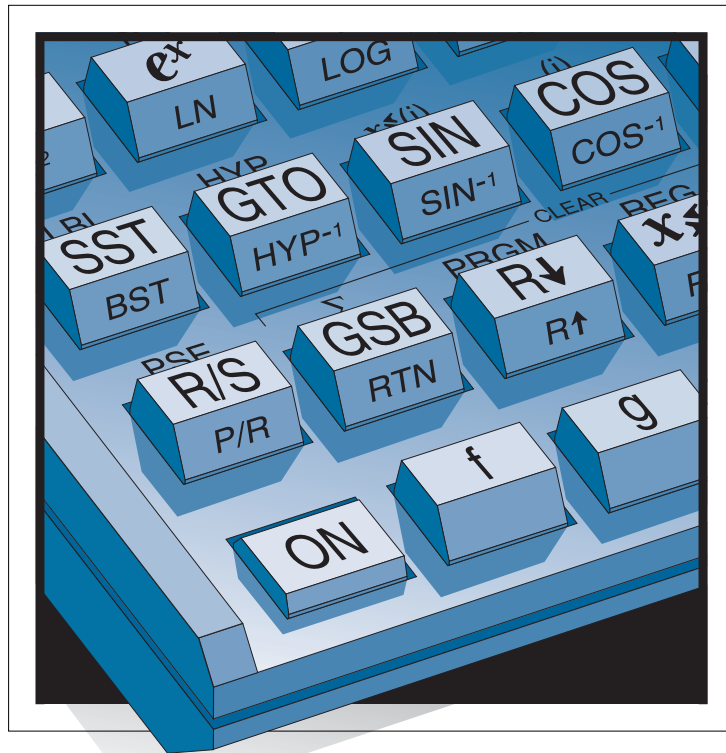


PLYWOOD DESIGN SPECIFICATION
SUPPLEMENT 5

Design and Fabrication of All-Plywood Beams

November 2008



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 specification apply only to products that bear the APA trademark. Only products bearing the APA trademark are subject to the Association's quality auditing program.

FOREWORD

This publication formerly was issued as Research Report 124-A, Form D410. It presents recommended methods for the design and fabrication of staple-glued all-plywood beams. Allowable stresses and other design criteria are given in Part 1, and in APA's PLYWOOD DESIGN SPECIFICATION (PDS). References are also made to the NATIONAL DESIGN SPECIFICATION FOR WOOD CONSTRUCTION (NDS), published by the American Forest & Paper Association. Part 2 of this publication covers beam fabrication.

Beam design and fabrication recommendations are based on tests conducted by APA, as described in Research Report 124, "All-Plywood Beams for Mobile Homes." The tests showed that such beams comply with the structural load test criteria in the Federal Manufactured Home Construction and Safety Standards. These standards and subsequent amendments are published in the FEDERAL REGISTER by the U.S. Department of Housing and Urban Development, and include procedures and criteria for conducting and evaluating structural load tests on assemblies such as all-plywood beams.

The product use recommendations in this publication are based on APA – The Engineered Wood Association's continuing programs of laboratory testing, product research, and comprehensive field experience, however, because the Association has no control over quality of workmanship or the conditions under which engineered wood products are used, it cannot accept responsibility for product performance or designs as actually constructed.

All-plywood beams designed and fabricated with these recommendations have been widely used in manufactured homes. Check with model building code regulatory agencies for acceptance of these methods for construction of components to be used in other code-complying structural applications.

CONTENTS

Foreword	3
Part 1 – Design of All-Plywood Beams	5
1. General	5
2. Determine Total Load Based on Allowable Web and Flange Bending Stress	6
3. Determine Total Load Based on Allowable Web Shear Stress	7
4. Determine Total Load Based on Allowable Flange-Web Shear Stress	8
5. Determine Final Total Allowable Load	9
6. Calculate Deflection at Allowable Load	9
7. Beam Support and Connection Details	10
Part 2 – Fabrication of All-Plywood Beams	12
1. Scope	12
2. Materials	12
3. Fabrication	13
4. Test Samples	16
5. Identification	16
Literature Cited	17
Appendix A – Design Example for All-Plywood Beams	18

A Word on Components

Plywood components are major structural members which depend on the glued joints to integrate the separate pieces into an efficient unit capable of carrying high stresses. Materials in these components may be stressed to an appreciably higher level than in conventional construction.

Since improperly designed or fabricated components could constitute a hazard to life and property, it is strongly recommended that components be designed by qualified architects or engineers, using recognized design and fabrication methods, and that adequate quality control be maintained during manufacture.

To be sure that such quality control has been carefully maintained, we recommend the services of an independent testing agency. A requirement that each unit bear the trademark of an approved agency will assure adequate independent inspection.

PART 1 – DESIGN OF ALL-PLYWOOD BEAMS

1. General

This method is applicable to beams fabricated in accordance with Part 2, Fabrication of All-Plywood Beams.

1.1 Plywood Grade

Applicable grades include APA RATED SHEATHING EXP 1, APA RATED SHEATHING EXT, APA STRUCTURAL I RATED SHEATHING EXP 1, and APA STRUCTURAL I RATED SHEATHING EXT. Panels must be marked PS 1.⁽¹⁾

1.2 Plywood Layup

Typical plywood layups are shown in Table 1. Design should be based on the value in boldface for each combination of thickness and Span Rating, unless another layup is specified and available.

TABLE 1

EFFECTIVE THICKNESS FOR TYPICAL UNSANDED PS 1 PLYWOOD CONSTRUCTIONS⁽¹⁾⁽²⁾

Nominal Plywood Thickness (in.) and Span Rating	No. of Plies — — — No. of Layers	Nominal Face Veneer Thickness (in.)	Thickness for Bending Stress and Bending Deflection, t_b (in.)		Thickness for Shear Stress and Shear Deflection, t_s (in.)	
			All plies Group 1 (including STRUCTURAL I)	All Other	All plies Group 1 (including STRUCTURAL I)	All Other
3/8" 24/0	3/3	1/8	.216	.170	.371	.280
		1/10	.185	.136	.371	.278
15/32" or 1/2" 32/16	3/3	1/6	.302 ⁽³⁾	.220	.395⁽³⁾	.295⁽³⁾
	4/3	1/8	.227	.167	.535	.400
		1/10	.272	.182	.676	.500
19/32" or 5/8" 40/20	4/3	1/6	.270⁽³⁾	.207	.567⁽³⁾	.421
		1/6, 1/8				
	5/5	1/8	.347	.236	.707	.518
		1/10	.289	.246	.715	.561
23/32" or 3/4" 48/24	4/3	1/6	.320⁽³⁾	.256	.598⁽³⁾	.441
		3/16				
		1/6	.407	.281	.739	.532
	5/5	1/8				
		1/8, 1/7	.352	.254	.739	.539
		1/7				
		1/8, 1/6				
6/5	1/10	.373	.293	.746	.573	
	1/8	.352	.299	.879	.694	
	7/7	.373	.290	1.020	.784	

(1) Use value in **boldface** for combination of plywood thickness and Span Rating unless another layup is specified and available. Check availability of panel layup and species group before specifying.

(2) Values do not apply to plywood panels marked "Butt-Jointed Center."

(3) Not available in STRUCTURAL I grade.

1.3 Species Group

Section properties are presented below both for plywood having all plies of Group 1 species, and for plywood made with other species combinations. For some designs, it may be advantageous to specify STRUCTURAL I grades or panels with all plies of Group 1 species. Check availability before specifying.

1.4 Effective Thickness

Table 1 gives values of effective thickness of parallel plies (t_b) for calculating bending stress and bending deflection. Also listed is the effective thickness (t_s) for calculating shear stress and shear deflection.

1.5 Allowable Stresses

Design shall be based on allowable stresses, modulus of elasticity, and shear modulus as listed in Table 3 of the PANEL DESIGN SPECIFICATION (PDS)⁽²⁾ for Group 1 face ply, except that:

- (a) Allowable bending stress (F_b) shall be 3300 psi for plywood with minimum 5-ply, 5-layer panel construction; and 2800 psi for 3-, 4- or 5-ply, 3-layer plywood. These allowable F_b stresses are for use in all-plywood beam design. They are not applicable to other uses.
- (b) Allowable stress in shear through the thickness (F_v) shall be 190 psi. When beams consist of two or more web laminations, or when flanges are glued to the top and bottom of the plywood beam, F_v may be 225 psi (increased 19% in accordance with PDS Section 3.8.1). Because of the limited effectiveness of splice plates and stiffeners as edge reinforcement, the 1/3 increase in PDS Section 3.8.1 for full perimeter framing may not be taken.

Note: F_v may be 250 psi for beams with or without flanges when plywood panels are regraded to limit core gap width and placement in accordance with PDS Section 3.8.1.

The above stresses may be increased for duration of load in accordance with the PDS.

For plywood which is not specified as STRUCTURAL I or all Group 1, the designer should still use Group 1 stresses in combination with the section properties listed under the heading "All Other." These values have been adjusted to compensate for allowable variations in panel makeup, to simplify the design procedure.

1.5.1 Modulus of Elasticity in Pure Bending (E)

When calculating the bending deflection of beams separately from shear deflection, it is customary to use the modulus of elasticity of the materials in pure bending. For plywood, the "bending E" is 10% higher than the effective E values listed in Table 3 of the PDS.

2. Determine Total Load Based on Allowable Web and Flange Bending Stress

For single-span beams under uniform load, the total uniform load, w_b , based on allowable bending stress in the web and flanges, can be calculated from the following formula:

$$w_b = \frac{8 F_b I_n}{12c L^2}$$

where

w_b = Total uniform load, based on allowable bending stress (lb/ft).

F_b = Allowable plywood bending stress (psi) from Section 1.5.

I_n = Net moment of inertia about the neutral axis of all continuous parallel-grain material at the *minimum* section containing a web or flange joint (in.⁴). See Section 2.1.

c = Distance to extreme fiber in bending (in.). For symmetrical beam cross-sections, this distance is half the beam depth.

L = Clear span of the beam, measured between supports (ft).

2.1 Net Moment of Inertia (I_n)

For all-plywood beams it will usually be necessary to check more than one cross section, depending on location of web and flange joints. Sometimes visual comparison of the sections will quickly show which will be critical. The net moment of inertia about the neutral axis of all continuous parallel plies can be calculated by adding applicable values from the following formulas:

$$I_w (\text{web}) = \frac{\sum t_{bw} h_w^3}{12}$$

$$I_{ws} (\text{web splice plates}) = \frac{\sum t_{bs} h_s^3}{12}$$

(See Note)

$$I_f (\text{flanges}) = \frac{\sum t_{bf} [h_w^3 - (h_w - 2d)^3]}{12}$$

where

t_b = Total thickness of all parallel plies per lamination (in.). Use t_b from Table 1.

d , h_w , h_s = Depth, or “height” of flanges, web and web splice plate (in.).

Note: Consider splice plate only if directly glued to the web containing the butt joint.

3. Determine Total Load Based on Allowable Web Shear Stress

For single-span beams under uniform load, the total uniform load, w_v , based on allowable horizontal shear stress at the neutral axis of the web, can be calculated from the following formula:

$$w_v = \frac{2F_v I_t \Sigma t_s}{QL}$$

where

w_v = Total uniform load, based on allowable horizontal shear stress (lb/ft).

F_v = Allowable plywood shear stress (psi) from Section 1.5.

I_t = Total moment of inertia about the neutral axis of all parallel-grain material in the web and flanges, regardless of joints (in.⁴). Disregard stiffeners or web splice plates. See Section 3.1.

t_s = Effective shear thickness of continuous webs (and/or web splice plates and stiffeners, if applicable) at the neutral axis of the section (in.). Use t_s from Table 1.

Q = Statical moment about the neutral axis of the area of all parallel-grain material in the web and flanges regardless of joints, lying above (or below) the neutral axis (in.³). Disregard stiffeners or web splice plates. See Section 3.3.

L = Clear span of beam, measured between supports (ft). A value of $L' = L - 2hw$ may be used if desired.

3.1 Total Moment of Inertia (I_t)

For symmetrical beams, the total moment of inertia about the neutral axis of all parallel plies in the plywood web and flanges can be calculated by adding applicable values from the following formulas. Joints in webs and flanges, and web stiffeners or splice plates, are not considered in calculating I_t .

$$I_{(\text{web})} = \frac{\Sigma t_b h_w^3}{12}$$

$$I_{(\text{flanges})} = \frac{\Sigma t_b [h_w^3 - (h_w - 2d)^3]}{12}$$

3.2 Effective Total Web Shear Thickness (t_s)

As is true for bending, a number of cross sections must be considered, depending on location of joints in webs and flanges.

The proximity of these sections to end or interior supports must be considered, because shear forces are higher near the supports. Web joints in single-web beams should be located 24 inches or more from supports. (See Part 2, Fabrication of All-Plywood Beams.) Also, in calculating shear, all loads may be ignored that fall within a distance from the support equal to the beam depth. Therefore, the maximum shear stress for beams with single-layer webs will occur either at an unreinforced web section, located adjacent to the web stiffener over the support, or at h_w from the support. For beams with multiple-layer webs, the maximum horizontal shear stress will occur at the web joint located nearest to the support.

3.3 Statical Moment of Area of Parallel Plies (Q)

The statical moment of the area of parallel plies in the web and flanges, above or below the neutral axis, can be calculated from the general formula $Q = A y$, where A = Area of parallel plies above or below the neutral axis, and y = Distance from the neutral axis to the centroid of the area of the parallel plies above or below the neutral axis. For a symmetrical beam, Q can be calculated by adding applicable values from the following formulas:

$$Q_{w(\text{web})} = \sum t_b \frac{h_w}{2} \frac{h_w}{4} = \frac{\sum t_b h_w^2}{8}$$

$$Q_{f(\text{flanges})} = \sum t_b d \frac{(h_w - d)}{2}$$

3.4 Web Splices

Butt joints in single-layer webs shall be spliced with plywood web splice plates per Section 3.5 of Part 2 of this Specification. When web splice plates are specified for beams with multiple-layer web laminations, the splice plate shall be glued directly to the web lamination containing the butt joint. In accordance with Section 5.6.3.2 of the PDS, the web splice plate grade and thickness shall be equal to the web lamination, and its length shall be at least twelve times its nominal thickness, t . The splice plate shall be centered over the joint. The beam web joint design for vertical shear capacity shall be based on the allowable rolling shear stress, reduced 50% for stress concentration at the web joint in accordance with Section 3.8.2 of the PDS. Shear capacity shall be reduced proportionately for shorter splice plate lengths.

4. Determine Total Load Based on Allowable Flange-Web Shear Stress

For uniformly loaded, single-span beams with plywood flanges, the maximum flange-web shear stress will occur at the supports, where shear forces are highest. The total uniform load (w_s) based on allowable shear stress between the web and flange can be calculated from the following formula:

$$w_s = \frac{2F_s I_t d}{Q_f L}$$

where

w_s = Total uniform load, based on allowable rolling shear stress (lb/ft).

F_s = Allowable plywood rolling shear stress (psi). See PDS Table 3. Note: This stress must be reduced 50% for stress concentration at the edge of the panel.

I_t = Total moment of inertia about the neutral axis of all parallel-grain material in the web and flanges, regardless of joints (in.⁴). Disregard web stiffeners or splice plates. See Section 3.1.

d = Depth of flange (in.).

Q_f = Statical moment about the neutral axis of the area of all parallel-grain material in the top or bottom flange, regardless of joints (in.³). See Section 3.3.

L = Clear span of beam, measured between supports (ft). A value of $L' = L - 2h_w$, maybe used if desired.

5. Determine Final Total Allowable Load (w)

The final allowable load will be the smallest of those controlled by bending, horizontal shear; or rolling shear.

6. Calculate Deflection at Allowable Load

The total deflection may be determined by separately calculating and adding the bending deflection and shear deflection of the beam. (Paragraph 3280.305 (d) of the Federal Manufactured Home Construction and Safety Standards requires that deflection be less than $\ell/180$ at design live load. All-plywood beams are usually stiffer.)

6.1 Bending Deflection (Δ_b)

For single-span beams under uniform load, the maximum bending deflection may be calculated by the following formula:

$$\Delta_b = \frac{5 w L^4 \times 1728}{384 E I_t}$$

where

w = Total allowable load (lb/ft). See Section 5.

L = Clear span measured between supports (ft).

E = Modulus of elasticity of plywood in pure bending (psi). See Section 1.5.1.

I_t = Total moment of inertia about the neutral axis of all parallel-grain material in the web and flanges, regardless of joints (in⁴). Disregard web stiffeners and splice plates. See Section 3.1.

6.2 Shear Deflection (Δ_s)

The shear deflection for a single-span beam under uniform load is given in the following formula:

$$\Delta_s = \frac{K w L^2}{8 A_s G}$$

where

K = A factor determined by the ratio of the beam dimensions and the ratio of the shear modulus (G) of the web and flange. See Section 6.2.1.

A_s = Total effective shear area in the web and flanges, regardless of joints.

G = Shear modulus of the plywood web and flanges (see PDS Table 3).

Note: For derivation of shear-deflection equations, and for other loading conditions or beam configurations, see Forest Service Research Note FPL-02100⁽³⁾. Information in this publication should allow the engineer to handle non-uniform loads, multiple spans, non-symmetrical beams, and beams whose webs and flanges have different shear or elastic moduli.

6.2.1 Shear Deflection Constant (K)

For symmetrical beams with webs and flanges having equal shear modulus, G, and equal modulus of elasticity, E, values for K are determined from Figure 1.

$$\text{For use in Figure 1, } r = \frac{\sum t_s}{b}$$

where

t_s = Total effective shear thickness of webs, regardless of joints (in.). (See Table 1.) Disregard web splice plates or stiffeners.

b = Total effective shear thickness of webs and flanges, regardless of joints (in.). (See Table 1.)

6.2.2 Effective Shear Area (A_v)

The effective shear area in the webs and flanges can be calculated by adding applicable values from the following formulas:

$$\Delta_{sw} \text{ (web)} = \Sigma (t_s h_w)$$

$$\Delta_{sf} \text{ (flanges)} = \Sigma (t_s d)$$

7. Beam Support and Connection Details

As final steps in the overall design, determine the structural adequacy of beam supports and connections for beam half-sections at end or interior bearing walls, and connection details for attaching trussed rafters to beam half-sections, in accordance with recognized engineering practice. Designs should be based on allowable stresses listed in NATIONAL DESIGN SPECIFICATION FOR WOOD CONSTRUCTION (NDS)⁽⁴⁾ or on stresses supported by adequate test data which are approved by regulatory agencies responsible for design approval or inspection.

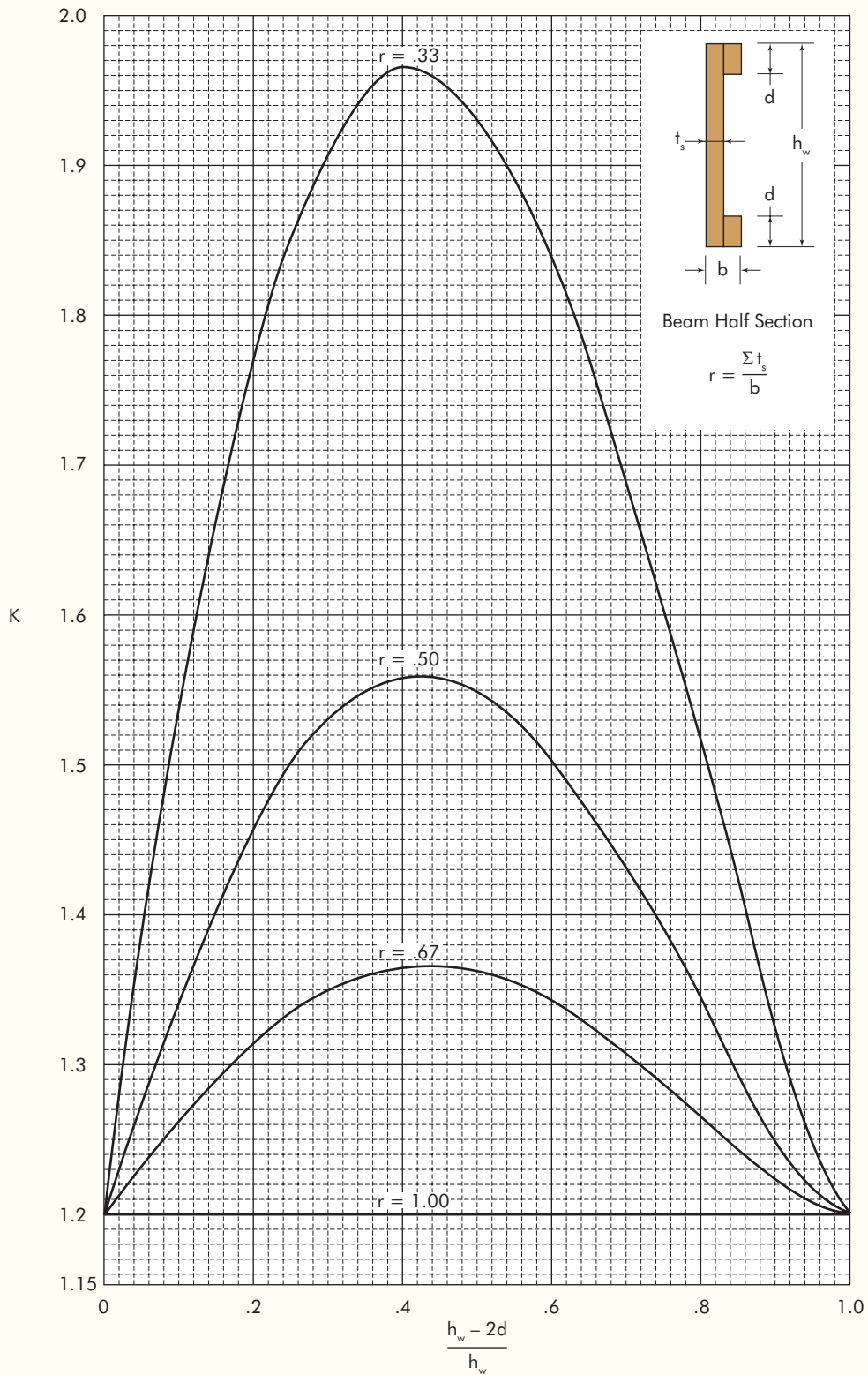
7.1

The compression edges of the beam shall be positively restrained from lateral buckling. This can usually be accomplished by structural panel roof sheathing, trussed rafters spaced not further than 24 inches o.c., and/or by ceiling material.

7.2

Details for connecting ridge beam half-sections at the site shall be in accordance with manufacturer's installation instructions approved by the regulatory agency responsible for design approval or inspection. Fasteners shall not be used in tension areas where bending stresses exceed one-half of the allowable bending stress. (See Section 1.5.) For further information on lag screws or bolts for connecting ridge beam half-sections, see APA Technical Note M320⁽⁷⁾.

FIGURE 1
 SHEAR DEFLECTION CONSTANT (K) FOR SYMMETRICAL BEAMS WITH EQUAL SHEAR MODULI FOR
 WEB AND FLANGE



PART 2 – FABRICATION OF ALL-PLYWOOD BEAMS

1. Scope

1.1

This specification covers the fabrication of all-plywood beams. The design and fabrication of these beams is based on the results of tests which demonstrate compliance with the structural performance requirements of the Federal Manufactured Housing Construction and Safety Standards as published by the U.S. Department of Housing and Urban Development (HUD)⁽⁵⁾.

1.2

The beams should be designed in accordance with the method suggested in Part 1, Design of All-Plywood Beams. The latest edition of APA's PLYWOOD DESIGN SPECIFICATION (PDS) should be used where indicated. Other design methods may be employed, provided they are supported by adequate test data.

1.3

The product use recommendations in this publication are based on APA's continuing programs of laboratory testing, product research, and comprehensive field experience. However, because the Association has no control over quality of workmanship or the conditions under which engineered wood products are used, it cannot accept responsibility for product performance or designs as actually constructed.

2. Materials

2.1 Plywood

Plywood shall conform with the latest edition of U.S. Product Standard PS 1 for Structural Plywood. All plywood shall bear the trademark of APA.

2.1.1

If required by the regulatory agency responsible for design approval or inspection, plywood cut for webs or flanges shall be accompanied by written confirmation from the cutter certifying that the original plywood panel was of the specified type and grade, and was stamped with the trademark of APA.

2.1.2

The recommended plywood grades are APA RATED SHEATHING EXP 1, APA RATED SHEATHING EXT, APA STRUCTURAL I RATED SHEATHING EXP 1, and APA STRUCTURAL I RATED SHEATHING EXT. Panels must be marked PS 1.

Note: In some instances, plywood of grades other than STRUCTURAL I may have all plies of Group 1 or other species group. If specified by design, the plywood shall be accompanied by written confirmation from the plywood manufacturer certifying that all plies are of the required species group.

2.1.3

For some designs, a specific plywood layup may be required to satisfy span or load conditions. In these instances, the plywood shall be accompanied by written confirmation from the plywood manufacturer certifying that it was manufactured with the specified layup, subject to PS 1 manufacturing tolerances.

2.1.4

Plywood pieces cut 4-1/2 inches or less in width for flanges shall be visually inspected after cutting for size of knots. Pieces containing knots in face or back plies larger than two-thirds of the flange width shall not be used in fabricating flanges for ridge beams.

Note: Knot size is determined by (1) a difference in color of limbwood and surrounding trunkwood; (2) an abrupt change in growth ring width between the knot and bordering trunkwood; and (3) the diameter of circular or oval shape described by points where checks on the face of a knot that extend radially from its center to its side experience an abrupt change in direction.

2.1.5

Surfaces of plywood to be glued shall be dry, clean, and free from oil, dust, paper tape or other materials which would be detrimental to satisfactory gluing. At the time of gluing, the plywood moisture content shall be 15% or less.

2.2 Glue

Adhesives conforming to ASTM Standard D3930⁽⁶⁾ are suggested for laminating plywood webs, flanges, splice plates and stiffeners. Other structural adhesives (for example, adhesives meeting ASTM Specifications D4689 or D2559) may be required by regulatory agencies responsible for design approval or inspection.

2.3 Staples

Staples shall be 16 gage x minimum 7/16-inch crown, made from galvanized steel wire. Staple length shall be approximately 1/8 inch less than the total thickness of the materials joined.

3. Fabrication

3.1 General

Plywood beams shall be fabricated with glue and staples.

3.1.1

Plywood face grain for webs, flanges, web splice plates and stiffeners shall be oriented parallel to the span (i.e., horizontally).

3.1.2

D-grade backs of plywood shall be glued together, or to C-grade faces, when laminating beam webs and/or flanges. Beams shall be fabricated so that C-grade faces are oriented on the visible surfaces of web and flange laminations. In single-web ridge beams, the C-grade face shall be oriented on the side opposite the rafter.

3.1.3

Dimensions and tolerances shall be as specified in the design.

3.2 Web and Flange End Joints

3.2.1

End joints in plywood webs and flanges shall be located as specified in the design. Joints in any web or flange lamination shall be spaced at least 24 inches from the nearest joint in any other lamination.

3.2.2

Butt joints at ends of plywood web or flange pieces shall be trimmed square and tightly butted (maximum gap 1/32 inch).

3.2.3

In single-web beams, joints in webs shall be located at least 24 inches from any end or interior support.

3.3 Adhesive Application

3.3.1

Mixing of the adhesive (if applicable), spreading, storage-, pot-, and working-life, and assembly time and temperature shall be in accordance with the adhesive manufacturer's recommendations.

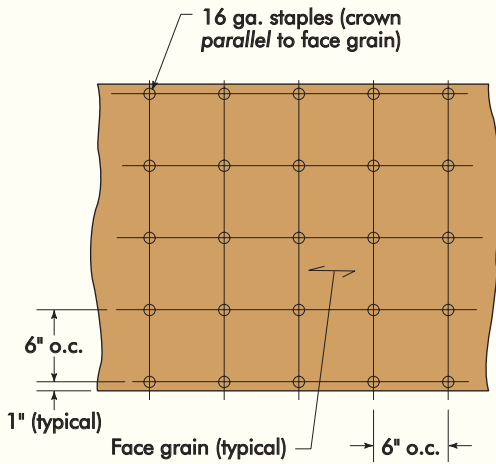
3.3.2

Adhesive shall be spread uniformly over the full contact area of mating web and/or flange surfaces. Application by roller, notched trowel or spray equipment is recommended to insure complete adhesive coverage. The adhesive may be spread on one or both mating surfaces.

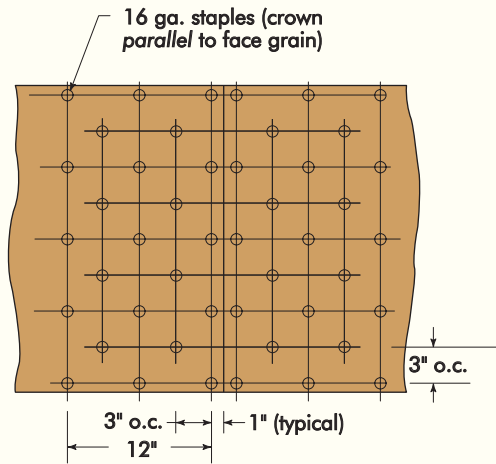
FIGURE 2

STAPLE SPACING FOR PLYWOOD WEBS, FLANGES, SPLICE PLATES AND STIFFENERS^(a)

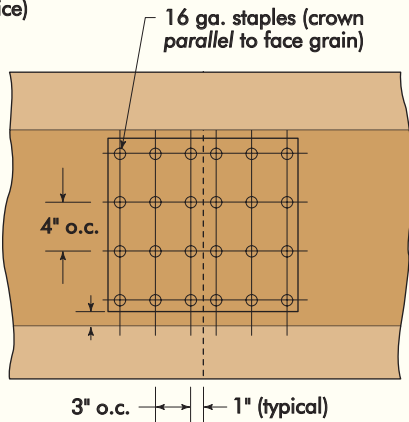
Web (field)



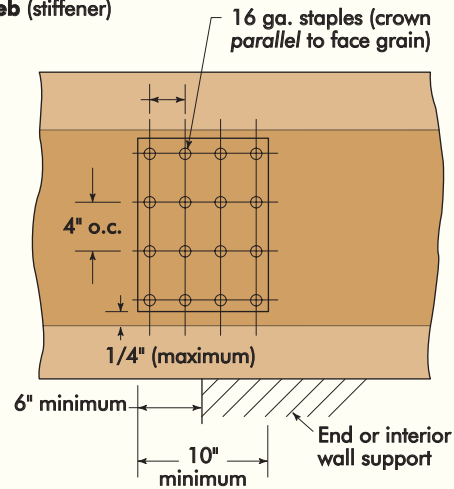
Web (joint)



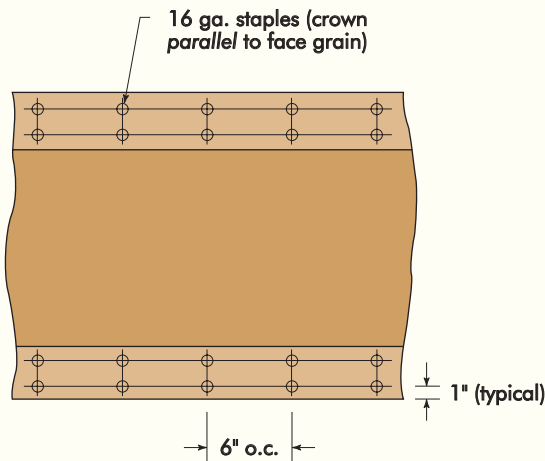
Web (splice)



Web (stiffener)



Flange



(a) Staple location tolerances shall be $\pm 1"$ for field spacings and $\pm 1/2"$ for edge distances, unless otherwise specified in the design.

3.3.3

Unless otherwise specified by the adhesive manufacturer, an adhesive spread rate of approximately 1.7 gallons per 100 square feet of glued area is suggested.

3.3.4

When web or flange laminations are glued under pressure, such pressure shall be applied by clamping or other mechanical means. Pressure shall be sufficient to provide adequate contact and insure good glue bonds (100 to 150 psi is suggested, unless otherwise specified by the adhesive manufacturer). Movement of the members shall be prevented until the adhesive develops sufficient handling strength, as recommended by the adhesive manufacturer.

3.3.5

In any case, it shall be the responsibility of the fabricator to produce a glue bond which meets or exceeds applicable specifications.

3.4 Staple Installation

3.4.1

Staples shall be installed with their crowns *parallel* to the plywood face-grain direction. Staple spacing shall be as shown in Figure 2.

3.4.2

Hand pressure may be needed during stapling to flatten plywood webs and flanges, to insure uniform contact between mating glued surfaces.

3.4.3

Installation of staples may start at any point, but shall progress to the end or ends of each piece.

3.5 Web Splices

Splices at butt joints in webs shall be as specified in the design. Butt joints shall be spliced with a plywood plate centered over the joint. The splice plate shall be glued over its full contact area and stapled to the web in accordance with Figure 2. The plate shall extend to at least 1/4 inch of each flange (if applicable), shall be equal in thickness to the web, of a length as specified in the design or in the PDS, and shall have its face-grain direction parallel with that of the web. In multiple-layer webs, the splice plate shall be directly glued to the web containing the butt joint.

3.6 Web Stiffeners

3.6.1

Stiffeners for single-layer webs shall be located as shown in the design, but in any case, they shall be placed at end supports and at interior concentrated-load points.

3.6.2

The stiffeners shall consist of a plywood plate glued over its full contact area and stapled to the web in accordance with Figure 2. The plate shall extend to at least 1/4 inch of each flange (if applicable), shall be at least equal in thickness to the web, of a length as specified in the design but in no case less than 10 inches, and shall have its face-grain direction parallel with that of the web. The end or ends of the stiffener shall extend at least 6 inches beyond the edge of the support at the end and any interior supports. Best performance will be obtained if the stiffener actually contacts the inner edges of the plywood flanges.

3.6.3

Cutouts for openings in plywood webs may be provided at locations shown in the design. Single-layer webs shall be reinforced at cutouts with a plywood web stiffener.

4. Test Samples

4.1 General

Quality control and testing of beams shall be in accordance with the requirements of the regulatory agency responsible for design approval and inspection.

5. Identification

5.1 General

If required, beams shall be identified as specified by the regulatory agency responsible for design approval or inspection.

5.2 Unsymmetrical Beams

If the beam is designed such that it must be installed with a specific orientation, the top edge shall be clearly marked so that the proper orientation can be verified during in-plant inspection of the construction.

LITERATURE CITED

- (1) *Voluntary Product Standard PS 1-07, Structural Plywood*. Office of Standards Services, National Institute of Standards and Technology. Available from APA – *The Engineered Wood Association*, Tacoma, Washington.
- (2) *Plywood Design Specification*. APA – *The Engineered Wood Association*, Tacoma, Washington.
- (3) *Simplified Method for Calculating Shear Deflection of Beams*. Orosz, Ivan. U.S. Department of Agriculture, Forest Service Research Note FPL-0210. Forest Products Laboratory, Madison, Wisconsin.
- (4) *National Design Specification for Wood Construction*. American Forest & Paper Association, Washington, D.C.
- (5) *Federal Manufactured Home Construction and Safety Standards*. U.S. Department of Housing and Urban Development, Washington, D.C.
- (6) D3930, *Standard Specification for Adhesives for Wood-Based Materials for Construction of Manufactured Homes*. ASTM International. West Conshohocken, Pennsylvania.
- (7) *Fastener Loads for Plywood Ridge Beam Connections*. Technical Note, Form M320. APA – *The Engineered Wood Association*, Tacoma, Washington.

APPENDIX A – DESIGN EXAMPLE FOR ALL-PLYWOOD BEAMS

Problem:

Given the 24-ft-span, 23-7/8-inch deep all-plywood ridge beam shown. Determine the allowable total load and deflection. Beam to be fabricated in accordance with Part 2, Fabrication of All-Plywood Beams.

Design is based on single-span condition, where deflection and bending stress are greatest. Shear stresses for multiple-span conditions may be as much as 25% greater than stresses for single-span conditions.

AI. Plywood Design Information

AI.1 Plywood Grade

Design is based on APA RATED SHEATHING Exposure 1 (panels marked PS 1).

AI.2 Plywood Layup

Design is based on 5-layer, 19/32" plywood. To avoid further restriction on availability, thickness of plies is not specified.

AI.3 Species Group

Design is based on plywood having all plies of Species Group 1.

AI.4 Effective Thickness

From Table 1, minimum $t_b = 0.289"$; $t_s = 0.707"$ for 19/32", 5-layer plywood.

AI.5 Allowable Stresses

Bending Stress (F_b)

From Part 1, Paragraph 1.5, the basic bending stress for 5-layer plywood is 3300 psi. This may be increased by 15% for snow-load duration.

$$F_b = 3300 \times 1.15 = 3800 \text{ psi}$$

Shear in Plane Perpendicular to Plies (F_v)

From Part 1, Paragraph 1.5, the allowable stress for shear in plane perpendicular to plies for beams with flanges top and bottom is 225 psi. This may be increased by 15% for snow-load duration.

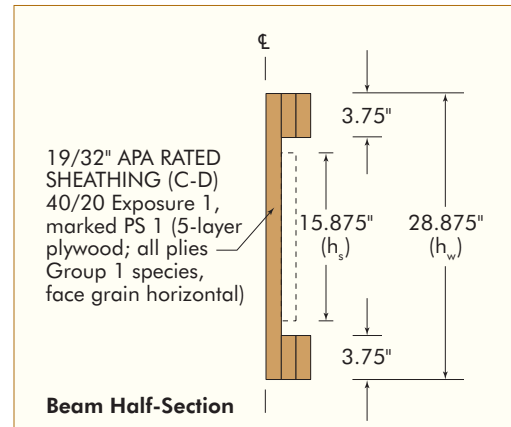
$$F_v = 225 \times 1.15 = 260 \text{ psi}$$

Rolling-Shear Stress (F_s)

From PDS Table 3, the basic rolling-shear stress is 53 psi for APA RATED SHEATHING Exposure 1.

Since this plywood has been specified as having all plies of Group 1 species, however, it is eligible for a basic stress of 75 psi. This stress must be reduced 50% in accordance with PDS Section 3.8.2 for stress concentration at the edge of the panel, but maybe increased by 15% for snow-load duration.

$$F_s = 75 \times 0.5 \times 1.15 = 43.1 \text{ psi}$$



Modulus of Elasticity in Pure Bending (E)

From PDS Table 3, the Modulus of Elasticity for plywood having face plies of Group 1 species is 1,800,000 psi. This value may be increased 10% to obtain E in pure bending when shear deflection is considered separately.

$$E = 1,800,000 \times 1.10 = 1,980,000 \text{ psi}$$

Shear Modulus (G)

From PDS Table 3, $G = 90,000$ psi for plywood having face plies of Group 1 species.

A2. Determine Total Load Based on Allowable Web and Flange Bending Stress

A2.1 Net Moment of Inertia (I_n)

For this design example, the following beam cross-sections are possible at web or flange joint locations:

A visual comparison of the three possible cross-sections reveals that the *minimum* section for bending stress calculations occurs at a web joint (Case 1).

$$I_{ws} (\text{web splice plate}) = \frac{\sum t_b h_s^3}{12} = \frac{0.289 \times 15.875^3}{12} = 96 \text{ in.}^4$$

$$I_f (\text{flanges}) = \frac{\sum t_b [h_w^3 - (h_w - 2d)^3]}{12} = \frac{2 \times 0.289 (23.875^3 - 16.375^3)}{12} = 444 \text{ in.}^4$$

$$I_n = I_{ws} + I_f = 96 + 444 = 540 \text{ in.}^4$$

A2.2 Calculate Total Load Based on Allowable Web and Flange Bending Stress (w_b)

$$w_b = \frac{8 F_b I_n}{12c L^2} = \frac{8 \times 3800 \times 540}{12 \times \frac{23.875}{2} \times 24^2} = 199 \text{ lb/ft}$$

A3. Determine Total Load Based on Allowable Web Shear Stress

A3.1 Total Moment of Inertia (I_t)

$$I_w (\text{web}) = \sum t_b h_w^3 = \frac{0.289 \times 23.875^3}{12} = 328 \text{ in.}^4$$

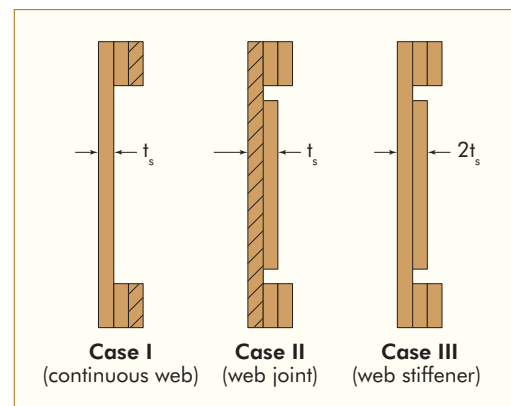
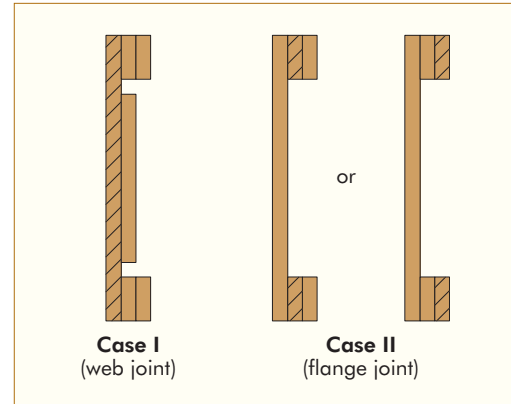
$$I_f (\text{flanges}) = 444 \text{ in.}^4 \text{ (from A2.1)}$$

$$I_t = I_w + I_f = 328 + 444 = 772 \text{ in.}^4$$

A3.2 Effective Total Web Shear Thickness (t_s)

For this design example, the effective web thickness (t_s) for shear calculations is shown on the following cross-sections which may occur along the beam:

A visual comparison of the three possible cross sections reveals that the minimum thickness for horizontal shear calculations occurs at either a continuous (unreinforced) web (Case I), or at a web joint (Case II). If the beam is detailed so that web joints are kept out of high-shear areas, then the controlling location will be in the unreinforced web, at the edge of the bear-



ing stiffeners, near the end support. Total t_s , therefore, equals 0.707 inches (Case D). The design method permits ignoring all loads within a distance from either support equal to h_w . Since clear span is given as 24 ft, the effective length for calculating w_v is 24 ft, less 2 ft at each end, or 20 ft.

A3.3 Statical Moment of Area of Parallel Plies (Q)

$$Q_{w(\text{web})} = \frac{\Sigma t_b h_w^2}{8} = \frac{0.289 \times 23.875^2}{8} = 20.6 \text{ in.}^3$$

$$Q_f(\text{flanges}) = \frac{\Sigma t_b d (h_w - d)}{2} = \frac{2 \times 0.289 \times 3.75 \times (23.875 - 3.75)}{2} = 21.8 \text{ in.}^3$$

$$Q = Q_w + Q_f = 20.6 + 21.8 = 42.4 \text{ in.}^3$$

A3.4 Calculate Total Load Based on Allowable Web Shear Stress (w_v)

$$w_v = \frac{2 F_v I_t \Sigma t_s}{Q L'} = \frac{2 \times 260 \times 772 \times 0.707}{42.4 \times 20} = 335 \text{ lb/ft}$$

Note: If a higher total load were required, the length of the web stiffener could be extended until the horizontal shear stress in the unreinforced web was within allowable limits.

A3.5 Calculate Total Load Based on Allowable Web Splice Plate Shear Stress (w_{sw})

$$w_{sw} = \frac{2 F_s A}{L'} = \frac{2 \times 43.1 \times 0.594 \times 12 \times 0.5 \times 15.875}{20} = 244 \text{ lb/ft}$$

Note: This calculation assumes that web butt joints are located 24 inches from end supports (minimum distance per Section 3.2 in Part 1 of this Specification); and splice plate length is twelve times nominal thickness of web.

A4. Calculate Total Load Based on Allowable Flange-Web Shear Stress (w_{sf})

$$w_{sf} = \frac{2 F_s I_t d}{Q_f L'} = \frac{2 \times 43.1 \times 772 \times 3.75}{21.8 \times 20} = 572 \text{ lb/ft}$$

where

$$I_t = 772 \text{ in.}^4 \text{ from A3.1}$$

$$Q_f = 21.8 \text{ in.}^3 \text{ from A3.3}$$

A5. Determine Final Total Allowable Load (w)

Stress Criterion	Total Load (lb/ft)
Bending (web and flange)	$w_b = 199$ (see A2)
Horizontal shear (web)	$w_v = 335$ (see A3)
Rolling shear (web splice)	$w_{sw} = 244$ (see A3)
Rolling shear (web-flange)	$w_{sf} = 572$ (see A4)

Therefore, the uniform-load capacity for the beam used in this design example is limited by the bending stress. The total allowable load for design is 199 lb/ft.

A6. Calculate Deflection at Total Allowable Load

A6.1 Bending Deflection (Δ_b)

$$\Delta_b = \frac{5 w L^4 \times 1728}{384 E I_t} = \frac{5 \times 199 \times 24^4 \times 1728}{384 \times 1,980,000 \times 772} = 0.972 \text{ in.}$$

A6.2 Shear Deflection (Δ_s)

A6.2.1 Shear Deflection Constant, K

$$r = \frac{\Sigma t_s}{b} = \frac{0.707}{3 \times 0.707} = 0.33$$

$$\frac{h_w - 2d}{h_w} = \frac{23.875 - 2 \times 3.75}{23.875} = 0.69$$

From Figure 1, page 8:

$$\text{For } r = 0.33 \text{ and } \frac{h_w - 2d}{h_w} = 0.69, K = 1.70$$

A6.2.2 Effective Shear Area (A_s)

$$A_s = A_{sw} + A_{sf} = \Sigma t_s h_w + \Sigma t_s d = 0.707 \times 23.875 + 2 \times 2 \times 0.707 \times 3.75$$

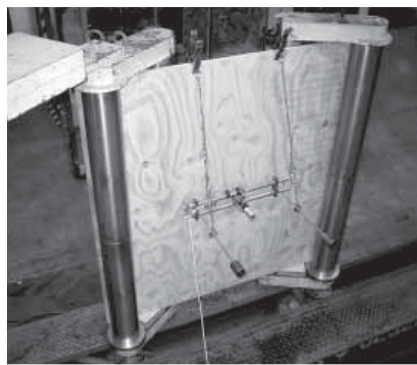
$$A_s = 27.5 \text{ in}^2$$

A6.2.3 Calculate Δ_s

$$\Delta_s = \frac{K w L^2}{8 A_s G} = \frac{1.70 \times 199 \times 24^2 \times 12}{8 \times 27.5 \times 90,000} = 0.118 \text{ in.}$$

A6.3 Calculate Total Deflection (Δ)

$$\Delta = \Delta_b + \Delta_s = 0.972 + 0.118 = 1.090 \text{ in.} = L/265 @ w = 199 \text{ lb/ft}$$



APA – The Engineered Wood Association’s 42,000-square-foot Research Center in Tacoma, Washington is one of the most sophisticated facilities for basic panel research and testing in the world. The center is staffed with an experienced corps of engineers, wood scientists, and wood product technicians. Their research and development assignments directly or indirectly benefit all specifiers and users of engineered wood products.

Design and Fabrication of All Plywood Beams

We have field representatives in many major U.S. cities and in Canada who can help answer questions involving APA trademarked products. For additional assistance in specifying engineered wood products, contact us:

APA HEADQUARTERS

7011 So. 19th St. ■ Tacoma, Washington 98466 ■ (253) 565-6600 ■ Fax: (253) 565-7265

www.apawood.org



PRODUCT SUPPORT HELP DESK

(253) 620-7400 ■ E-mail Address: help@apawood.org

DISCLAIMER

The information contained herein is based on APA – The Engineered Wood Association’s continuing programs of laboratory testing, product research and comprehensive field experience. Neither APA, nor its members make any warranty, expressed or implied, or assume any legal liability or responsibility for the use, application of, and/or reference to opinions, findings, conclusions or recommendations included in this publication. Consult your local jurisdiction or design professional to assure compliance with code, construction and performance requirements. Because APA has no control over quality of workmanship or the conditions under which engineered wood products are used, it cannot accept responsibility for product performance or designs as actually constructed.

Form No. H815F/Revised November 2008



REPRESENTING THE ENGINEERED WOOD INDUSTRY