup Principles

Bending Members

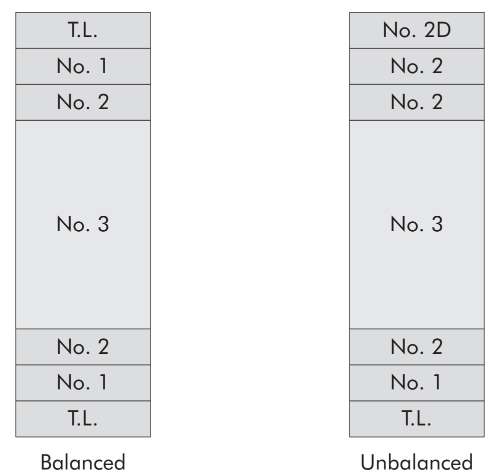
In addition to being able to produce virtually any size or shape of structural member, the laminating process also permits the manufacturer to optimize the use of the available wood fiber resource by selecting and positioning the lumber based on the stresses it will be subjected to in-service. For example, for members stressed primarily in bending, a graded layup of lumber is used throughout the depth of the beam with the highest quality laminations used in the outer zones of the beam where the bending stresses are highest. Lower quality laminations are used in zones subjected to lower bending stresses. Layup combinations for members stressed primarily in bending are provided in Table 1. These members may range in cross-section from straight rectangular beams to pitched and tapered curved beams.

As indicated in Table 1, bending members can be further divided into balanced and unbalanced layups as shown in Figure 1. Unbalanced beams are asymmetrical in their layups with the highest quality laminations, referred to as tension laminations, used only on the bottom of the member. These are intended for use in simple-span applications or short, cantilevered conditions where only the bottom of the beam is subjected to maximum tension stresses. Results of a large number of full-scale beam tests conducted or sponsored by the glued laminated timber industry over the past 30 years have shown that the quality of the laminations used in the outer tension zone controls the overall bending strength of the member.

For a balanced beam, the grade of laminations used is symmetrical throughout the depth of the member. This type of member is typically used for cantilever or continuous, multiple-span beams which may have either the top or bottom of the member stressed in tension.

FIGURE 1

BALANCED VERSUS UNBALANCED LAYUP EXAMPLE



T.L. = Tension Lamination

In addition to stamping the beam with the *APA EWS* trademark signifying that the member has been manufactured in accordance with the provisions of *ANSI/AITC Standard A190.1 for Structural Glued Laminated Timber,* unbalanced beams also have the word TOP prominently stamped on the top of the member as shown in Figure 2. This is provided as guidance to the contractor to ensure that the member is installed with the proper orientation. If members are inadvertently installed with an improper orientation, i.e., "upside down," the allowable F_b value for the compression zone stressed in tension is applicable. The controlling bending stress and the capacity of the beam in this orientation must be checked to determine if they are adequate to meet the design conditions.

Axially Loaded Members

For members stressed primarily in axial tension or axial compression, where the stresses are uniform over the cross-section of the member, single-grade lamination layups, such as those given in Table 2 are recommended since there is no benefit to using a graded layup.

Combined Stress Members

If the member is to be subjected to high bending stresses as well as axial stresses, such as occur in arches or beam-columns, a bending member combination as tabulated in Table 1 is typically the most efficient. Tapered beams or pitched and tapered curved beams are special configurations that are also specified using Table 1 bending member combinations.

FIGURE 2

TOP IDENTIFICATION FOR AN UNBALANCED LAYUP

Development of Allowable Stresses

The laminating process used in the manufacture of glulam results in a random dispersal of naturally occurring lumber strength-reducing characteristics throughout the glulam member. This results in mechanical properties for glulam having higher values and lower variability as compared to sawn lumber products. For example, the coefficient of variation for the modulus of elasticity (E) of glulam is published as 10% which is equal to or lower than any other wood product.

Since glulam is manufactured with kiln-dried lumber having a maximum moisture content at the time of fabrication of 16%, this results in higher allowable design stresses as compared to dry (moisture content of 19% or less) or green lumber.

The use of kiln-dried laminating lumber also means that the moisture content of a glulam is relatively uniform throughout the member unlike green sawn timbers which may have widely varying moisture contents within a given member. This use of uniformly dry lumber gives glulam excellent dimensional stability. Thus, a glulam member will not undergo the dimensional changes normally associated with larger solid-sawn green timbers, and will remain straight and true in cross-section. A "dry" glulam is also less susceptible to the checking and splitting which is often associated with "green" timbers as they undergo in-service drying.

Allowable stresses for glulam are determined in accordance with the principles of ASTM D 3737, *Standard Practice for Establishing Stresses for Structural Glued Laminated Timber.* A key strength consideration accounted for in this standard is the random dispersal of strength reducing characteristics previously discussed. By randomly distributing the strength-reducing characteristics found in dimension lumber, the effect of any given defect is greatly minimized. Other strength considerations accounted for in this standard are those associated with using dry lumber and characteristics unique to the glued laminated timber manufacturing process such as being able to vary the grade of lumber throughout the depth of the member.

Many different species of lumber can be used to produce glued laminated timber. In addition, a wide range of grades of both visually graded and mechanically graded lumber can be used in the manufacture of glulam. This wide variety of available species and grades results in numerous options for the producers to combine species and grades to create a wide array of glulam layup combinations.

For some layup combinations, the use of different species within the same member is permitted. This is done when it is desirable to use a lower strength species in the core of a glued laminated timber and a higher strength species in the outer zones. However, the specifier is cautioned that when mixed species are used, they may result in an appearance that may not be suitable for an exposed application as the species will typically have different coloration and visual characteristics.

Published Design Stresses for *APA EWS* Trademarked Glulam

Table 1 provides the allowable design stresses for layup combinations primarily intended for use as bending members as commonly produced by APA members. Table 1 tabulates the layup combinations based on species, whether the combination is for a balanced or unbalanced layup and whether the lumber used is visually or mechanically graded as signified by a V (visual) or E (E-rated or mechanically graded).

Table 2 provides similar stresses for members primarily intended for use in axially loaded applications. Other combinations as tabulated in ICC Evaluation Service Report ESR-1940 may also be specified but availability should be verified with the supplier.

Published Grade Requirements for *APA EWS* Trademarked Glulams

Tables S-1 and S-2 of *Glulam Layup Combinations* (form Y117-SUP) provide the grade requirements for the laminations used in manufacturing the beams listed in Tables 1 and 2, respectively.

In addition to the layup combinations tabulated in Tables 1 and 2, APA periodically evaluates the use of new layup combinations and stresses based on the use of a computer simulation model identified as GAP. The GAP simulation model is based on the provisions of ASTM D 3737 and has been verified by extensive laboratory testing of full-size glulam beams at the APA Research Center in Tacoma, Wash. and at other laboratories throughout North America. As these new special layups are evaluated and approved by APA, they are added to ICC Evaluation Service Report ESR-1940 as part of the periodic reexamination process. ESR-1940 is subject to periodic re-examination and revisions.

Specifying Glulam

Common Layup Combinations

While the use of a wide variety of species and grades results in optimizing the use of the lumber resource by the manufacturer, the multiplicity of possible layup combinations can be confusing.

To simplify the selection process, only the layup combinations typically available from APA members have been tabulated in the tables in this specification.

By selecting one of these combinations the specifier will be identifying glulam products that have sufficiently high design properties to satisfy virtually any design situation and which are typically available in most major market areas in the U.S. Other layup combinations are available on a regional basis and the designer should verify availability of any combination for a given geographic area by contacting local suppliers or the APA glulam manufacturers (see APA Source List of Glulam Manufacturers), or go to the APA web site for a link to APA member web sites.

Specific End-Use Layup Combinations

It is important to note that certain layup combinations in Tables 1 and 2 have been developed for specific end-use applications. Several examples of these are as follows:

The **20F-V12** (unbalanced) and **20F-V13** (balanced) combinations use Alaska Yellow Cedar (AYC). These are intended for applications exposed to the elements or high humidity conditions where the use of the heartwood of a naturally durable species is preferred instead of using a pressure-preservative-treated glulam.

Another option is to specify Port Orford Cedar (POC) combinations **22F-V/POC 1** or **22F-V/POC 2** which exhibit characteristics similar to AYC.

The **24F-1.8E** layup is a general-purpose layup combination intended primarily for stock beams used in residential construction. This layup permits the use of a variety of species and is suitable for virtually any simple span beam application.

The **26F-E/DF1, 26F-E/DF1M1, 30F-E2, 30F-E2M2,** and **30F-E2M3** combinations were developed primarily for use in combination with prefabricated wood I-joists and are often referred to as “I-joist depth-compatible” (IJC) layups.

TABLE 1

DESIGN VALUES FOR STRUCTURAL GLUED-LAMINATED SOFTWOOD TIMBER STRESSED PRIMARILY IN BENDING[1,2,3]

Combination Symbol	Species[4] Outer/Core	Balanced/ Unbalanced[5]	Bending About X-X Axis (Loaded Perpendicular to Wide Faces of Laminations): Extreme Fiber in Bending[6]: Tension Zone Stressed in Tension F_{bx}^{+} (psi)	Extreme Fiber in Bending[6]: Compression Zone Stressed in Tension F_{bx}^{-} (psi)	Compression Perpendicular to Grain: Tension Face $F_{c\perp x}$ (psi)	Compression Perpendicular to Grain: Compression Face $F_{c\perp x}$ (psi)	Shear Parallel to Grain (Horizontal)[7] F_{vx} (psi)	Modulus of Elasticity[8] E_x (10^6 psi)
1	2	3	4	5	6	7	8	9
Western Species								
EWS 20F-E/ES1[11]	ES/ES	B	2000	2000	560	560	200	1.8
EWS 20F-E/SPF1[12]	SPF/SPF	B	2000	2000	425	425	215	1.5
EWS 20F-E8M1	ES/ES	B	2000	2000	450	450	200	1.5
EWS 20F-V12	AYC/AYC	U	2000	1400	560	560	265	1.5
EWS 20F-V13	AYC/AYC	B	2000	2000	560	560	265	1.5
EWS 22F-V/POC1	POC/POC	B	2200	2200	560	560	265	1.8
EWS 22F-V/POC2	POC/POC	U	2200	1600	560	560	265	1.8
EWS 24F-E/ES1	ES/ES	U	2400	1700	560	560	200	1.7
EWS 24F-E/ES1M1	ES/ES	B	2400	2400	560	560	200	1.8
EWS 24F-V4	DF/DF	U	2400	1850	650	650	265	1.8
EWS 24F-V4M2[13]	DF/DF	U	2400	1850	650	650	220	1.8
EWS 24F-V8	DF/DF	B	2400	2400	650	650	265	1.8
EWS 24F-V10	DF/HF	B	2400	2400	650	650	215	1.8
EWS 26F-E/DF1[11]	DF/DF	U	2600	1950[14]	650	650	265	2.0
EWS 26F-E/DF1M1[11]	DF/DF	B	2600	2600	650	650	265	2.0
EWS 24F-1.8E Glulam Header[15]	WS,SP/ WS,SP	U	2400	1600	500	500	215	1.8
Southern Pine								
EWS 24F-V3	SP/SP	U	2400	1950	740	740	300	1.8
EWS 24F-V5	SP/SP	B	2400	2400	740	740	300	1.7
EWS 26F-V4	SP/SP	B	2600	2600	740	740	300	1.9
EWS 30F-E2	SP/SP	B	3000	3000	805	805	300	2.1[19]
EWS 30F-E2M2[16]	LVL/SP	B	3000[17]	3000[17]	650[18]	650[18]	300	2.1
EWS 30F-E2M3[16]	LVL/SP	B	3000[17]	3000[17]	650[18]	650[18]	300	2.1
Wet-use factors			0.8	0.8	0.53	0.53	0.875	0.833

Footnotes on page 8.

Bending About Y-Y Axis (Loaded Parallel to Wide Faces of Laminations)				Axially Loaded			Fasteners		
Extreme Fiber in Bending[9]	Compression Perpendicular to Grain	Shear Parallel to Grain (Horizontal)[7,10]	Modulus of Elasticity[8]	Tension Parallel to Grain	Compression Parallel to Grain	Modulus of Elasticity[8]	Specific Gravity for Dowel-Type Fastener Design		
							Top or Bottom Face	Side Face	
F_{by} (psi)	$F_{c\perp y}$ (psi)	F_{vy} (psi)	E_y (10^6 psi)	F_t (psi)	F_c (psi)	E_{axial} (10^6 psi)	SG		Combination Symbol
10	11	12	13	14	15	16	17	18	
1100	300	175	1.5	1050	1150	1.6	0.41	0.41	EWS 20F-E/ES1[11]
875	425	190	1.4	425	1100	1.4	0.42	0.42	EWS 20F-E/SPF1[12]
1400	315	175	1.4	800	1000	1.4	0.41	0.41	EWS 20F-E8M1
1250	470	230	1.4	900	1500	1.4	0.46	0.46	EWS 20F-V12
1250	470	230	1.4	925	1550	1.5	0.46	0.46	EWS 20F-V13
1500	375	230	1.6	1150	1950	1.6	0.45	0.45	EWS 22F-V/POC1
1500	375	230	1.6	1150	1900	1.6	0.45	0.45	EWS 22F-V/POC2
1100	300	175	1.5	1050	1150	1.6	0.41	0.41	EWS 24F-E/ES1
1100	300	175	1.5	1050	1150	1.6	0.41	0.41	EWS 24F-E/ES1M1
1450	560	230	1.6	1100	1650	1.7	0.50	0.50	EWS 24F-V4
1450	560	230	1.6	1100	1650	1.7	0.50	0.50	EWS 24F-V4M2[13]
1450	560	230	1.6	1100	1650	1.7	0.50	0.50	EWS 24F-V8
1450	375	200	1.5	1100	1550	1.6	0.50	0.43	EWS 24F-V10
1850	560	230	1.8	1400	1800	1.8	0.50	0.50	EWS 26F-E/DF1[11]
1850	560	230	1.8	1400	1800	1.8	0.50	0.50	EWS 26F-E/DF1M1[11]
1300	375	200	1.5	950	1200	1.6	0.42	0.42	EWS 24F-1.8E Glulam Header[15]
1750	650	265	1.6	1150	1650	1.7	0.55	0.55	EWS 24F-V3
1750	650	265	1.5	1150	1650	1.6	0.55	0.55	EWS 24F-V5
2100	650	265	1.8	1200	1600	1.9	0.55	0.55	EWS 26F-V4
1750	650	265	1.7	1350	1750	1.7	0.55	0.55	EWS 30F-E2
1750	650	265	1.7	1350	1750	1.7	0.50	0.50	EWS 30F-E2M2[16]
1750	650	265	1.7	1350	1750	1.7	0.50	0.50	EWS 30F-E2M3[16]
0.8	0.53	0.875	0.833	0.8	0.73	0.833	See NDS	See NDS	

Footnotes to Table 1:

(1) The combinations in this table are applicable to members consisting of 4 or more laminations, unless otherwise noted, and are intended primarily for members stressed in bending due to loads applied perpendicular to the wide faces of the laminations.

(2) The tabulated design values are for dry conditions of use. For wet conditions of use, multiply the tabulated values by the factors shown at the bottom of the table.

(3) The tabulated design values are for normal duration of loading. For other durations of loading, see applicable building code.

(4) The symbols used for species are AYC = Alaska yellow cedar, DF = Douglas fir-larch, ES = Eastern spruce, HF = Hem-fir, POC = Port Orford cedar, SP = Southern pine, and SPF = Spruce-pine-fir.

(5) The unbalanced layups are intended primarily for simple-span applications and the balanced layups are intended primarily for continuous or cantilevered applications.

(6) The tabulated design values in bending, F_{bx}, are based on members 5-1/8 inches in width by 12 inches in depth by 21 feet in length. For members with larger volumes, F_{bx} shall be multiplied by a volume factor, C_v, determined in accordance with the applicable building code. The tabulated F_{bx} values require the use of special tension laminations. If these special tension laminations are omitted, the F_{bx} values shall be multiplied by 0.75 for members greater than or equal to 15 inches or by 0.85 for members less than 15 inches in depth.

(7) For non-prismatic members, notched members, members subject to impact or cyclic loading, or shear design of bending members at connections (NDS 3.4.3.3), the design value for shear (Fvx) shall be multiplied by a factor of 0.72.

(8) The tabulated E values already include a 5% shear deflection (also known as "apparent E"). For beam and column stability calculations, E_{min} shall be determined by multiplying the tabulated modulus of elasticity by 0.518.

(9) The values of F_{by} were calculated based on members 12 inches in depth (bending about Y-Y axis). For depths other than 12 inches, the F_{by} values shall be permitted to be increased by multiplying by the size factor, $(12/d)^{1/9}$, where d is the beam depth in inches. When d is less than 3 inches, use the size adjustment factor for 3 inches.

(10) Design values are for timbers with laminations made from a single piece of lumber across the width or multiple pieces that have been edge bonded. For timber manufactured from multiple-piece laminations (across width) that are not edge bonded, value shall be multiplied by 0.4 for members with 5, 7, or 9 laminations or by 0.5 for all other members. This reduction shall be cumulative with the adjustment in Footnote No. 7.

(11) The beam depth limitation is as follows – 20F-E/ES1: 15 inches or less; 26F-E/DF1 and 26F-E/DF1M1: 9-1/2, 11-7/8, 14, and 16 inches.

(12) This layup combination is limited to 1-1/2 to 3-1/2 inches in width, and 7-1/2, 9, 9-1/2, 11-7/8, and 14 inches in depth.

(13) When containing wane, this combination shall be used in dry conditions only. In this case, wet-use factors shall not be applied. Because of the wane, this combination is available only for an industrial appearance characteristic. If wane is omitted, these restrictions shall not apply. This combination is limited to 9 to 20 laminations in depth.

(14) This tabulated value is permitted to be increased to 2,200 psi for beam depths less than 16 inches.

(15) This combination shall be manufactured from either EWS 24F-V4/WS, EWS 24F-V5M1/WS, EWS 24F-V5M2/WS, EWS 24F-V5M3/WS, EWS 24F-E15M1/WS, EWS 24F-E/SPF4, or EWS 24F-V3/SP, and is intended primarily for use in header applications.

(16) The beam depth is limited to 16 inches or less for 30F-E2M2/SP, and between 7-1/4 and 30 inches for 30F-E2M3/SP. The tension lamination requirements for these layups shall not be omitted.

(17) The tabulated design values in bending, F_{bx}, shall be multiplied by a volume factor, C_v, determined in accordance with the applicable building code using 1/10 as the exponent.

(18) The allowable compressive stress perpendicular to grain of the beam shall be permitted to be increased to the published allowable compressive stress perpendicular to grain of the outermost laminated veneer lumber.

(19) For members with more than 15 laminations, $E_x = 2.0 \times 10^6$ psi.

TABLE 2

DESIGN VALUES FOR STRUCTURAL GLUED-LAMINATED SOFTWOOD TIMBER STRESSED PRIMARILY IN AXIAL TENSION OR COMPRESSION(1,2,3)

					Axially Loaded			Bending About Y-Y Axis				Bending About X-X Axis		Fasteners
								Loaded Parallel to Wide Faces of Laminations				Loaded Perpdendicular to Wide Faces of Laminations		Specific Gravity for Dowel-Type Fastener Design
					Tension Parallel to Grain	Compression Parallel to Grain		Bending			Shear Parallel to Grain	Bending	Shear Parallel to Grain	
Comb. Symbol	Species	Grade	Modulus of Elasticity E(4) 10^6 psi	Compression Perpendicular to Grain $F_{c\perp}$ psi	2 or More Lams F_t psi	4 or More Lams F_c psi	2 or 3 Lams F_c psi	4 or More Lams F_{by} psi	3 Lams F_{by} psi	2 Lams F_{by} psi	See Notes 5 and 6 F_{vy} psi	2 Lams to 15 in. Deep(7) F_{bx} psi	See Note 8 F_{vx} psi	SG
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Western Species														
EWS 1	DF	L3	1.5	560	900	1550	1200	1450	1250	1000	230	1250	265	0.50
EWS 2	DF	L2	1.6	560	1250	1950	1600	1800	1600	1300	230	1700	265	0.50
EWS 3	DF	L2D	1.9	650	1450	2300	1850	2100	1850	1550	230	2000	265	0.50
EWS 5	DF	L1	2.0	650	1600	2400	2100	2400	2100	1800	230	2200	265	0.50
EWS 22(9)	SW	L3	1.0	315	525	850	675	800	700	550	170	725	195	0.35
EWS 69	AYC	L3	1.2	470	725	1150	1100	1100	975	775	230	1000	265	0.46
EWS 70	AYC	L2	1.3	470	975	1450	1450	1400	1250	1000	230	1350	265	0.46
EWS 71	AYC	L1D	1.6	560	1250	1900	1900	1850	1650	1400	230	1700	265	0.46
EWS ES 11	ES	C4	1.5	450	975	1550	1350	1750	1600	1400	175	1350	200	0.41
EWS ES 12	ES	1.9E6	1.8	560	1600	2300	1700	2400	2400	2300	175	1950	200	0.41
EWS POC 1	POC	L1	1.8	560	1350	2300	2000	1950	1750	1500	230	1850	265	0.45
EWS POC 2	POC	L2	1.5	375	1050	1900	1550	1500	1300	1100	230	1400	265	0.45
Southern Pine														
EWS 47	SP	N2M14	1.4	650	1200	1900	1150	1750	1550	1300	260	1400	300	0.55
EWS 48	SP	N2D14	1.7	740	1400	2200	1350	2000	1800	1500	260	1600	300	0.55
EWS 49	SP	N1M16	1.7	650	1350	2100	1450	1950	1750	1500	260	1800	300	0.55
EWS 50	SP	N1D14	1.9	740	1550	2300	1700	2300	2100	1750	260	2100	300	0.55
Wet-use factors			0.833	0.53	0.8	0.73	0.73	0.8	0.8	0.8	0.875	0.8	0.875	See NDS

Footnotes:

(1) The tabulated design values are for dry conditions of use. For wet conditions of use, multiply the tabulated values by the factors shown at the end of the table.

(2) The tabulated design values are for normal duration of loading. For other durations of loading, see applicable building code.

(3) The symbols used for species are AYC = Alaska yellow cedar, DF = Douglas fir-larch, ES = Eastern spruce, POC = Port Orford cedar, SP = Southern pine, and SW = Softwood species.

(4) For beam stability and column stability calculations, E_{min} shall be determined by multiplying the tabulated modulus of elasticity by 0.518.

(5) The tabulated F_{vy} values are for members of 4 or more lams. The tabulated F_{vy} values shall be multiplied by a factor of 0.95 for 3 lams and 0.84 for 2 lams.

(6) For members with 5, 7, or 9 lams manufactured from multiple-piece lams with unbonded edge joints, the tabulated F_{vy} values shall be multiplied by a factor of 0.4. For all other members manufactured from multiple-piece lams with unbonded edge joints, the tabulated F_{vy} values shall be multiplied by a factor of 0.5. This adjustment shall be cumulative with the adjustment given in Footnote No. 4.

(7) The tabulated F_{bx} values are for members without special tension lams up to 15 inches in depth. If the member depth is greater than 15 inches without special tension lams, the tabulated F_{bx} values shall be multiplied by a factor of 0.88. If special tension lams are used, the tabulated F_{bx} values are permitted to be increased by a factor of 1.18 regardless of the member depth.

(8) For non-prismatic members, notched members, members subject to impact or cyclic loading, or shear design of bending members at connections (NDS 3.4.3.3), the tabulated F_{vx} values shall be multiplied by 0.72.

(9) When Western Cedars, Western Cedars (North), Western Woods, and Redwood (open grain) are used in combinations for Softwood Species (SW), the design values for modulus of elasticity (E_x and E_y) shall be reduced by 100,000 psi. When Coast Sitka Spruce, Coast Species, Western White Pine, and Eastern White Pine are used in combinations for Softwood Species (SW), design values for shear parallel to grain (F_{vx} and F_{vy}) shall be reduced by 10 psi before applying any adjustments.

Stress Classes

Another option for specifying glulam is to specify one of the stress classes in Table 3. These stress classes have been included in the 2005 National Design Specification for Wood Construction (NDS) and represent commonly available glulam. Note that these do not designate the species used or whether the layups use visually or E-rated laminations. Species may be specified in combination with these stress classes to obtain certain design properties as indicated in the footnotes.

TABLE 3

STRESS CLASSES

Stress Class	F_{bx}^{+} (psi)	$F_{bx}^{-(1)}$ (psi)	$F_{c\perp x}$ (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

Footnotes:

(1) For balanced layups, F_{bx}^{-} (bending stress when compression zone is stressed in tension) shall be equal to F_{bx}^{+} (bending stress when tension zone is stressed in tension) for the stress class. Designer shall specify when balanced layup is required.

(2) Negative bending stress, F_{bx}^{-}, is permitted to be increased to 1850 psi for Douglas-fir and to 1950 psi for southern pine for specific combinations. Designer shall specify when these increased stresses are required.

(3) For non-prismatic members, notched members, and members subject to impact or cyclic loading, the design value for shear shall be multiplied by a factor of 0.72.

(4) F_{vx} = 300 psi for glulam made of southern pine.

(5) E_x may be increased to 1.8 x 10^6 psi for glulam made of Canadian spruce-pine-fir or Eastern spruce.

(6) E_x = 2.0 x 10^6 psi for members with more than 15 laminations.

(7) Limited to a maximum width of 6 inches.

(8) Requires the use of an outermost LVL lamination on the top and bottom.

(9) Compressive perpendicular to grain stress can be increased to the published value for the outermost LVL lamination.

Design values in this table represent design values for groups of similar glued laminated timber combinations. Higher design values for some properties may be obtained by specifying a particular combination listed in Table 1 or in ICC Evaluation Service Report ESR-1940. Design values are for members with 4 or more laminations. Some stress classes are not available in all species. Contact glulam manufacturer for availability.

Specifying by Stresses

When the specifier or end user is uncertain as to the availability or applicability of a specific layup combination or stress class, another way to specify glulam is to provide the manufacturer or supplier with the required stresses to satisfy a given design. For example, assume a simple-span beam design requires the following allowable stresses to carry the in-service design loads:

F_b = 2250 psi
F_v = 150 psi
F_{cperp} = 500 psi
MOE = 1.6 x 10^6 psi

If the designer provides the manufacturer or supplier with these required stresses, a number of layup combinations satisfying these stress requirements could then be supplied depending on availability. This will often result in the lowest cost option being supplied while still satisfying all design requirements.

Member Sizes

In addition to specifying the allowable design stresses, it is also necessary to specify the size of member required. While glulam can be manufactured in virtually any cross-sectional size and length required, it is important to understand that since glulam is manufactured using dimension lumber, certain widths and depths become de facto standards which should be specified whenever possible. Table 4 provides typical net finished widths for glulam.

TABLE 4

TYPICAL NET FINISHED GLULAM WIDTHS

Nominal Width	3	4*	6*	8	10	12
Western species	2-1/2	3-1/8	5-1/8	6-3/4	8-3/4	10-3/4
Southern pine	2-1/2	3	5	6-3/4	8-1/2	10-1/2

* For the 4-inch and 6-inch nominal widths, glulam may also be available in 3-1/2" and 5-1/2" widths respectively. These "full-width" members correspond to the dimensions of 2x4 and 2x6 framing lumber and are supplied with "hit or miss" surfacing which is only acceptable for concealed applications. For additional information on the appearance characteristics of glulam, see APA Technical Note Y110, *Glued Laminated Timber Appearance Classifications for Construction Applications.*

The depths of glulam are typically specified in multiples of 1-1/2 inches for Western species and 1-3/8 inches for southern pine. Thus, a 10-lamination member using Western species will have a net depth of 15 inches while a 10-lamination southern pine member will have a net depth of 13-3/4 inches. Other thicknesses of laminations may be specified but these will require a custom order. An example would be the use of 3/4-inch-thick laminations to produce members with a tight radius-of-curvature such as occurs in most arch members.

When used in conjunction with I-joists, glulam may be supplied in I-joist-compatible (IJC) depths. For residential construction, these are 9-1/2 inches, 11-7/8 inches, 14 inches and 16 inches. Section properties for some of these depths are shown in Tables 5 and 6 for 3-1/2- and 5-1/2-inch net widths.

Section Properties

Tables 5 and 6 provide net section properties for both Western species and southern pine glulam. Other sizes are also available.

Further Information

In addition to properly specifying the member size and allowable design properties, other considerations associated with the proper design of glulam include providing proper bearing support, assuring adequate lateral bracing and detailing connections to account for all in-service loads and environmental considerations.

For further information on specifying or using glued laminated timber, contact APA at the address listed on the back page.

TABLE 5

DOUGLAS-FIR GLUED LAMINATED BEAM SECTION PROPERTIES AND CAPACITIES

F_b = 2,400 psi, E = 1,800,000 psi, F_v = 265 psi

3-1/8-INCH WIDTH

Depth (in.)	6	7-1/2	9	10-1/2	12	13-1/2	15	16-1/2	18	19-1/2	21	22-1/2	24	25-1/2	27
Beam Weight (lb/ft)	4.6	5.7	6.8	8.0	9.1	10.3	11.4	12.5	13.7	14.8	16.0	17.1	18.2	19.4	20.5
A (in.^{2})	18.8	23.4	28.1	32.8	37.5	42.2	46.9	51.6	56.3	60.9	65.6	70.3	75.0	79.7	84.4
S (in.^{3})	19	29	42	57	75	95	117	142	169	198	230	264	300	339	380
I (in.^{4})	56	110	190	301	450	641	879	1170	1519	1931	2412	2966	3600	4318	5126
EI (10^6 lb-in.^{2})	101	198	342	543	810	1153	1582	2106	2734	3476	4341	5339	6480	7773	9226
Moment Capacity (lb-ft)	3750	5859	8438	11484	15000	18984	23438	28359	33750	39609	45938	52734	60000	67734	75938
Shear Capacity (lb)	3313	4141	4969	5797	6625	7453	8281	9109	9938	10766	11594	12422	13250	14078	14906

3-1/2-INCH WIDTH

Depth (in.)	6	7-1/2	9	10-1/2	12	13-1/2	14	15	16	16-1/2	18	19-1/2	21	22-1/2	24
Beam Weight (lb/ft)	5.1	6.4	7.7	8.9	10.2	11.5	11.9	12.8	136	14.0	15.3	16.6	17.9	19.1	20.4
A (in.^{2})	21.0	26.3	31.5	36.8	42.0	47.3	49.0	52.5	560	57.8	63.0	68.3	73.5	78.8	84.0
S (in.^{3})	21	33	47	64	84	106	114	131	149	159	189	222	257	295	336
I (in.^{4})	63	123	213	338	504	718	800	984	1195	1310	1701	2163	2701	3322	4032
EI (10^6 lb-in.^{2})	113	221	383	608	907	1292	1441	1772	2150	2358	3062	3893	4862	5980	7258
Moment Capacity (lb-ft)	4200	6563	9450	12863	16800	21263	22867	26250	29867	31763	37800	44363	51450	59063	67200
Shear Capacity (lb)	3710	4638	5565	6493	7420	8348	8657	9275	9893	10203	11130	12058	12985	13913	14840

5-1/8-INCH WIDTH

Depth (in.)	12	13-1/2	15	16-1/2	18	19-1/2	21	22-1/2	24	25-1/2	27	28-1/2	30	31-1/2	33
Beam Weight (lb/ft)	14.9	16.8	18.7	20.6	22.4	24.3	26.2	28.0	29.9	31.8	33.6	35.5	37.4	39.2	41.1
A (in.^{2})	61.5	69.2	76.9	84.6	92.3	99.9	107.6	115.3	123.0	130.7	138.4	146.1	153.8	161.4	169.1
S (in.^{3})	123	156	192	233	277	325	377	432	492	555	623	694	769	848	930
I (in.^{4})	738	1051	1441	1919	2491	3167	3955	4865	5904	7082	8406	9887	11531	13349	15348
EI (10^6 lb-in.^{2})	1328	1891	2595	3453	4483	5700	7119	8757	10627	12747	15131	17796	20756	24028	27627
Moment Capacity (lb-ft)	24600	31134	38438	46509	55350	64959	75338	86484	98400	111084	124538	138759	153750	169509	186038
Shear Capacity (lb)	10865	12223	13581	14939	16298	17656	19014	20372	21730	23088	24446	25804	27163	28521	29879

5-1/2-INCH WIDTH

Depth (in.)	12	13-1/2	14	15	16	16-1/2	18	19-1/2	21	22-1/2	24	25-1/2	27	28-1/2	30
Beam Weight (lb/ft)	16.0	18.0	18.7	20.1	21.4	22.1	24.1	26.1	28.1	30.1	32.1	34.1	36.1	38.1	40.1
A (in.^{2})	66.0	74.3	77.0	82.5	88.0	90.8	99.0	107.3	115.5	123.8	132.0	140.3	148.5	156.8	165.0
S (in.^{3})	132	167	180	206	235	250	297	349	404	464	528	596	668	745	825
I (in.^{4})	792	1128	1258	1547	1877	2059	2673	3398	4245	5221	6336	7600	9021	10610	12375
EI (10^6 lb-in.^{2})	1426	2030	2264	2784	3379	3706	4811	6117	7640	9397	11405	13680	16238	19098	22275
Moment Capacity (lb-ft)	26400	33413	35933	41250	46933	49913	59400	69713	80850	92813	105600	119213	133650	148913	165000
Shear Capacity (lb)	11660	13118	13603	14575	15547	16033	17490	18948	20405	21863	23320	24778	26235	27693	29150

6-3/4-INCH WIDTH

Depth (in.)	18	19-1/2	21	22-1/2	24	25-1/2	27	28-1/2	30	31-1/2	33	34-1/2	36	37-1/2	39
Beam Weight (lb/ft)	29.5	32.0	34.5	36.9	39.4	41.8	44.3	46.8	49.2	51.7	54.1	56.6	59.1	61.5	64.0
A (in.^{2})	121.5	131.6	141.8	151.9	162.0	172.1	182.3	192.4	202.5	212.6	222.8	232.9	243.0	253.1	263.3
S (in.^{3})	365	428	496	570	648	732	820	914	1013	1116	1225	1339	1458	1582	1711
I (in.^{4})	3281	4171	5209	6407	7776	9327	11072	13021	15188	17581	20215	23098	26244	29663	33367
EI (10^6 lb-in.^{2})	5905	7508	9377	11533	13997	16789	19929	23438	27338	31647	36386	41577	47239	53394	60060
Moment Capacity (lb-ft)	72900	85556	99225	113906	129600	146306	164025	182756	202500	223256	245025	267806	291600	316406	342225
Shear Capacity (lb)	21465	23254	25043	26831	28620	30409	32198	33986	35775	37564	39353	41141	42930	44719	46508

8-3/4-INCH WIDTH

Depth (in.)	24	25-1/2	27	28-1/2	30	31-1/2	33	34-1/2	36	37-1/2	39	40-1/2	42	43-1/2	45
Beam Weight (lb/ft)	51.0	54.2	57.4	60.6	63.8	67.0	70.2	73.4	76.6	79.8	82.9	86.1	89.3	92.5	95.7
A (in.^{2})	210.0	223.1	236.3	249.4	262.5	275.6	288.8	301.9	315.0	328.1	341.3	354.4	367.5	380.6	393.8
S (in.^{3})	840	948	1063	1185	1313	1447	1588	1736	1890	2051	2218	2392	2573	2760	2953
I (in.^{4})	10080	12091	14352	16880	19688	22791	26204	29942	34020	38452	43253	48439	54023	60020	66445
EI (10^6 lb-in.^{2})	18144	21763	25834	30383	35438	41023	47167	53896	61236	69214	77856	87190	97241	108036	119602
Moment Capacity (lb-ft)	168000	189656	212625	236906	262500	289406	317625	347156	378000	410156	443625	478406	514500	551906	590625
Shear Capacity (lb)	37100	39419	41738	44056	46375	48694	51013	53331	55650	57969	60288	62606	64925	67244	69563

Footnotes:

(1) Beam weight is based on density of 35 pcf.

(2) Moment capacity must be adjusted for volume effect: $C_v = \left(\frac{12}{d}\right)^{1/10} \times \left(\frac{5.125}{b}\right)^{1/10} \times \left(\frac{21}{L}\right)^{1/10} \leq 1.0$, where d = beam depth (in.), b = beam width (in.), and L = beam length (ft).

(3) Moment and shear capacities are based on a normal (10 years) duration of load and should be adjusted for the design duration of load per the applicable building code.

TABLE 6

SOUTHERN PINE GLUED LAMINATED BEAM SECTION PROPERTIES AND CAPACITIES

F_b = 2,400 psi, E = 1,800,000 psi, F_v = 300 psi

3-INCH WIDTH

Depth (in.)	6-7/8	8-1/4	9-5/8	11	12-3/8	13-3/4	15-1/8	16-1/2	17-7/8	19-1/4	20-5/8	22	23-3/8	24-3/4	26-1/8
Beam Weight (lb/ft)	5.2	6.2	7.2	8.3	9.3	10.3	11.3	12.4	13.4	14.4	15.5	16.5	17.5	18.6	19.6
A (in.^{2})	20.6	24.8	28.9	33.0	37.1	41.3	45.4	49.5	53.6	57.8	61.9	66.0	70.1	74.3	78.4
S (in.^{3})	24	34	46	61	77	95	114	136	160	185	213	242	273	306	341
I (in.^{4})	81	140	223	333	474	650	865	1123	1428	1783	2193	2662	3193	3790	4458
EI (10^6 lb-in.^{2})	146	253	401	599	853	1170	1557	2021	2570	3210	3948	4792	5747	6822	8024
Moment Capacity (lb-ft)	4727	6806	9264	12100	15314	18906	22877	27225	31952	37056	42539	48400	54639	61256	68252
Shear Capacity (lb)	4125	4950	5775	6600	7425	8250	9075	9900	10725	11550	12375	13200	14025	14850	15675

3-1/2-INCH WIDTH

Depth (in.)	6-7/8	8-1/4	9-5/8	11	12-3/8	13-3/4	14	15-1/8	16	16-1/2	17-7/8	19-1/4	20-5/8	22	23-3/8
Beam Weight (lb/ft)	6.0	7.2	8.4	9.6	10.8	12.0	12.3	13.2	14.0	14.4	15.6	16.8	18.0	19.3	20.5
A (in.^{2})	24.1	28.9	33.7	38.5	43.3	48.1	49.0	52.9	56.0	57.8	62.6	67.4	72.2	77.0	81.8
S (in.^{3})	28	40	54	71	89	110	114	133	149	159	186	216	248	282	319
I (in.^{4})	95	164	260	388	553	758	800	1009	1195	1310	1666	2081	2559	3106	3725
EI (10^6 lb-in.^{2})	171	295	468	699	995	1365	1441	1817	2150	2358	2998	3745	4606	5590	6705
Moment Capacity (lb-ft)	5514	7941	10808	14117	17866	22057	22867	26689	29867	31763	37277	43232	49629	56467	63746
Shear Capacity (lb)	4813	5775	6738	7700	8663	9625	9800	10588	11200	11550	12513	13475	14438	15400	16363

5-INCH WIDTH

Depth (in.)	12-3/8	13-3/4	15-1/8	16-1/2	17-7/8	19-1/4	20-5/8	22	23-3/8	24-3/4	26-1/8	27-1/2	28-7/8	30-1/4	31-5/8
Beam Weight (lb/ft)	15.5	17.2	18.9	20.6	22.3	24.1	25.8	27.5	29.2	30.9	32.7	34.4	36.1	37.8	39.5
A (in.^{2})	61.9	68.8	75.6	82.5	89.4	96.3	103.1	110.0	116.9	123.8	130.6	137.5	144.4	151.3	158.1
S (in.^{3})	128	158	191	227	266	309	354	403	455	510	569	630	695	763	833
I (in.^{4})	790	1083	1442	1872	2380	2972	3656	4437	5322	6317	7429	8665	10031	11534	13179
EI (10^6 lb-in.^{2})	1421	1950	2595	3369	4284	5350	6580	7986	9579	11371	13373	15598	18056	20760	23722
Moment Capacity (lb-ft)	25523	31510	38128	45375	53253	61760	70898	80667	91065	102094	113753	126042	138961	152510	166690
Shear Capacity (lb)	12375	13750	15125	16500	17875	19250	20625	22000	23375	24750	26125	27508	28875	30250	31625

5-1/2-INCH WIDTH

Depth (in.)	12-3/8	13-3/4	14	15-1/8	16	16-1/2	17-7/8	19-1/4	20-5/8	22	23-3/8	24-3/4	26-1/8	27-1/2	28-7/8
Beam Weight (lb/ft)	17.0	18.9	19.3	20.8	22.0	22.7	24.6	26.5	28.4	30.3	32.1	34.0	35.9	37.8	39.7
A (in.^{2})	68.1	75.6	77.0	83.2	88.0	90.8	98.3	105.9	113.4	121.0	128.6	136.1	143.7	151.3	158.8
S (in.^{3})	140	173	180	210	235	250	293	340	390	444	501	562	626	693	764
I (in.^{4})	869	1191	1258	1586	1877	2059	2618	3269	4021	4880	5854	6949	8172	9532	11034
EI (10^6 lb-in.^{2})	1563	2145	2264	2855	3379	3706	4712	5885	7238	8785	10537	12508	14710	17157	19862
Moment Capacity (lb-ft)	28076	34661	35933	41940	46933	49913	58578	67936	77988	88733	100172	112303	125128	138646	152857
Shear Capacity (lb)	13613	15125	15400	16638	17600	18150	19663	21175	22688	24200	25713	27225	28738	30250	31763

6-3/4-INCH WIDTH

Depth (in.)	17-7/8	19-1/4	20-5/8	22	23-3/8	24-3/4	26-1/8	27-1/2	28-7/8	30-1/4	31-5/8	33	34-3/8	35-3/4	37-1/8
Beam Weight (lb/ft)	30.2	32.5	34.8	37.1	39.4	41.8	44.1	46.4	48.7	51.0	53.4	55.7	58.0	60.3	62.6
A (in.^{2})	120.7	129.9	139.2	148.5	157.8	167.1	176.3	185.6	194.9	204.2	213.5	222.8	232.0	241.3	250.6
S (in.^{3})	359	417	479	545	615	689	768	851	938	1029	1125	1225	1329	1438	1551
I (in.^{4})	3213	4012	4935	5990	7184	8528	10030	11698	13542	15570	17792	20215	22848	25701	28782
EI (10^6 lb-in.^{2})	5783	7222	8883	10781	12932	15350	18054	21057	24376	28027	32025	36386	41127	46262	51808
Moment Capacity (lb-ft)	71891	83377	95713	108900	122938	137827	153566	170156	187597	205889	225032	245025	265869	287564	310110
Shear Capacity (lb)	24131	25988	27844	29700	31556	33413	35269	37125	38981	40838	42694	44550	46406	48263	50119

8-1/2-INCH WIDTH

Depth (in.)	24-3/4	26-1/8	27-1/2	28-7/8	30-1/4	31-5/8	33	34-3/8	35-3/4	37-1/8	38-1/2	39-7/8	41-1/4	42-5/8	44
Beam Weight (lb/ft)	52.6	55.5	58.4	61.4	64.3	67.2	70.1	73.0	76.0	78.9	81.8	84.7	87.7	90.6	93.5
A (in.^{2})	210.4	222.1	233.8	245.4	257.1	268.8	280.5	292.2	303.9	315.6	327.3	338.9	350.6	362.3	374.0
S (in.^{3})	868	967	1071	1181	1296	1417	1543	1674	1811	1953	2100	2253	2411	2574	2743
I (in.^{4})	10739	12630	14731	17053	19607	22404	25455	28772	32364	36244	40422	44910	49718	54857	60339
EI (10^6 lb-in.^{2})	19330	22734	26516	30696	35293	40328	45820	51789	58256	65239	72760	80837	89492	98742	108610
Moment Capacity (lb-ft)	173559	193379	214271	236234	259268	283373	308550	334798	362118	390509	419971	450504	482109	514786	548533
Shear Capacity (lb)	42075	44413	46750	49088	51425	53763	56100	58438	60775	63113	65450	67788	70125	72463	74800

Footnotes:

(1) Beam weight is based on density of 36 pcf.

(2) Moment capacity must be adjusted for volume effect: $C_v = \left(\frac{12}{d}\right)^{1/20} \times \left(\frac{5.125}{b}\right)^{1/20} \times \left(\frac{21}{L}\right)^{1/20} \leq 1.0$, where d = beam depth (in.), b = beam width (in.), and L = beam length (ft).

(3) Moment and shear capacities are based on a normal (10 years) duration of load and should be adjusted for the design duration of load per the applicable building code.

Cathedral of Christ the Light in Oakland, CA is unlike any structure in the world. The inner chords are made with (26) 10 ¾″ curved glulam ribs, roughly 100′ in length and varying in depth from 30″ at the base to 19 ½″ at the top.

Austin, Texas' Palmer Events Center features glulam trusses attached to a matrix of concrete columns.

The Milwaukee Street Bridge in Jefferson, Wisconsin features 3-hinged buttressed arches each with an 85-foot radius.

Western Archrib.

The classic symmetry of these pitched glulam trusses frame the dining hall at Shawinigan Lake's Marion Hall in British Columbia.

Glulam Design Specification

We have field representatives in many major U.S. cities and in Canada
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Form No. Y117E/Revised August 2008

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