

# PLYWOOD DESIGN SPECIFICATION

January 1997



**A P A**

*The Engineered Wood Association*

# APA

## The Engineered Wood Association

### DO THE RIGHT THING RIGHT™

**Wood is good.** It is the earth's natural, energy efficient and renewable building material.

**Engineered wood is a better use of wood.** It uses less wood to make more wood products.

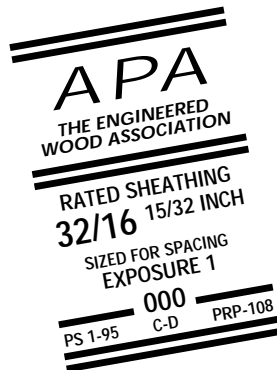
That's why using APA trademarked I-joists, glued laminated timbers, laminated veneer lumber, plywood and oriented strand board is the right thing to do.

#### A few facts about wood.

- **We're not running out of trees.** One-third of the United States land base – 731 million acres – is covered by forests. About two-thirds of that 731 million acres is suitable for repeated planting and harvesting of timber. But only about half of the land suitable for growing timber is open to logging. Most of that harvestable acreage also is open to other uses, such as camping, hiking, hunting, etc.
- **We're growing more wood every day.** 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.
- **Manufacturing wood products 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.
- **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.

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

Wood. It's the right product for the environment.



**NOTICE:**  
The recommendations in this report apply only to panels that bear the APA trademark. Only panels bearing the APA trademark are subject to the Association's quality auditing program.

This Specification presents section properties, recommended design stresses, and design methods for plywood when used in building construction and related structures. Design information on other plywood applications such as concrete forming, trench shoring, pallets, bins, tanks, shelving and agricultural structures can be found in other APA publications. The information stems from extensive and continuing test programs conducted by APA – *The Engineered Wood Association*, by other wood associations, and by the United States Forest Products Laboratory, and is supported by years of satisfactory experience. Information in this Specification applies to untreated (except as noted) construction and industrial plywood made in accordance with Voluntary Product Standard PS 1-95, promulgated by the United States Department of Commerce, and/or with APA manufacturing specifications.

The technical data in this Specification are presented as the basis for competent engineering design. For such design to result in satisfactory service, adequate materials and fabrication are also required.

All plywood should bear the trademark of APA – *The Engineered Wood Association*. All lumber should bear the grademark of a recognized lumber-grading agency.

Supplements to this Specification present design methods and fabrication specifications for glued plywood components and other units where plywood performs a major structural function.

The plywood use recommendations contained in this publication are based on the continuing programs of laboratory testing, product research and comprehensive field experience of APA – *The Engineered Wood Association*. However, there are wide variations in quality of workmanship and in the conditions under which plywood is used. Because the Association has no control over those elements of fabrication, it cannot accept responsibility for plywood performance or for designs as actually constructed.

**Technical Services Division**

**APA – *The Engineered Wood Association***

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# 1. GENERAL REQUIREMENTS FOR PLYWOOD STRUCTURAL DESIGN

This publication presents section properties, allowable stresses, and practices to be followed in designing buildings and related structures with plywood. Presentation of this design information is not intended to preclude further development. Where adequate test data are available, therefore, the design properties and provisions may be modified. If they are modified, any such change must be noted when referring to this publication.

In this specification the word “shall” is mandatory and the word “should” is advisory. Explanatory information and examples are included throughout this Specification in *italics* to aid the user, and are not a formal part of the Specification.

## 1.1 Scope

### 1.1.1 Practice Defined

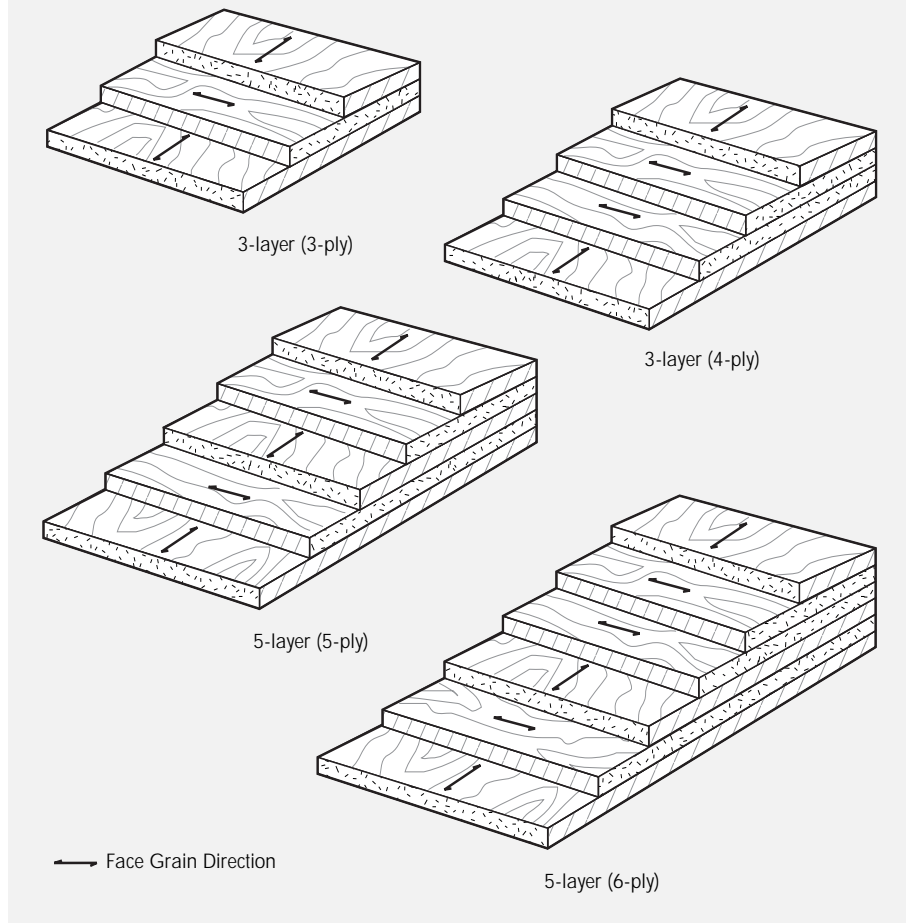
This Specification defines the practice to be followed in structural design of buildings and related structures with plywood when used in conventional, mechanically fastened applications, and in glued structural assemblies.

### 1.1.2 Competent Supervision

The plywood section properties given in Tables 1 and 2, and the allowable unit stresses given in Table 3, are for designs made and carried out under competent supervision, and for plywood of assured type and grade.

FIGURE 1.1

TYPICAL THREE- AND FIVE-LAYER CONSTRUCTION WITH PARALLEL-LAMINATED CROSS BANDS IN THE 4- AND 6-PLY PANELS.



## 1.2 Plywood Manufacture

The manufacturing steps for construction and industrial plywood are basically the same for all species. Plywood is manufactured with an odd number of layers, each layer consisting of one or more sheets of veneer (thin sheets of wood). The layers are glued together with the grain of adjacent layers at right angles. (See Figure 1.1.) Veneer for panels covered in this Specification is usually “rotary peeled” rather than sliced or sawn.

Plywood is manufactured from peeler logs cut into “blocks” usually about 8-1/2 feet long. The blocks are then placed in a giant lathe and rotated against a long knife which peels the wood off in long, continuous, thin sheets known as veneer. The veneer is conveyed to clippers which cut it to desired widths, after which it is run through dryers and reduced to about two to five percent moisture content. After careful grading, the veneer goes to the glue spreaders where adhesive is applied and the plywood panel is laid up.

The plywood is then generally hot-pressed in a large multi-opening hydraulic press. The application of both heat and pressure cures the glue in a matter of minutes. After removal from the press, panels are trimmed to size, and some grades are sanded. Plywood produced by APA – The Engineered Wood Association member mills to conform with Voluntary Product Standard PS 1-95 carries a trademark on every panel. This mark permits easy identification and assures the consumer of a quality product.

### **1.2.1 Product Standard**

Plywood type, grade, and species group where required, shall be specified by commercial designations as outlined in the latest edition of VOLUNTARY PRODUCT STANDARD PS 1-95 FOR CONSTRUCTION AND INDUSTRIAL PLYWOOD.

### **1.3 Exposure Durability Classification**

Plywood is made in four exposure durability classifications – Exterior, Exposure 1, IMG or Exposure 2, and Interior. The classification is made on the basis of resistance of the gluebond to moisture, as affected by the adhesive used, veneer grade and panel construction.

*Some allowable stresses vary with exposure durability classification.*

#### **1.3.1 Exterior**

Plywood that is permanently exposed to the weather shall be Exterior.

*Exterior plywood is made with fully waterproof glue and, in addition, is composed of C-grade or better veneers throughout. This combination provides maximum resistance to the effects of daily cyclic variations of moisture and temperature caused by permanent exposure to weather.*

#### **1.3.2 Exposure 1**

Exposure 1 plywood may be used for applications which are not permanently exposed to the weather.

*Exposure 1 plywood is made with fully waterproof glue, but may include D-grade veneers. It is suitable for applications where long construction delays may be expected prior to providing protection, or where high moisture conditions may be encountered in service. It is also suitable for pressure-preservative or fire-retardant treatment.*

*Because of the veneer grades used, panels under prolonged severe moisture conditions may occasionally develop limited, highly localized glue-line delaminations coincident with grade characteristics. However, such localized delamination, within allowable limits defined in Voluntary Product Standard PS 1-95, will not affect structural performance.*

#### **1.3.3 IMG (intermediate glue) or Exposure 2**

IMG or Exposure 2 plywood may be used for protected applications which are not continuously exposed to high humidity conditions.

*IMG or Exposure 2 plywood is made with glue of intermediate resistance to moisture. It may be used where conditions of intermittent high humidity may exist. Check local suppliers for availability before specifying Exposure 2.*

#### **1.3.4 Interior**

Interior plywood may be used for permanently protected interior applications.

*Interior plywood is made with moderately moisture resistant interior glue. Short periods of humidity up to 90% in service can usually be tolerated.*

### **1.4 Plywood Grade**

Plywood is graded according to one of two basic systems. The first system includes the unsanded C- D Interior and C-C Exterior sheathing panels designated APA RATED SHEATHING, and the touch-sanded Underlayment panels 19/32" or thicker designated APA RATED STURD-I-FLOOR.® RATED SHEATHING may be modified by the term STRUCTURAL I. Plywood panels conforming to this system are designated by a thickness or Span Rating without reference to veneer species. See Section 1.4.1.

*Plywood panels of several grades may be modified by the STRUCTURAL I designation. This term is intended to identify panels conforming to special provisions of PS 1. STRUCTURAL I is intended for use where shear and cross-panel strength properties are of maximum importance, as in panelized roofs and diaphragms. STRUCTURAL I is limited to Group 1 species. (See Section 1.5 for Species Groups.) STRUCTURAL I is made only with exterior glue, and has some further restrictions, as on knot size and repairs.*

Panels in grades other than those mentioned above are designated by the panel thickness, by the veneer grade classification of face and back veneers, and by the species group of the veneers. PLYFORM is an exception, where Class designates a species mix.

#### **1.4.1 Span Rating**

The Span Rating used on sheathing panels is a measure of plywood stiffness and strength parallel to the face grain. It consists of two numbers presented in a manner similar to a fraction. The number on the left in the Span Rating gives the maximum spacing for roof supports

under average loading conditions (good for 30 psf live load, or better). The number on the right of the slash shows the maximum spacing for floor supports, again under average residential loading. (Maximum allowable uniform loads vary, but all are 100 psf or more. Strength is adequate to carry heavy concentrated loads such as pianos, home freezers, water heaters, etc.) For APA RATED STURD-I-FLOOR panels the Span Rating is a single number indicating the maximum spacing of supports for combination subfloor-underlayment under average residential loading.

The "Span Rating" system was established to simplify specification of plywood without resorting to specific structural engineering design. This system indicates performance without the need to refer to species group or panel thickness. It gives the allowable span when the face grain is placed across supports. Span Ratings and load capacities are based on untreated panels, and may not apply following fire-retardant treatment (see Section 3.3.2.2).

For roof sheathing, therefore, on a 24-inch span, the user will specify APA RATED SHEATHING 24/0, which in actuality might be 3/8" Group 1, or 1/2" Group 2, 3, or 4 plywood. So that there need be no problem with differing thicknesses on the same job, panels should also be specified as to thickness. Initially, the user might not care whether his 24/0 plywood were 3/8" or 1/2", but if he reordered he would wish to have the same thickness with which he started. His reorder, then, might read 3/8" APA RATED SHEATHING 24/0.

*Voluntary Product Standard PS 1-95 includes provisions for performance testing to qualify a plywood panel construction for a Span Rating as an alternate to traditional prescriptive thickness and species requirements. When combined with prescriptive options, the result is that each Span Rating number applies to several different panel constructions, with similar strength and stiffness. Thus, the section properties listed may be quite conservative for some panels.*

#### **1.4.2 Veneer Classifications**

Veneer is divided into essentially five levels as follows: (These veneer classifications are referred to as "veneer grades.")

- N and A – Highest grade level. No knots, restricted patches. *N is intended for natural finish while A is intended for a paintable surface. Check local suppliers for availability of N grade before specifying.*
- B – Solid surface – Small round knots. Patches and round plugs are allowed. *Most common use is faces for PLYFORM.*
- C – Special improved C grade. *Used in APA RATED STURD-I-FLOOR and UNDERLAYMENT.*
- Plugged C – Small knots, knotholes, patches. Lowest grade allowed in Exterior-type plywood. *For sheathing faces, and inner plies in Exterior panels.*
- D – Larger knots, knotholes, some limited white pocket in sheathing grades. This grade not permitted in Exterior panels.

## **1.5 Wood Species**

The woods which may be used to manufacture plywood under Voluntary Product Standard PS 1-95 are classified into five groups based on elastic modulus in bending, and important strength properties. Most woods listed in Table 1.5 are individual species but some are trade groups of related species commonly traded under a single name without further identification.

Design stresses for a group are determined from the clear wood group assignments developed using principles set forth in ASTM D-2555, ESTABLISHING CLEAR WOOD STRENGTH VALUES. Design stresses are published for groups 1 through 4. All woods within a group are assigned the same working stress.

*The species grouping system is designed to simplify the design and identification that would otherwise be necessary for the seventy-some species and trade groups of wood from which construction plywood may be manufactured. Thus, the designer need only concern himself with four design stress groups rather than seventy.*

*The group classification of a plywood panel is usually determined by the face and back veneer with the inner veneers allowed to be of a different group. Certain grades such as MARINE and the STRUCTURAL I grades, however, are required to have all plies of Group 1 species.*

TABLE 1.5

## CLASSIFICATION OF SPECIES

Group 1	Group 2	Group 3	Group 4	Group 5 <sup>(a)</sup>
<b>Apitong</b> <sup>(b)(c)</sup>	<b>Cedar, Port</b>	<b>Maple, Black</b>	<b>Alder, Red</b>	<b>Aspen</b>
<b>Beech, American</b>	<b>Orford</b>	<b>Mengkulang</b> <sup>(b)</sup>	<b>Birch, Paper</b>	Bigtooth Quaking
<b>Birch</b>	<b>Cypress</b>	<b>Meranti, Red</b> <sup>(b)(e)</sup>	<b>Cedar, Alaska</b>	<b>Cativo</b>
Sweet	<b>Douglas-Fir 2</b> <sup>(d)</sup>	<b>Mersawa</b> <sup>(b)</sup>	<b>Fir, Subalpine</b>	<b>Cedar</b>
Yellow	<b>Fir</b>	<b>Pine</b>	<b>Hemlock,</b>	Incense Western Red
<b>Douglas-Fir 1</b> <sup>(d)</sup>	Balsam	Pond	<b>Eastern</b>	
<b>Kapur</b> <sup>(b)</sup>	California Red	Red	<b>Maple, Bigleaf</b>	<b>Cottonwood</b>
<b>Keruing</b> <sup>(b)(c)</sup>	Grand	Virginia	<b>Pine</b>	Eastern
<b>Larch, Western</b>	Noble	Western White	Jack	Black (Western Poplar)
<b>Maple, Sugar</b>	Pacific Silver	<b>Spruce</b>	Lodgepole	<b>Pine</b>
<b>Pine</b>	White	Black	Ponderosa	Eastern White
Caribbean	<b>Hemlock, Western</b>	Red	Spruce	Sugar
Ocote	<b>Lauan</b>	Sitka	<b>Redwood</b>	
<b>Pine, Southern</b>	Almon	<b>Sweetgum</b>	<b>Spruce</b>	
Loblolly	Bagtikan	<b>Tamarack</b>	Engelmann	
Longleaf	Mayapis	<b>Yellow-poplar</b>	White	
Shortleaf	Red Lauan			
Slash	Tangile			
<b>Tanoak</b>	White Lauan			

(a) Design stresses for Group 5 not assigned.

(b) Each of these names represents a trade group of woods consisting of a number of closely related species.

(c) Species from the genus Dipterocarpus are marketed collectively: Apitong if originating in the Philippines; Keruing if originating in Malaysia or Indonesia.

(d) Douglas-fir from trees grown in the states of Washington, Oregon, California, Idaho, Montana, Wyoming, and the Canadian Provinces of Alberta and British Columbia shall be classed as Douglas-fir No. 1. Douglas-fir from trees grown in the states of Nevada, Utah, Colorado, Arizona and New Mexico shall be classed as Douglas-fir No. 2.

(e) Red Meranti shall be limited to species having a specific gravity of 0.41 or more based on green volume and oven dry weight.

## 2. PLYWOOD SECTION PROPERTIES

### 2.1 Application

Engineering section properties per foot of width are presented in Tables 1 and 2, pages 13 and 14. The tables are to be used for species and grade combinations as indicated in the "Guide to Use of Allowable Stress and Section Properties Tables," pages 16 and 17. The section properties shall be used in conjunction with the allowable stresses for the species group of the face plies. Stresses are as given in Table 3, page 15.

Section properties from Table 1 shall apply for all panels having veneers from mixed species groups, including most grades covered by Product Standard PS 1-95. Grades included in Table 2 are STRUCTURAL I and MARINE. These grades have all veneers from species Group 1 and certain other layup limitations. Both Tables 1 and 2 have separate section properties for unsanded, sanded and touch-sanded panels. Grades normally touch-sanded are APA RATED STURD-I-FLOOR, UNDERLAYMENT, C-D PLUGGED and C-C PLUGGED.

*Section properties for plywood are presented so that the engineer may design with the material as if it were a homogeneous orthotropic plate – a plate with different properties in the three directions. By using the corrected, or "effective" properties, the engineer need not concern himself with the actual multilayered makeup of the material.*

*The "effective" section properties presented in Tables 1 and 2 are computed by the transformed-section technique, taking into account the orthotropic nature of wood, the species groups used for outer and inner plies, and the manufacturing variables involved for each grade. Because these tables, in order to remain concise, represent a wide variety of grades and constructions possible under the Product Standard, the section properties presented are generally the minimums that can be expected. Hence, the actual panel obtained in the market place will usually have a section property greater than that represented in this Specification.*

*For the case of Span-Rated unsanded and touch-sanded panels, section properties for certain thicknesses have been combined in Tables 1 and 2. The performance testing provisions of Voluntary Product Standard PS 1-95 contemplate equal performance for each combination of thicknesses, since Span Ratings applied to the panels are the same.*

*Note that the section properties are reported per foot of width, and referred to the face grain direction. Where the stress is applied parallel to the face grain, the "parallel" section property should be used. Such is the case for most applications, where the panel is installed with the grain of the face plies across the supports. When stresses will be introduced in the cross-panel direction, the "perpendicular" properties should be used. This condition occurs when the panel is installed with the face grain parallel to the supports. For further detail note Figure 2.1 for a standard four-by-eight-foot panel.*

*The section properties included in Tables 1 and 2 are independent of the number of plies used in panel construction. For the majority of plywood applications, the specification of plywood type and grade is sufficient. However, in certain critical designs, such as slave pallets and panelized roofs, the panel construction may be critical. If such information is required for a particular design, it may be obtained from the Technical Services Division, APA – The Engineered Wood Association.*

*Normally all panels with A or B grade faces are sanded. Sheathing grade panels such as APA RATED SHEATHING are unsanded. APA RATED STURD-I-FLOOR, UNDERLAYMENT and the plugged grades*



are “touch-sanded,” and consequently have different section properties. Sanded section properties should be used for overlaid panels such as MDO or HDO.

## 2.2 Direction of Face Grain

Section properties parallel to the face grain of the plywood are based on a panel construction which gives minimum values in that direction. Properties perpendicular to the face grain are based

on a (usually) different panel construction, which gives minimum values in that direction. Both values, therefore, are conservative. Properties for the two directions, however, can not be added to achieve properties of the full panel.

*The reason for using different layups in calculation is that plywood mills may use different layups for the same panel thickness to make optimum use of raw materials. For a standard four-by-eight-foot plywood panel, the face-grain direction is parallel to the*

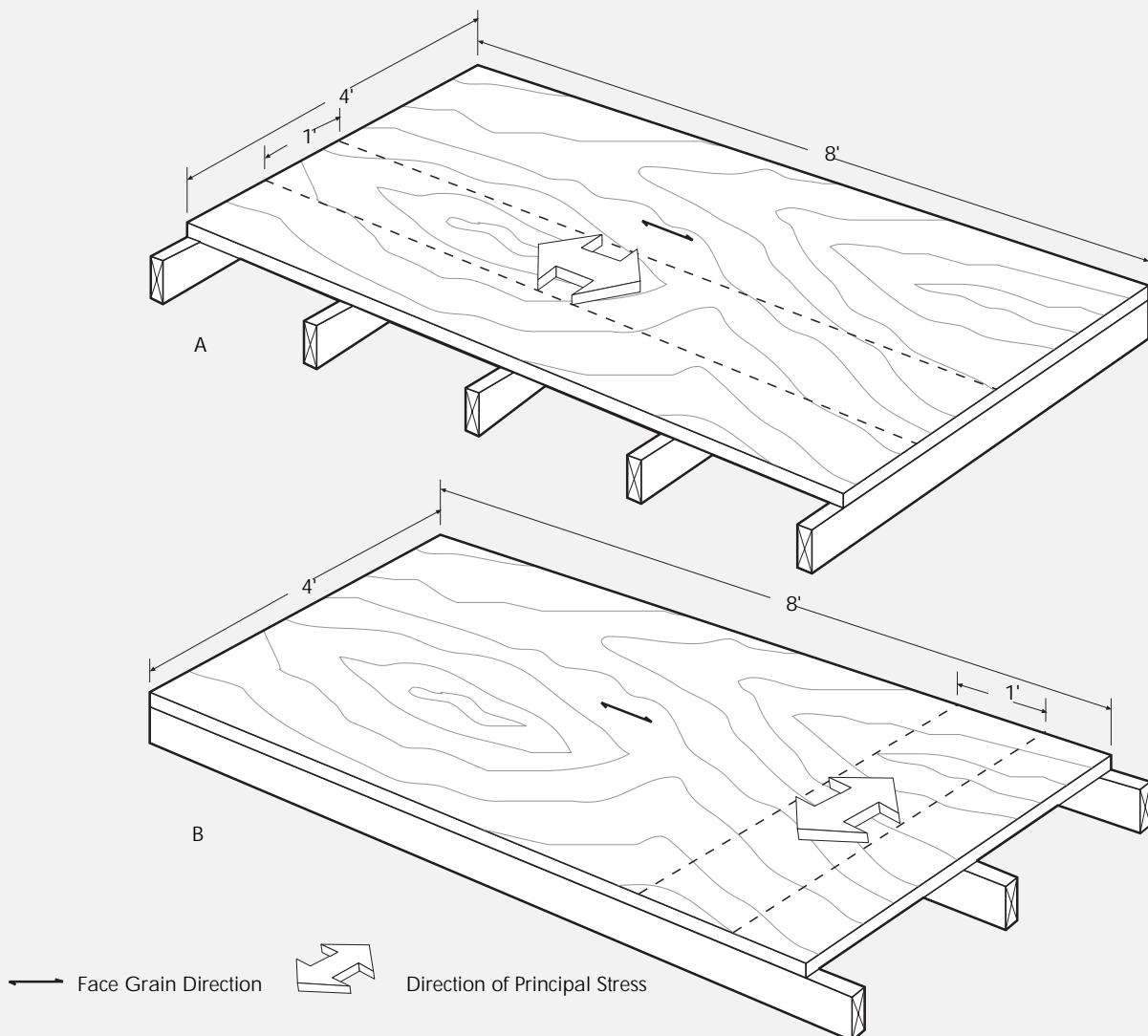
*eight-foot edge (Figure 2.1). Design calculations must take into account in which direction the stresses will be imposed in the panel. If stresses can be expected in both directions, then both the parallel and perpendicular directions should be checked.*

## 2.3 Weight

Approximate plywood weight in pounds per square foot (psf) for calculating actual dead loads shall be as given in Column 2 of Tables 1 and 2.

FIGURE 2.1

TYPICAL PLYWOOD PANEL WITH FACE GRAIN DIRECTION PERPENDICULAR TO OR ACROSS SUPPORTS (A) AND PARALLEL TO SUPPORTS (B). NOTE STANDARD 4' x 8' SIZE, FACE GRAIN DIRECTION, AND REPRESENTATIVE PORTION OF PANEL USED IN CALCULATION OF SECTION PROPERTIES FOR STRESS PARALLEL (A) OR PERPENDICULAR (B) TO THE FACE GRAIN.



## 2.4 Thickness (Except Shear)

Plywood thickness for calculation shall be the nominal thickness as given in Column 1 of Tables 1 and 2, except in calculating shear through the thickness.

*Plywood panel thickness used for computing section properties was the nominal thickness minus one-half of the allowable thickness tolerance permitted under Voluntary Product Standard PS 1-95. This less-than-nominal thickness insures that engineering computations will represent the near minimum that could be encountered in the market place.*

## 2.5 Thickness for Shear

Plywood panel thickness for calculation of shear through the thickness shall be as given in Column 3 of Tables 1 and 2. It shall be used in conjunction with the allowable shear stresses given in Table 3 for the species group of the face plies.

*The calculated effective thickness for shear through the thickness includes provisions to compensate for the reduced effectiveness of inner plies in mixed-species panels and also for the additional shear resistance afforded by the glue. The resulting value is directly related to veneer thickness, panel construction and number of glue lines in the panel. An explanation of shear through the thickness is provided in Section 3.8.1.*

## 2.6 Areas for Tension and Compression

Effective areas for calculation of allowable tension and compression shall be as given in Columns 4 and 8 of Tables 1 and 2. The allowable tension or compression stress to be used with these areas is that given in Table 3 for the species group of the face veneers.

*Areas effective for tension and compression are based on those plies whose grain is parallel with the stress, since perpendicular*

*plies are assumed to contribute essentially nothing to tensile and compressive strength.*

## 2.7 Moment of Inertia

Effective moments of inertia shall be as given in Columns 5 and 9 of Tables 1 and 2. They shall be used in stiffness calculations, in conjunction with the modulus of elasticity given in Table 3 for the species group of the face plies. THEY SHALL NOT BE USED IN BENDING-STRESS CALCULATIONS.

*The effective moments of inertia listed in Tables 1 and 2 have been adjusted to account for several variables, with the result that the adjusted values presented in the table may be used in conjunction with the modulus of elasticity of the face plies, in either direction, without reference to actual physical make-up of the panel. These effective properties were calculated with adequate recognition for the reduced effectiveness of perpendicular plies. The need for making these adjustments stems from the fact that the actual modulus of elasticity of peeled wood veneer perpendicular to the grain is only about 1/35 that of its parallel modulus. Also compensated is the effect of use of the weakest permitted species group. Figure 2.2 shows a plywood cross section for a five-ply, five-layer panel and its transformed section for computation.*

*Moment of inertia,  $I$ , may be used only in stiffness calculations, with  $KS$  used in bending-stress calculations. The reason for this practice is that, for some applications of plywood, section modulus is not simply equal to moment of inertia  $I$ , divided by distance to extreme fiber,  $c$ . See next section on section modulus. Note that the " $T$ " listed is for panels used "flat" with loads applied perpendicular to the plane of the panel. For computing  $I$  of panels loaded on edge, in plane of plies, see Plywood Design Specification Supplement 2, DESIGN AND FABRICATION OF PLYWOOD-LUMBER BEAMS.*

## 2.8 Section Modulus

Effective section moduli for plywood shall be as given in Columns 6 and 10 of Tables 1 and 2. They shall be used in bending-stress calculations in conjunction with the allowable stresses in flexure for the species group of the face plies, from Table 3.

*The effective section moduli presented have been computed taking into account species of plies, direction, and an empirical correction factor " $K$ ." The computations follow the principles presented in U.S. Forest Service Research Note FPL-059, BENDING STRENGTH AND STIFFNESS OF PLYWOOD.*

*The tabulated  $KS$  values must always be used in calculations for bending strength, rather than using  $I/c$ . The reason is that, in accordance with FPL-059, section moduli perpendicular to the grain have been calculated ignoring the outermost tension ply. This outermost ply on the tension side of a plywood panel stressed perpendicular to face grain adds little strength to the panel.*

*Note that the  $KS$  listed is for panels used "flat." For computing  $S$  of panels used vertically see Plywood Design Specification Supplement 2, DESIGN AND FABRICATION OF PLYWOOD-LUMBER BEAMS.*

## 2.9 Rolling-Shear Constant

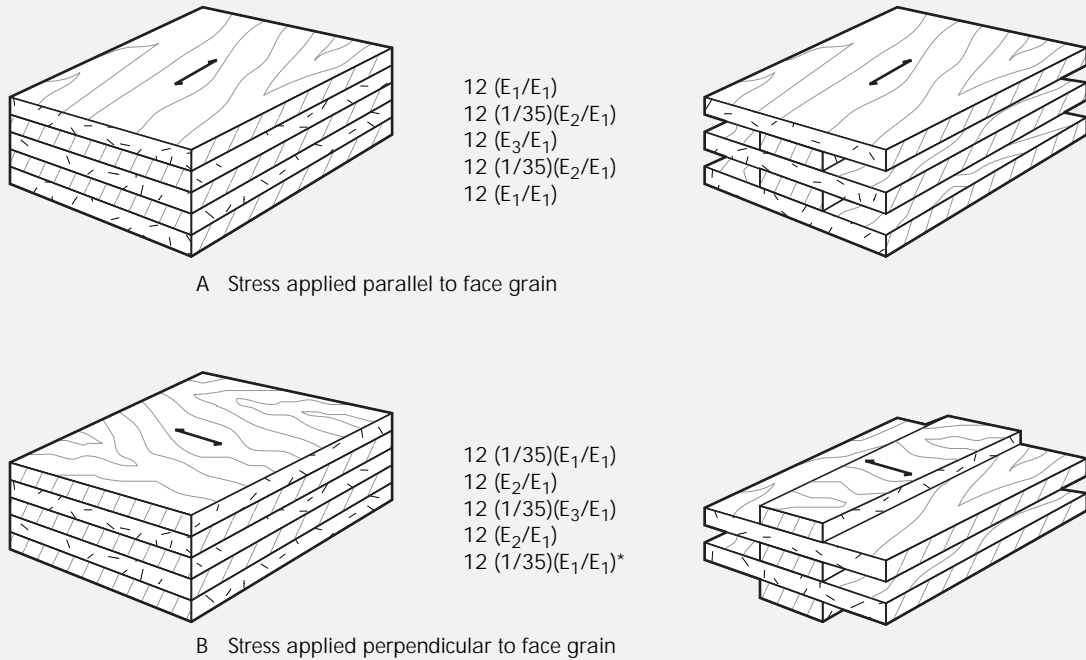
The rolling-shear constant,  $I_b/Q$ , from Column 7 or 11 of Tables 1 and 2 shall be used in conjunction with the allowable stress in rolling shear listed in Table 3 for the appropriate type and grade of plywood.

*The rolling-shear constant is presented simply as a convenience for use in the usual shear equation  $V = F_s(I_b/Q)$ .*

*A graphic description of rolling shear is shown in Figure 3.3, page 22.*

FIGURE 2.2

TRANSFORMED SECTIONS FOR A FIVE-LAYER (5-PLY) PLYWOOD PANEL. GROSS CROSS SECTIONS ON THE LEFT AND TRANSFORMED CROSS SECTIONS ON THE RIGHT. TRANSFORMED SECTIONS USED FOR CALCULATING LISTED SECTION PROPERTIES FOR STRESS PARALLEL (A) AND PERPENDICULAR (B) TO THE FACE GRAIN.



\*Note: This ply ignored in calculation of section modulus, KS. See Section 2.8.

### 3. STIFFNESS AND DESIGN STRESSES FOR PLYWOOD

#### 3.1 General

The allowable unit stresses and moduli of elasticity presented in Table 3, or modifications thereof, shall be used in accordance with the provisions of this Specification. Actual stress, computed on the basis of section properties given in Section 2, shall not exceed the allowable unit stresses shown in Table 3, except as hereafter modified. Moduli of

elasticity and allowable stresses for species group of the faces are to be used, in both parallel and perpendicular directions. Plywood with finger or scarf joints manufactured in accordance with Voluntary Product Standard PS 1-95 may be assumed to carry the full allowable stresses as reported in Table 3.

*Allowable unit stresses and moduli of elasticity presented in Table 3 are appropriate for design of building elements and related structures. Other applications may require downward or upward adjustment consistent with risk and use experience.*

*The designer may use the allowable stresses assigned to the species group used for the*

*face plies, regardless of actual species used in inner plies, since section properties have been adjusted to compensate for such differing materials.*

*To assist the designer in application of Tables 1 through 3, a guide to the use of these tables has been provided. The purpose of this guide is to present those plywood grades that are most often used in engineering design, and relate them to the tables of section properties and allowable stresses.*

*The allowable stresses reported in Table 3 are the result of continuing research by the Technical Services Division of APA – The Engineered Wood Association.*

(Section 3 continued on page 18.)

## KEY TO SPAN RATING AND SPECIES GROUP

For panels with "Span Rating" as across top, and thickness as at left, use stress for species group given in table.

(1) Thicknesses not applicable to APA RATED STURD-I-FLOOR.

(2) For APA RATED STURD-I-FLOOR 24 oc, use Group 4 stresses.

Thickness (in.)	Span Rating (APA RATED SHEATHING grade)						
	12/0	16/0	20/0	24/0	32/16	40/20	48/24
	Span Rating (STURD-I-FLOOR grade)						
	16 oc	20 oc	24 oc	48 oc			
5/16	4	3	1				
3/8			4	1			
15/32 & 1/2				4	1 <sup>(1)</sup>		
19/32 & 5/8					4	1	
23/32 & 3/4						4	1
7/8							3 <sup>(2)</sup>
1-1/8							1

## GUIDE TO USE OF ALLOWABLE STRESS AND SECTION PROPERTIES TABLES

### INTERIOR OR PROTECTED APPLICATIONS

Plywood Grade	Description and Use	Typical Trademarks	Veneer Grade			Common Thicknesses	Grade Stress Level (Table 3)	Species Group	Section Property Table
			Face	Back	Inner				
APA RATED SHEATHING EXP 1 or 2 <sup>(3)</sup>	Unsanded sheathing grade for wall, roof, subflooring, and industrial applications such as pallets and for engineering design, with proper stresses. Manufactured with intermediate and exterior glue. <sup>(1)</sup> For permanent exposure to weather or moisture only Exterior type plywood is suitable.		C	D	D	5/16, 3/8, 15/32, 1/2, 19/32, 5/8, 23/32, 3/4	S-3 <sup>(1)</sup>	See "Key to Span Rating"	Table 1 (unsanded)
APA STRUCTURAL I RATED SHEATHING EXP 1 <sup>(3)</sup>	Plywood grades to use where shear and cross-panel strength properties are of maximum importance. Made with exterior glue only. Structural I is made from all Group 1 woods.		C	D	D	5/16, 3/8, 15/32, 1/2, 19/32, 5/8, 23/32, 3/4	S-2	Group 1	Table 2 (unsanded)
APA RATED STURD-I-FLOOR EXP 1 or 2 <sup>(3)</sup>	For combination subfloor-underlayment. Provides smooth surface for application of carpet and pad. Possesses high concentrated and impact load resistance during construction and occupancy. Manufactured with intermediate and exterior glue. Touch-sanded. <sup>(4)</sup> Available with tongue-and-groove edges. <sup>(5)</sup>		C	D	C & D	19/32, 5/8, 23/32, 3/4, 1-1/8 (2-4-1)	S-3 <sup>(1)</sup>	See "Key to Span Rating"	Table 1 (touch-sanded)
APA UNDERLAYMENT EXP 1, 2 or INT	For underlayment under carpet and pad. Available with exterior glue. Touch-sanded. Available with tongue-and-groove edges. <sup>(5)</sup>		C	D	C & D	1/2, 19/32, 5/8, 23/32, 3/4	S-3 <sup>(1)</sup>	As specified	Table 1 (touch-sanded)
APA C-D PLUGGED EXP 1, 2 or INT	For built-ins, wall and ceiling tile backing. Not for underlayment. Available with exterior glue. Touch-sanded. <sup>(5)</sup>		C	D	D	1/2, 19/32, 5/8, 23/32, 3/4	S-3 <sup>(1)</sup>	As Specified	Table 1 (touch-sanded)
APA APPEARANCE GRADES EXP 1, 2 or INT	Generally applied where a high quality surface is required. Includes APA N-N, N-A, N-B, N-D, A-A, A-B, A-D, B-B, and B-D INT grades. <sup>(5)</sup>		B or better	D or better	C & D	1/4, 11/32, 3/8, 15/32, 1/2, 19/32, 5/8, 23/32, 3/4	S-3 <sup>(1)</sup>	As Specified	Table 1 (sanded)

# GUIDE TO USE OF ALLOWABLE STRESS AND SECTION PROPERTIES TABLES

## EXTERIOR APPLICATIONS

Plywood Grade	Description and Use	Typical Trademarks	Veneer Grade			Common Thicknesses	Grade Stress Level (Table 3)	Species Group	Section Property Table
			Face	Back	Inner				
APA RATED SHEATHING EXT(3)	Unsanded sheathing grade with waterproof glue bond for wall, roof, subfloor and industrial applications such as pallet bins.		C	C	C	5/16, 3/8, 15/32, 1/2, 19/32, 5/8, 23/32, 3/4	S-1(6)	See "Key to Span Rating"	Table 1 (unsanded)
APA STRUCTURAL I RATED SHEATHING EXT(3)	"Structural" is a modifier for this unsanded sheathing grade. For engineered applications in construction and industry where full Exterior-type panels are required. Structural I is made from Group 1 woods only.		C	C	C	5/16, 3/8, 15/32, 1/2, 19/32, 5/8, 23/32, 3/4	S-1(6)	Group 1	Table 2 (unsanded)
APA RATED STURD-I-FLOOR EXT(3)	For combination subfloor-underlayment where severe moisture conditions may be present, as in balcony decks. Possesses high concentrated and impact load resistance during construction and occupancy. Touch-sanded.(4) Available with tongue-and-groove edges.(5)		C plugged	C	C	19/32, 5/8, 23/32, 3/4	S-2	See "Key to Span Rating"	Table 1 (touch-sanded)
APA UNDERLAYMENT EXT and APA C-C-PLUGGED EXT	Underlayment for floor where severe moisture conditions may exist. Also for controlled atmosphere rooms and many industrial applications. Touch-sanded. Available with tongue-and-groove edges.(5)		C plugged	C	C	1/2, 19/32, 5/8, 23/32, 3/4	S-2	As Specified	Table 1 (touch-sanded)
APA B-B PLYFORM CLASS I or II(2)	Concrete-form grade with high reuse factor. Sanded both sides, mill-oiled unless otherwise specified. Available in HDO. For refined design information on this special-use panel see APA Design/Construction Guide: Concrete Forming, Form No. V345. Design using values from this specification will result in a conservative design.(5)		B	B	C	19/32, 5/8, 23/32, 3/4	S-2	Class I use Group 1; Class II use Group 3	Table 1 (sanded)
APA MARINE EXT	Superior Exterior-type plywood made only with Douglas-fir or Western Larch. Special solid-core construction. Available with MDO or HDO face. Ideal for boat hull construction.		A or B	A or B	B	1/4, 3/8, 1/2, 5/8, 3/4	A face & back use S-1 B face or back use S-2	Group 1	Table 2 (sanded)
APA APPEARANCE GRADES EXT	Generally applied where a high quality surface is required. Includes APA A-A, A-B, A-C, B-B, B-C, HDO and MDO EXT.(5)		B or better	C or better	C	1/4, 11/32, 3/8, 15/32, 1/2, 19/32, 5/8, 23/32, 3/4	A or C face & back use S-1(6) B face or back use S-2	As Specified	Table 1 (sanded)

- (1) When exterior glue is specified, i.e. Exposure 1, stress level 2 (S-2) should be used.
- (2) Check local suppliers for availability before specifying Plyform Class II grade, as it is rarely manufactured.
- (3) Properties and stresses apply only to APA RATED STURD-I-FLOOR and APA RATED SHEATHING manufactured entirely with veneers.
- (4) APA RATED STURD-I-FLOOR 2-4-1 may be produced unsanded.
- (5) May be available as Structural I. For such designation use Group 1 stresses and Table 2 section properties.
- (6) C face and back must be natural unrepaired; if repaired, use stress level 2 (S-2).

**EFFECTIVE SECTION PROPERTIES FOR PLYWOOD**

TABLE 1

**FACE PLIES OF DIFFERENT SPECIES GROUP FROM INNER PLIES  
(INCLUDES ALL PRODUCT STANDARD GRADES EXCEPT THOSE NOTED IN TABLE 2.)**

Nominal Thickness (in.)	Approximate Weight (psf)	$t_s$ Effective Thickness For Shear (in.)	Stress Applied Parallel to Face Grain				Stress Applied Perpendicular to Face Grain			
			A Area (in. <sup>2</sup> /ft)	I Moment of Inertia (in. <sup>4</sup> /ft)	KS Effective Section Modulus (in. <sup>3</sup> /ft)	Ib/Q Rolling Shear Constant (in. <sup>2</sup> /ft)	A Area (in. <sup>2</sup> /ft)	I Moment of Inertia (in. <sup>4</sup> /ft)	KS Effective Section Modulus (in. <sup>3</sup> /ft)	Ib/Q Rolling Shear Constant (in. <sup>2</sup> /ft)
<b>Unsanded Panels</b>										
5/16-U	1.0	0.268	1.491	0.022	0.112	2.569	0.660	0.001	0.023	4.497
3/8-U	1.1	0.278	1.866	0.039	0.152	3.110	0.799	0.002	0.033	5.444
15/32- & 1/2-U	1.5	0.298	2.292	0.067	0.213	3.921	1.007	0.004	0.056	2.450
19/32- & 5/8-U	1.8	0.319	2.330	0.121	0.379	5.004	1.285	0.010	0.091	3.106
23/32- & 3/4-U	2.2	0.445	3.247	0.234	0.496	6.455	1.563	0.036	0.232	3.613
7/8-U	2.6	0.607	3.509	0.340	0.678	7.175	1.950	0.112	0.397	4.791
1-U	3.0	0.842	3.916	0.493	0.859	9.244	3.145	0.210	0.660	6.533
1-1/8-U	3.3	0.859	4.725	0.676	1.047	9.960	3.079	0.288	0.768	7.931
<b>Sanded Panels</b>										
1/4-S	0.8	0.267	0.996	0.008	0.059	2.010	0.348	0.001	0.009	2.019
11/32-S	1.0	0.284	0.996	0.019	0.093	2.765	0.417	0.001	0.016	2.589
3/8-S	1.1	0.288	1.307	0.027	0.125	3.088	0.626	0.002	0.023	3.510
15/32-S	1.4	0.421	1.947	0.066	0.214	4.113	1.204	0.006	0.067	2.434
1/2-S	1.5	0.425	1.947	0.077	0.236	4.466	1.240	0.009	0.087	2.752
19/32-S	1.7	0.546	2.423	0.115	0.315	5.471	1.389	0.021	0.137	2.861
5/8-S	1.8	0.550	2.475	0.129	0.339	5.824	1.528	0.027	0.164	3.119
23/32-S	2.1	0.563	2.822	0.179	0.389	6.581	1.737	0.050	0.231	3.818
3/4-S	2.2	0.568	2.884	0.197	0.412	6.762	2.081	0.063	0.285	4.079
7/8-S	2.6	0.586	2.942	0.278	0.515	8.050	2.651	0.104	0.394	5.078
1-S	3.0	0.817	3.721	0.423	0.664	8.882	3.163	0.185	0.591	7.031
1-1/8-S	3.3	0.836	3.854	0.548	0.820	9.883	3.180	0.271	0.744	8.428
<b>Touch-Sanded Panels</b>										
1/2-T	1.5	0.342	2.698	0.083	0.271	4.252	1.159	0.006	0.061	2.746
19/32- & 5/8-T	1.8	0.408	2.354	0.123	0.327	5.346	1.555	0.016	0.135	3.220
23/32- & 3/4-T	2.2	0.439	2.715	0.193	0.398	6.589	1.622	0.032	0.219	3.635
1-1/8-T	3.3	0.839	4.548	0.633	0.977	11.258	4.067	0.272	0.743	8.535

**EFFECTIVE SECTION PROPERTIES FOR PLYWOOD**

TABLE 2

**STRUCTURAL I AND MARINE**

Nominal Thickness (in.)	Approximate Weight (psf)	$t_s$ Effective Thickness For Shear (in.)	Stress Applied Parallel to Face Grain				Stress Applied Perpendicular to Face Grain			
			A Area (in. <sup>2</sup> /ft)	I Moment of Inertia (in. <sup>4</sup> /ft)	KS Effective Section Modulus (in. <sup>3</sup> /ft)	Ib/Q Rolling Shear Constant (in. <sup>2</sup> /ft)	A Area (in. <sup>2</sup> /ft)	I Moment of Inertia (in. <sup>4</sup> /ft)	KS Effective Section Modulus (in. <sup>3</sup> /ft)	Ib/Q Rolling Shear Constant (in. <sup>2</sup> /ft)
<b>Unsanded Panels</b>										
5/16-U	1.0	0.356	1.619	0.022	0.126	2.567	1.188	0.002	0.029	6.037
3/8-U	1.1	0.371	2.226	0.041	0.195	3.107	1.438	0.003	0.043	7.307
15/32- & 1/2-U	1.5	0.535	2.719	0.074	0.279	4.157	2.175	0.012	0.116	2.408
19/32- & 5/8-U	1.8	0.707	3.464	0.154	0.437	5.685	2.742	0.045	0.240	3.072
23/32- & 3/4-U	2.2	0.739	4.219	0.236	0.549	6.148	2.813	0.064	0.299	3.540
7/8-U	2.6	0.776	4.388	0.346	0.690	6.948	3.510	0.131	0.457	4.722
1-U	3.0	1.088	5.200	0.529	0.922	8.512	5.661	0.270	0.781	6.435
1-1/8-U	3.3	1.118	6.654	0.751	1.164	9.061	5.542	0.408	0.999	7.833
<b>Sanded Panels</b>										
1/4-S	0.8	0.342	1.280	0.012	0.083	2.009	0.626	0.001	0.013	2.723
11/32-S	1.0	0.365	1.280	0.026	0.133	2.764	0.751	0.001	0.023	3.397
3/8-S	1.1	0.373	1.680	0.038	0.177	3.086	1.126	0.002	0.033	4.927
15/32-S	1.4	0.537	1.947	0.067	0.246	4.107	2.168	0.009	0.093	2.405
1/2-S	1.5	0.545	1.947	0.078	0.271	4.457	2.232	0.014	0.123	2.725
19/32-S	1.7	0.709	3.018	0.116	0.338	5.566	2.501	0.034	0.199	2.811
5/8-S	1.8	0.717	3.112	0.131	0.361	5.934	2.751	0.045	0.238	3.073
23/32-S	2.1	0.741	3.735	0.183	0.439	6.109	3.126	0.085	0.338	3.780
3/4-S	2.2	0.748	3.848	0.202	0.464	6.189	3.745	0.108	0.418	4.047
7/8-S	2.6	0.778	3.952	0.288	0.569	7.539	4.772	0.179	0.579	5.046
1-S	3.0	1.091	5.215	0.479	0.827	7.978	5.693	0.321	0.870	6.981
1-1/8-S	3.3	1.121	5.593	0.623	0.955	8.841	5.724	0.474	1.098	8.377
<b>Touch-Sanded Panels</b>										
1/2-T	1.5	0.543	2.698	0.084	0.282	4.511	2.486	0.020	0.162	2.720
19/32- & 5/8-T	1.8	0.707	3.127	0.124	0.349	5.500	2.799	0.050	0.259	3.183
23/32- & 3/4-T	2.2	0.739	4.059	0.201	0.469	6.592	3.625	0.078	0.350	3.596

## ALLOWABLE STRESSES FOR PLYWOOD

TABLE 3

**ALLOWABLE STRESSES FOR PLYWOOD (psi) conforming to Voluntary Product Standard PS 1-95 for Construction and Industrial Plywood. Stresses are based on normal duration of load, and on common structural applications where panels are 24" or greater in width. For other use conditions, see Section 3.3 for modifications.**

Type of Stress	Species Group of Face Ply	Grade Stress Level <sup>(1)</sup>				
		S-1		S-2		S-3
		Wet	Dry	Wet	Dry	Dry Only
EXTREME FIBER STRESS IN BENDING ( $F_b$ )	1	1430	2000	1190	1650	1650
TENSION IN PLANE OF PLYS ( $F_t$ )	$F_b$					
Face Grain Parallel or Perpendicular to Span (At 45° to Face Grain Use 1/6 $F_t$ )	& 2, 3	980	1400	820	1200	1200
	$F_t$					
	4	940	1330	780	1110	1110
COMPRESSION IN PLANE OF PLYS	1	970	1640	900	1540	1540
	$F_c$					
Parallel or Perpendicular to Face Grain (At 45° to Face Grain Use 1/3 $F_c$ )	2	730	1200	680	1100	1100
	3	610	1060	580	990	990
	4	610	1000	580	950	950
SHEAR THROUGH THE THICKNESS <sup>(3)</sup>	1	155	190	155	190	160
	$F_v$					
Parallel or Perpendicular to Face Grain (At 45° to Face Grain Use 2 $F_v$ )	2, 3	120	140	120	140	120
	4	110	130	110	130	115
ROLLING SHEAR (IN THE PLANE OF PLYS)						
	$F_s$					
Parallel or Perpendicular to Face Grain (At 45° to Face Grain Use 1-1/3 $F_s$ )	Marine & Structural I	63	75	63	75	—
	All Other <sup>(2)</sup>	44	53	44	53	48
MODULUS OF RIGIDITY (OR SHEAR MODULUS)	1	70,000	90,000	70,000	90,000	82,000
	2	60,000	75,000	60,000	75,000	68,000
Shear in Plane Perpendicular to Plys (through the thickness)	G					
(At 45° to Face Grain Use 4G)	3	50,000	60,000	50,000	60,000	55,000
	4	45,000	50,000	45,000	50,000	45,000
BEARING (ON FACE)	1	210	340	210	340	340
	$F_{c\perp}$					
Perpendicular to Plane of Plys	2, 3	135	210	135	210	210
	4	105	160	105	160	160
MODULUS OF ELASTICITY IN BENDING IN PLANE OF PLYS	1	1,500,000	1,800,000	1,500,000	1,800,000	1,800,000
	E					
	2	1,300,000	1,500,000	1,300,000	1,500,000	1,500,000
	3	1,100,000	1,200,000	1,100,000	1,200,000	1,200,000
Face Grain Parallel or Perpendicular to Span	4	900,000	1,000,000	900,000	1,000,000	1,000,000

(1) See pages 12 and 13 for Guide.

To qualify for stress level S-1, gluelines must be exterior and only veneer grades N, A, and C (natural, not repaired) are allowed in either face or back.

For stress level S-2, gluelines must be exterior and veneer grade B, C-Plugged and D are allowed on the face or back.

Stress level S-3 includes all panels with interior or intermediate (IMG) gluelines.

(2) Reduce stresses 25% for 3-layer (4- or 5-ply) panels over 5/8" thick. Such layups are possible under PS 1-95 for APA RATED SHEATHING, APA RATED STURD-I-FLOOR, UNDERLAYMENT, C-C Plugged and C-D Plugged grades over 5/8" through 3/4" thick.

(3) Shear-through-the-thickness stresses for MARINE and SPECIAL EXTERIOR grades may be increased 33%. See Section 3.8.1 for conditions under which stresses for other grades may be increased.



## EXAMPLES OF USING PROPERTY AND ALLOWABLE STRESS TABLES

The section properties and allowable stresses presented in Tables 1 through 3 are to be used with the proper type and grade of plywood produced under Voluntary Product Standard PS 1-95. Because the section properties must represent a wide variety of manufacturing techniques and combinations of species, they are of necessity conservative. This is especially true for the Span Rated panels. To relate plywood type and grade to Tables 1 through 3, a GUIDE TO USE OF ALLOWABLE STRESS AND SECTION PROPERTY TABLES has been provided for those grades most often used in engineering design. See pages 16 and 17.

The proper selection of plywood type and grade will insure good performance and often produce cost savings over the improper choice. Many publications are available from the APA which contain specific recommendations for many construction applications.

The designer and specifier should bear in mind that APA RATED SHEATHING and APA RATED STURD-I-FLOOR panels bear a Span Rating, and that each rating may be purchased in several thicknesses. Therefore, if thickness is important to a specific design, as a box beam or other component, the thickness and Span Rating should be specified. A "Key to Span Rating and Species Group" is provided on page 12 to show the relation of thickness, Span Rating and Species group.

The following examples further illustrate the use of the "Guide" and Tables 1 through 3. Units for section properties and stresses are as given in Tables 1 through 3.

### Sheathing-Grade Example:

The "Guide" indicates APA RATED SHEATHING Exposure 1 or 2 should be used for Interior applications and APA RATED SHEATHING Exterior is needed for exterior exposure. Both grades may be modified to the STRUCTURAL I category.

For an APA RATED SHEATHING 32/16 Exposure 1 panel the "Guide" indicates that section properties from Table 1 should be used in conjunction with stress level two (S-2). The reader is referred to the "Key to Span Rating and Species Group." The "Key" indicates that a 32/16 Span Rating is available in thicknesses 15/32" through 5/8". Selecting the 15/32" thickness indicates the use of Species Group 1 stresses. Hence, for a 15/32" APA RATED SHEATHING 32/16 Exposure 1 panel, the following values for stress applied parallel to the face grain are extracted from Tables 1 and 3:  $I = 0.067$ ,  $KS = 0.213$ ;  $Ib/Q = 3.921$ . Group 1 stresses in the dry condition for stress level two (S-2) are:  $E = 1,800,000$ ,  $F_b = 1650$ ,  $F_s = 53$ .

Should the panel be changed to 15/32" APA RATED SHEATHING 32/16 Exterior, the same section properties would be used but stress level one (S-1) would be used. Stress level three (S-3) should be used with an APA RATED SHEATHING panel if Exposure 2 is specified.

If APA STRUCTURAL I RATED SHEATHING is used, the "Guide" indicates that Table 2 section properties should be used along with level two (S-2) stresses. For a 15/32" APA STRUCTURAL I RATED SHEATHING panel the following section properties are obtained:  $I = 0.074$ ,  $KS = 0.279$ ,  $Ib/Q = 4.157$  where stress is applied parallel to the face grain. Should the

stress be applied perpendicular to the face grain, the following section properties should be used:  $I = 0.012$ ,  $KS = 0.116$ ,  $Ib/Q = 2.408$ .

### Sanded-Panel Example:

Plywood produced with an A or B face is generally fully sanded and considered an appearance grade. For a 3/4" APA B-C Group 3 Exterior panel the "Guide" indicates that stress level two (S-2) should be used. The "Guide" also shows that the sanded portion of Table 1 should be used to obtain section properties; they are:  $I = 0.197$ ,  $KS = 0.412$  and  $Ib/Q = 6.762$  for stress applied parallel to the face. The allowable stresses for the wet condition are:  $E = 1,100,000$ ,  $F_b = 820$ , and  $F_s = 44$ .

### Touch-Sanded Example:

Plywood manufactured as APA RATED STURD-I-FLOOR, UNDERLAYMENT, C-D PLUGGED or C-C PLUGGED is generally touch-sanded. To find the properties and stresses for a 19/32" APA RATED STURD-I-FLOOR 20 oc Exposure 1 panel (with veneer faces and inner plies), the "Guide" indicates level two (S-2) stresses should be used with Table 1 section properties. The reader is also referred to the "Key to Span Rating and Species Group," which indicates that for 19/32" thickness and 20 oc Span Rating, Species Group 1 stresses should be used. Stresses are therefore:  $E = 1,800,000$ ,  $F_b = 1650$ ,  $F_s = 53$ . Section properties are:  $I = 0.123$ ,  $KS = 0.327$ ,  $Ib/Q = 5.346$ . If 19/32" APA UNDERLAYMENT Group 1 Exposure 1 is specified, the same section properties and stresses are used.

(continued from page 11)

### **3.1.1 Plywood Grade Identification**

When the allowable stresses in Table 3 are used, the plywood shall be manufactured in accordance with Voluntary Product Standard PS 1-95, and shall be identified by the trademark of APA – The Engineered Wood Association.

### **3.1.2 Grade Stress Level**

The allowable stresses presented in Table 3 are divided into three levels which are related to grade. Plywood with exterior glue, and with face and back plies containing only N, A, or C veneers, shall use level one (S-1) stresses. Plywood with exterior glue, and with B, C-plugged or D veneers in either face or back, shall use level two (S-2) stresses. All grades with interior or intermediate glue (IMG or Exposure 2) shall use level three (S-3) stresses.

*The Guide to Table Use supplies direct relationship between Tables 1 through 3 and most plywood grades. The table Allowable Stresses for Plywood is based on research indicating that strength is directly related to veneer grade and glue type.*

*The derivation of the stress levels is as follows: Bending, tension, and compression stresses depend on the grade of the veneers. Since veneer grades N, A, and C are the strongest, panels having face and back plies of these grades have higher allowable stresses than panels with face and back plies of B, C-plugged, or D. Although veneer grades B and C-plugged are superior in appearance to C, they rate a lower stress level, because the “plugs” and “patches” which improve their appearance reduce their strength somewhat.*

*Shear stresses, on the other hand, do not depend on veneer grade, but do vary with kind of glue. (Therefore, as an illustration, if available, an N-N grade panel with N face*

*and back and inner plies of C veneers, but with interior glue, would qualify for the higher bending, tension, and compression stresses, but for the lower shear values.)*

*Stiffness and bearing strength do not depend either on glue or on veneer grade, but on species group.*

### **3.2 Service Moisture Conditions**

Table 3 lists allowable stresses for both wet and dry moisture conditions. The use of these stresses shall be as defined in this Section.

#### **3.2.1 Dry Conditions**

The allowable stresses in the columns titled “dry” in Table 3, and adjustments thereof, apply to plywood under service conditions which are continuously dry. Dry conditions are defined in this Specification as involving an equilibrium moisture content of less than 16%.

#### **3.2.2 Wet Conditions**

When equilibrium moisture content in service will be 16% or greater, as in applications that are directly exposed to the weather, the allowable stresses in Table 3 under the columns titled “wet” shall be used.

### **3.3 Modification of Stresses**

#### **3.3.1 Duration of Loading**

The allowable unit stresses in Table 3 are for normal duration of load, and are applicable to all conditions other than those for which specific exceptions are made. *Normal duration of load* refers to fully stressing a member by the application of the full maximum design load, either continuously or cumulatively, for a duration of approximately ten years.

Allowable stresses shall be adjusted for other durations of loading. These adjustments also apply to mechanical fasteners, but not to modulus of elasticity.

*For a more detailed explanation of adjustments for duration of load, see NATIONAL DESIGN SPECIFICATION FOR WOOD CONSTRUCTION, American Forest & Paper Association, Washington, D.C. or U.S. Forest Products Laboratory Report R1916.*

**3.3.1.1 Load Duration Less than Normal –** When the duration of the full maximum load does not exceed the period indicated, increase the allowable stresses in Table 3 as follows:

15% for two months’ duration, as for snow

25% for seven days’ duration

33-1/3% or 60% for earthquake or wind (consult local code)

100% for impact

Allowable stresses given in Table 3 for normal loading conditions may be used without regard to impact if the stress induced by impact does not exceed the allowable unit stress for normal duration of load.

The above increases are not cumulative. The resulting structural sections shall not be smaller than required for design with loading associated with a longer duration.

#### **3.3.1.2 Permanent Duration of Load –**

Where a member is fully stressed to the maximum allowable stress for more than 10 years either continuously or cumulatively under the condition of maximum design load, use working stresses 90% of those in Table 3.

#### **3.3.2 Pressure Treatment**

Allowable stresses for pressure-treated plywood shall be adjusted as described in this Section. The resulting stresses are subject to further adjustments for duration of load and moisture content, as set forth in Sections 3.2 and 3.3.

### 3.3.2.1 Preservative Treatment –

The allowable stresses in Table 3 apply without adjustment to plywood pressure-impregnated with preservative chemicals in accordance with American Wood Preservers Association (AWPA) Specification C-9 or Specification C-22.

3.3.2.2 Fire-Retardant Treatment – For plywood pressure-impregnated with fire-retardant chemicals, the allowable stresses in Table 3 and other structural performance characteristics shall be adjusted in accordance with recommendations of the company providing the treatment and redrying service.

*Due to the introduction of new fire-retardant treatments in recent years, standardized allowable stress reduction recommendations and Span Rating adjustments are not available at this time.*

### 3.3.3 Panel Size

The allowable stresses in bending ( $F_b$ ), tension ( $F_t$ ) and compression ( $F_c$ ) given in Table 3 are appropriate for panels 24 inches or greater in width. Width is taken to be the dimension perpendicular to the applied stress. For small, highly stressed pieces of plywood there is an increased possibility of having a random strength-reducing defect in a critical section. A reduction in allowable stresses therefore is recommended for applications where human life may be endangered by failure of a single piece of plywood, such as a highly stressed gusset plate. In such cases, a reduction in  $F_b$ ,  $F_t$ , and  $F_c$  should be applied to plywood strips in proportion to their width, commencing with no reduction at 24" and ranging to 50% at 8" and less. Single strips less than 8" used in stressed applications should be chosen such that they are relatively free of surface defects.

*Development of the allowable stresses is based on plywood panels at least 24 inches in width. On the other hand, plywood has historically performed well in smaller sizes such as narrow panels for roof sheathing, shelving, rigid frames, pallet bins, and gussets for trusses. The designer should consider that with a small piece of plywood a defect allowed in the grade will have a greater effect, especially if it is located in an area of high stress. Also the chance that a significant strength-reducing defect will occur in a highly stressed area decreases as the number of parallel plies increases. Thus, a 5-ply panel should be superior to a 3-ply panel. The reduction is intended only for applications which would endanger human life. For critical applications, culling of pieces with surface defects is recommended.*

### 3.3.4 Edge Support

Under some edge support conditions, allowable shear-through-the-thickness ( $F_v$ ) and rolling shear ( $F_s$ ) stresses may require modification. See Section 3.8 for modifications and discussion.

### 3.3.5 Elevated Temperature

Stresses in Table 3 shall apply at temperatures of 70°F and lower. Plywood structural parts of buildings shall not be exposed to temperatures above 200°F for more than very brief periods. Between 70°F and 200°F, all wet stresses (used where moisture content will be 16 percent or greater) shall be reduced 1/2 percent for each degree above 70°F when plywood can be expected to remain wet at elevated temperatures. All dry stresses shall be reduced by the same amount when moisture content at elevated temperatures will remain at 12 percent or above.

*At temperatures above 200°F plywood undergoes slow thermal decomposition which permanently reduces its strength.*

*Between 70°F and 200°F strength loss is recovered when temperature is reduced. Between 70°F and 200°F the need for adjustment of dry stresses depends upon whether moisture content will remain in the 12 to 15% range or whether the plywood will dry to lower moisture contents as a result of the increase in temperature. If drying occurs, the increase in strength due to drying can offset the loss in strength due to elevated temperature. For instance, temperatures of up to 150°F do occur under roof coverings of buildings on hot days, but they are accompanied by moisture content reductions which offset the strength loss so that high temperatures are not considered in the design of roof structures. To maintain a moisture content of 12% at 150°F, sustained relative humidity of around 80% would be required. The designer will need to exercise judgment in determining whether high temperature and moisture content occur simultaneously, and the corresponding need for temperature adjustment.*

## 3.4 Modulus of Elasticity

Moduli of elasticity (MOE or E) presented in Table 3 shall be used for all grades of plywood, except where modified as required in Section 3.2 and 3.3. Modulus of elasticity for the species group of the face ply is to be used, in both parallel and perpendicular directions. When shear deflection is computed separately from bending deflection, the modulus of elasticity shall be increased by 10% in calculating the bending deflection.

*The modulus of elasticity listed in Table 3 is an effective modulus including an allowance for average shear deflection. Plywood sheathing is generally used in applications where the loads are considered to be uniformly distributed and where the spans are normally from 30 to 50 times the thickness*

of the plywood. Tests have shown that shear deformation accounts for only a small percentage of the total deflection occurring at these span-to-depth ( $l/d$ ) ratios.

Because the test data on which the tables are based include a shear-deflection component of approximately 10%, the tabulated modulus of elasticity value itself contains an adequate allowance for the shear deflection that occurs in most applications.

In certain cases, however, where short spans are involved ( $l/d$  from 15 to 20, or lower) deflections computed using the tabulated modulus of elasticity will tend to underestimate total actual deflection. In such cases, the shear deflection should be calculated separately and added to the bending deflection. The recommended shear deflection formula is given in Section 4.1.3.2.

Bending deflection in these cases should be calculated by the conventional formulas, using a true modulus of elasticity in bending, which is 1.1 times the tabulated effective modulus of elasticity shown in Table 3.

### 3.5 Plywood Stressed in Bending

The allowable stresses for extreme fiber in bending ( $F_b$ ) from Table 3 shall be chosen with proper regard for plywood grade, as noted in Section 3.1.2; for service moisture conditions as in Section 3.2 and for duration of load as in 3.3. The allowable stress in bending for the species group of the face ply shall be used for stress applied either parallel or perpendicular to the face grain.

#### 3.5.1 Load Applied Perpendicular to the Plane of the Panel

When the loads are applied perpendicular to the plane of the panel, the allowable bending stresses shall be used with section-modulus values ( $KS$ ) from Tables 1 and 2; not with values for moment of inertia.

#### 3.5.2 Loads Applied Parallel to the Plane of the Panel

Where end joints occur, the allowable stresses in bending shall be modified as provided in Section 5.6.

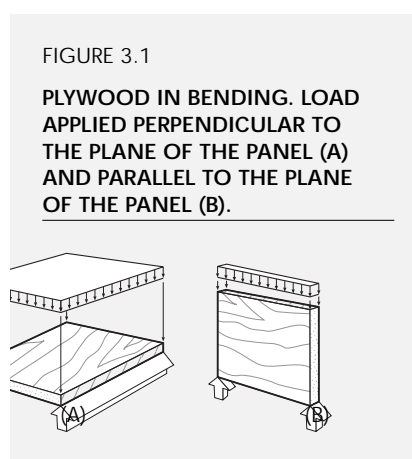


Figure 3.1 indicates the direction of loading relative to the plane of the plywood panel as specified in this Section. For design of plywood-lumber beams, where plywood is used vertically as in Figure 3.1(B), see PDS Supplement 2. For recommendations on designing all-plywood beams with laminated webs see PDS Supplement 5, available from APA.

### 3.6 Plywood Stressed in Tension or Compression

The allowable stresses for tension in the plane of the plies ( $F_t$ ) and compression in the plane of the plies ( $F_c$ ) from Table 3 shall be chosen with proper regard for plywood grades as noted in Section 3.1.2, for service moisture as in Section 3.2 and for duration of load as in 3.3. The allowable stress for the species group of the face shall be used for stress applied either parallel or perpendicular to the face grain, with the appropriate area from Tables 1 and 2. The use of these allowable stresses is further restricted as set forth in this Section.

#### 3.6.1 Allowable Stresses in Axial Tension

The allowable stress for tension in Table 3 shall be applied to the area from Column 4 of Tables 1 and 2 when the stress is applied in the direction of the face grain. The same allowable stress shall be applied to the area from Column 8 of Tables 1 and 2 for tension stress applied perpendicular to the face grain.

#### 3.6.2 Allowable Stresses in Axial Compression

The allowable stress for compression in Table 3 shall be applied to the area from Column 4 of Tables 1 and 2 when the stress is applied in the direction of the face grain. The same allowable stress shall be applied to the area from Column 8 of Tables 1 and 2 for compression stress applied perpendicular to the face grain.

#### 3.6.3 Tension or Compression at Angles to the Face Grain

See italicized section below for angles other than 45 degrees.

*3.6.3.1 Tension at 45 Degrees to the Face Grain* – The allowable stresses for tension at 45 degrees to the face grain shall be as given in Table 3. The value may be applied to the full thickness of the panel if all plies are of the same species group, as in STRUCTURAL I. If the inner plies are not of the same species group, total area must be adjusted in proportion to the actual moduli of elasticity and actual area of all plies.

*3.6.3.2 Compression at 45 Degrees to the Face Grain* – The allowable stresses for compression at 45 degrees to the face grain shall be as given in Table 3. They may be applied to the full thickness of the panel if all plies are of the same species group, as in STRUCTURAL I.

If the inner plies are not of the same species group, total area must be adjusted.

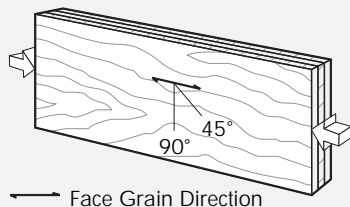
*For tension or compression parallel or perpendicular to the face grain, section properties have been adjusted so that allowable stress for the species group of the faces may be applied to the area given in Tables 1 and 2. Thus, no additional correction need be made for species group of inner plies.*

*For tension or compression stress applied at 45° to the face grain, allowable stresses from Table 3 may be applied to the full thickness under consideration if all plies are of the same species group as the face. If the inner plies are not of the same species group, an adjusted area may be approximated by using 70% of the gross cross section.*

*For angles between 0° (direction of the face grain) and 45°, an approximate solution may be obtained by straight-line interpolation between the product of area and stress for the parallel direction and the similar product for 45° to the face grain. For angles between 45° and 90° to the face grain, a similar approximate solution may be obtained by straight-line interpolation between the product of area and stress for 45° to the face grain and the product of area and stress for 90° (perpendicular to the face grain). Figure 3.2 details the directions for axial loads in the plane of the plies.*

FIGURE 3.2

**AXIAL LOADS IN THE PLANE OF THE PLYS. FACE GRAIN ASSUMED TO BE ZERO DEGREES.**



### 3.7 Plywood Stressed in Bearing on the Face

Allowable stresses for bearing on the face ( $F_{c\perp}$ ) from Table 3 shall be used for all plywood grades, modified as required in Sections 3.2 and 3.3. The allowable stress for the species group of the face shall be used.

### 3.8 Plywood Stressed in Shear

Due to the cross-laminated construction of plywood, two different types of shear must be considered.

#### 3.8.1 Allowable Stresses for Shear Through the Thickness

Allowable stresses for shear through the thickness ( $F_v$ ) shall be as given in Table 3, modified as required in Section 3.2 and 3.3. The allowable stresses shall be used for plywood grades as noted in Section 3.1.2 and shall be for the species group of the face ply. The allowable stresses shall be applied to the appropriate thickness in Column 3 of Tables 1 and 2. For shear imposed at 45° to the face grain, the allowable stress may be increased 100%.

Shear-through-the-thickness stresses in Table 3 may be increased 33% for Marine and Special Exterior grades due to manufacturing restrictions on core gaps. The following adjustments are applicable to other grades.

Shear-through-the-thickness stresses in Table 3 are based on the most common structural applications, as where plywood is mechanically fastened to framing. If the plywood is rigidly glued (see Section 5.3) to full-length, continuous (unjointed) framing around all panel edges, increase allowable shear-through-the-thickness stresses by 33%. If the continuous framing is glued to

only two edges parallel to the face grain, increase allowable stresses by 19%. To qualify for strength increase, continuous framing must provide a total width of glued surface (one side or total of two sides) at any cross section equal to at least 30% of the inside distance between framing members. When continuous framing is only at edges perpendicular to the face grain, no increase in stresses shall be taken.

In lieu of the increase in shear-through-the-thickness stresses given above for continuous glued framing, a 33% increase may be taken when panels are regraded to limit core gap width and placement. Contiguous core gaps in adjacent plies within a layer shall be measured as a single gap from the outermost edge of one to the opposite edge of the other. Non-contiguous core gaps in any parallel ply of the panel shall be offset by at least 1 inch, measured from innermost edges of the gaps. Gap width limitations are as follows:

- 1) For all 3-layer panels (including 3-ply and 4-ply), core gaps shall not be wider than 1/4 inch.
- 2) For panels with 5 or more layers, core gaps shall be limited to 1 inch in 1/2-inch-thick panels, and to 1/2 inch in thicker panels.

Shear-through-the-thickness values as given in Table 3 shall also be used for "punching shear" calculations. However, no increases in allowable stress shall be taken for face grain orientation, glued frame reinforcement, or restricted core gaps.

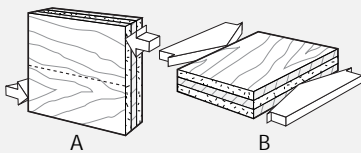
*See Figure 3.3(A) for an illustration of shear through the thickness.*

### 3.8.2 Allowable Stresses for Rolling Shear

The allowable stresses given in Table 3 for rolling shear ( $F_v$ ) shall be used for shear in the plane of the plies, modified as required in Section 3.3. The allowable stress shall be applied to the contact area under stress. For certain applications involving stress concentrations, allowable stress shall be reduced 50%. Such applications include the outside stringer of stressed-skin panels, the flange-to-web joint in box beams and glued truss gussets. If the rolling shear is imposed at an angle of  $45^\circ$  to the face grain, the allowable stress may be increased by  $1/3$ .

FIGURE 3.3

THE TWO TYPES OF SHEAR IN PLYWOOD. TYPICAL SHEAR THROUGH THE THICKNESS (A) AND ROLLING SHEAR (B).



See Figure 3.3(B) for an illustration of rolling shear. Since some of the plies in plywood are at right angles to others, certain types of loading subject them to stresses which tend to make them roll, and a “rolling-shear” stress is induced. The allowable stresses presented in Table 3 apply to most cases of rolling-shear stress, except where the stressed area occurs at the edge of a panel, so that stress concentrations may occur. For applications where such stress concentrations are expected, it is conventional to reduce allowable design rolling-shear stresses by 50% due to an imbalance of stress on the total area under

consideration. Methods for handling plywood component design are included as Supplements to this Specification or in APA – The Engineered Wood Association design methods. These design methods indicate where such reductions are necessary, and include means for implementing them.

### 3.9 Specifications and Plans

When plywood is used structurally, specifications and plans should accurately designate grades required for each application. They should require that the plywood conform with Voluntary Product Standard PS 1-95 and bear the trademark of APA – The Engineered Wood Association. They should be prepared using stresses and section properties in accordance with this PLYWOOD DESIGN SPECIFICATION and design methods in accordance with this Specification and its Supplements, and should so state.

The following design methods are currently available as supplements:

SUPPLEMENT 1 – DESIGN AND FABRICATION OF PLYWOOD CURVED PANELS

SUPPLEMENT 2 – DESIGN AND FABRICATION OF PLYWOOD-LUMBER BEAMS

SUPPLEMENT 3 – DESIGN AND FABRICATION OF PLYWOOD STRESSED-SKIN PANELS

SUPPLEMENT 4 – DESIGN AND FABRICATION OF PLYWOOD SANDWICH PANELS

SUPPLEMENT 5 – DESIGN AND FABRICATION OF ALL-PLYWOOD BEAMS

## 4. DESIGN LOADS AND DESIGN FORMULAS

Design loads for mechanical fasteners, and allowable stresses for stress-grade lumber, shall be as given in the latest edition of the NATIONAL DESIGN SPECIFICATION FOR WOOD CONSTRUCTION, American Forest & Paper Association, Washington, D.C.

Design formulas shall be as given in this PLYWOOD DESIGN SPECIFICATION and its Supplements, or otherwise according to accepted engineering practice.

Appendix A3 tabulates section capacities for Span-Rated plywood panels when stress is applied parallel to face grain. Values may be used in the following formulas when it is desired that loads apply to a panel Span Rating without regard to thickness.

### 4.1 Uniform Loads for Plywood

Computation of uniform-load capacity of plywood panels shall be as outlined in this section for such applications as roofs, floors and walls. The allowable stresses are subject to modification as specified in Section 3.

Three basic span conditions are presented for computing uniform-load capacities of plywood. For normal framing practice and a standard plywood panel size (4'x8'), APA has used the following assumptions in computing recommendations for load-span tables. When the face grain is across (perpendicular to) the supports, the three-span condition is used for support spacing up to and including 32 inches. The two-span condition is assumed for support spacing greater than 32 inches.

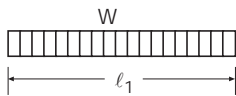
When plywood face grain is placed parallel to the supports the three-span condition is assumed for support spacing up to and including 16 inches; the two-span condition is assumed for face grain parallel to supports when the support spacing is 20 or 24 inches, and the single-span condition is used for spans greater than 24 inches. Four-inch-nominal framing is assumed for support spacing of 48 inches or greater.

The equations presented in this section are standard beam formulas altered to accept the mixed units noted. These formulas are provided for computing uniform loads on plywood over conventional framing. They assume one-way "beam" action, rather than two-way, or "slab" action. The resulting loads are assumed to be applied to full-sized panels in standard sheathing-type applications. Loads are for the plywood only, and in no way account for the design of the framing supports. Further consideration should be given to concentrated loads, in compliance with local building codes and with published recommendations of APA – The Engineered Wood Association.

#### 4.1.1 Uniform Loads Based on Bending Stress

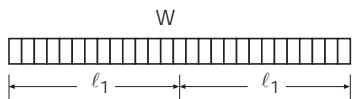
The following formulas shall be used for computing loads based on allowable bending stress ( $F_b$ ).

For a single span:

$$w_b = \frac{96 F_b KS}{\ell_1^2}$$


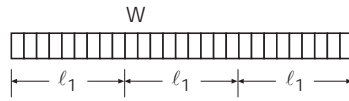
For a two-span condition:

$$w_b = \frac{96 F_b KS}{\ell_1^2}$$



For a three-span condition:

$$w_b = \frac{120 F_b KS}{\ell_1^2}$$



Where:

$w_b$  = uniform load based on bending stress (psf)

$F_b$  = allowable bending stress (psi)

$KS$  = effective section modulus (in.<sup>3</sup>/ft)

$\ell_1$  = span center-to-center of supports (in.)

#### 4.1.2 Uniform Loads Based on Shear Stress

The following formulas shall be used for computing loads based on allowable shear stress ( $F_s$ ). Span conditions are as shown in Section 4.1.1 and symbols are the same unless otherwise noted.

For a single span:

$$w_s = \frac{24 F_s (Ib/Q)}{\ell_2}$$

For a two-span condition:

$$w_s = \frac{19.2 F_s (Ib/Q)}{\ell_2}$$

For a three-span condition:

$$w_s = \frac{20 F_s (Ib/Q)}{\ell_2}$$

Where:

$w_s$  = uniform load based on shear stress (psf)

$F_s$  = allowable rolling-shear stress (psi)

$Ib/Q$  = rolling shear constant (in.<sup>2</sup>/ft)

$\ell_2$  = clear span (in.) (center-to-center span minus support width)

#### 4.1.3 Uniform Loads Based on Deflection Requirements

The following formulas shall be used for computing deflection under uniform load, or allowable loads based on deflection requirements.

##### 4.1.3.1 Bending Deflection –

The following formulas are used to compute deflection due to bending. For most cases, as described in Section 3.4, a single calculation is sufficient, using these equations and the effective moduli of elasticity listed in Table 3. For cases where shear deflection is computed separately, and added to bending deflection to obtain total deflection, E for these bending-deflection equations should be increased 10%.

For a single span:

$$\Delta_b = \frac{w \ell_3^4}{921.6 EI}$$

For a two-span condition:

$$\Delta_b = \frac{w \ell_3^4}{2220 EI}$$

For a three-span condition:

$$\Delta_b = \frac{w \ell_3^4}{1743 EI}$$

Where:

$\Delta_b$  = bending deflection (in.)

$w$  = uniform load (psf)

$E$  = modulus of elasticity (psi)

$I$  = effective moment of inertia (in.<sup>4</sup>/ft)

$\ell_3$  = clear span + SW

SW = support-width factor, equal to 0.25" for two-inch nominal framing and 0.625" for four-inch nominal framing. For additional information on this factor see APA Research Report Number 120.

4.1.3.2 *Shear Deflection* – The shear deflection may be closely approximated for all span conditions by the following formula:

$$\Delta_s = \frac{wCt^2\ell_2^2}{1270 EI}$$

Where:

$\Delta_s$  = shear deflection (in.)

w = uniform load (psf)

C = constant, equal to 120 for panels applied with face grain perpendicular to supports and 60 for panels with face grain parallel to supports.

t = nominal panel thickness (in.)

E = modulus of elasticity unadjusted (psi)

I = effective moment of inertia (in.<sup>4</sup>/ft)

4.1.3.3 *Uniform Load* – For uniform load based on a deflection requirement, compute bending deflection and shear deflection (if desired) with a uniform load (w) equal to one psf. The allowable uniform load based on the allowable deflection is then computed as:

$$w_d = \frac{\Delta_{all.}}{\Delta_b + \Delta_s}$$

Where:

$w_d$  = uniform load for deflection (psf)

$\Delta_{all.}$  = allowable deflection (in.)

## 5. DESIGN OF RIGIDLY GLUED PLYWOOD-LUMBER STRUCTURAL ASSEMBLIES

This Section deals solely with rigidly glued assemblies where the adhesive unites the plywood and lumber, if used, into a single unit. No provision of this section should be interpreted to preclude use of adhesives simply to add stiffness to a unit designed as mechanically fastened.

### 5.1 Design Methods

The provisions of this section should be used in conjunction with design methods for specific components, as given in Supplements to this Specification, or, if a Supplement is not available for a component, with the design method published by APA – *The Engineered Wood Association*. Other design methods may be employed, provided they are supported by adequate test data or rational analysis.

### 5.2 Fabrication Specifications

This Specification applies to the design of structural assemblies of plywood and lumber that will be carefully fabricated in accordance with good practice, employing materials and workmanship of good quality. For best assurance of quality, they shall be subject to the inspection of a qualified agency. Fabrication specifications which define good practice are given in Supplements to this Specification (see Section 3.9).

### 5.2.1 “Structural Glued Laminated Timber”

“Structural Glued Laminated Timber” shall be fabricated in accordance with the current edition of ANSI A190.1 for STRUCTURAL GLUED LAMINATED TIMBER.

### 5.3 Adhesives

Adhesives for plywood-lumber structural assemblies should provide both stiffness and strength to the assembly. The adhesives used for this purpose shall be as defined in this Section.

#### 5.3.1 Interior (Dry) Exposure

When the moisture content of the assembly does not continuously or repeatedly exceed 18%, water-resistant adhesives, such as those conforming with ASTM Specification D3024 or D4689, may be specified for assembly gluing.

#### 5.3.2 Exterior (Wet) Exposure

When the moisture content of the assembly continuously or repeatedly exceeds 18%, as when exposed to the weather, exterior type adhesives, such as those conforming with ASTM Specification D2559, shall be specified for assembly gluing. Some epoxies, if specifically formulated for wood, may meet exterior performance requirements.

### 5.4 Plywood for Structural Assemblies

#### 5.4.1 Classification

Type and grade of plywood used in structural assemblies shall be specified as covered in Sections 1.3 and 1.4 of this Specification.



#### **5.4.2 Allowable Stresses for Plywood**

The stiffness and allowable unit stresses shall be applied for the proper type and grade as specified in Section 3 of this Specification. Additional modification of stresses may be required as defined in Sections 5.4.5 and 5.4.6.

*Where plywood is bonded into multiple layers and used in strips, as ridge beams for mobile homes, the resulting member may be stronger than a single sheet, due to randomization of defects. In such a case, allowable stresses could be higher than given in Table 3 when the particular application has been demonstrated.*

#### **5.4.3 Section Properties for Plywood**

The section properties of plywood shall be applied for the proper type and grade as specified in Section 2 of this Specification.

#### **5.4.4 Shear Deflection**

When the shear deflection of an assembly having plywood flanges (such as a stressed-skin panel) is calculated separately and added to the bending deflection, the elastic modulus of the plywood, given in Table 3, may be increased 10%.

#### **5.4.5 Radial Tension**

For plywood used in curved assemblies where radial tension stresses will occur, the tension stress shall not exceed one-half the allowable stress in rolling shear as defined in Section 3.

#### **5.4.6 Radial Compression**

For plywood used in curved assemblies where radial compression stress will occur, the compression stress shall not exceed the allowable stress in bearing, as defined in Section 3.

*For plywood used in curved assemblies, the recommended minimum radii of curvature are given in Appendix A2.*

### **5.5 Lumber for Structural Assemblies**

#### **5.5.1 Classification**

Lumber for use in plywood structural assemblies shall fall into one of the following two categories.

**5.5.1.1 Stress-Grade Lumber** – Stress-grade lumber is defined in this Specification as lumber conforming with standard stress-grading rules, and so identified by a qualified grading agency, but not subject to the additional restrictions imposed on glued-laminated lumber. Even if laminated, it is still defined as stress-grade lumber.

**5.5.1.2 “Structural Glued Laminated Timber”** – For purposes of this Specification, lumber may be classed as “Structural Glued Laminated Timber” when it conforms with the latest edition of STANDARD SPECIFICATIONS FOR STRUCTURAL GLUED LAMINATED TIMBER OF SOFTWOOD SPECIES, AITC 117 as published by the American Institute of Timber Construction (AITC) or with approved EWS glued laminated timber combinations.

#### **5.5.2 Allowable Stresses for Lumber**

**5.5.2.1 Stress-Grade Lumber** – Allowable stresses and modifications thereof shall be as defined in the latest edition of NATIONAL DESIGN SPECIFICATION FOR WOOD CONSTRUCTION, American Forest & Paper Association. Stress-grade lumber does not qualify for structural glued laminated timber stresses, regardless of the number of laminations.

**5.5.2.2 “Structural Glued Laminated Timber”** – Allowable stresses for “Structural Glued Laminated Timber” and modifications thereof shall be as defined in the latest edition of STANDARD SPECIFICATIONS FOR STRUCTURAL GLUED LAMINATED TIMBER

OF SOFTWOOD SPECIES, AITC 117 or with approved EWS glued laminated timber combinations.

**5.5.2.3 Number of Laminations for Determining Allowable Stress Level** – The number of laminations to be used in determining the allowable stress level of a laminated member shall include all lumber laminations of appropriate grade that are subjected to the principal stress, but shall not include plywood webs or plywood shims within the member. Lumber shims, if appropriately graded, may be grouped to equal or exceed the lamination thickness, and the group considered as a lamination. Similarly, in a member where laminations are ripped diagonally (as in some folded-plate chords), ripped portions of laminations may be paired to equal or exceed the full lamination width, and the pair considered as a lamination.

**5.5.2.4 Number of Laminations for Resisting Stress** – All laminations, including webs and shims, may be considered as resisting stress with due consideration for grade and end joints.

#### **5.5.3 Adjustments for Service Moisture Conditions**

**5.5.3.1 Stress-Grade Lumber** – Allowable stresses for stress-grade lumber shall be modified for in-use moisture content of the lumber as set forth in the latest edition of NATIONAL DESIGN SPECIFICATION FOR WOOD CONSTRUCTION.

**5.5.3.2 “Structural Glued Laminated Timber”** – Allowable stresses for “Structural Glued Laminated Timber” shall be modified for in-use moisture content as set forth in the latest edition of STANDARD SPECIFICATIONS FOR STRUCTURAL GLUED LAMINATED TIMBER OF SOFTWOOD SPECIES, AITC 117 or with approved EWS glued laminated timber combinations.

**5.5.4 Allowance for Surfacing**

In applying stresses, actual sizes of finished lumber shall be used, including any necessary allowance for resurfacing.

**5.5.5 Shear Deflection**

When the shear deflection of an assembly having lumber flanges (such as a plywood beam) is calculated separately and added to the bending deflection, the elastic modulus of the lumber flanges may be increased 3% in calculating bending deflection.

*Values for modulus of elasticity have been derived from tests which involve both bending and shear deflection, while such built-up assemblies as stressed-skin panels and box beams have such low shear stresses in the flanges that shear deflection in the flanges may be ignored. For these assemblies, therefore, the usual modulus of elasticity of the flange material may be increased to restore the portion of the deflection which is ordinarily caused by shear.*

**5.5.6 Radial Tension**

The allowable tension stress across the grain shall be limited to one-third the allowable unit stress in horizontal shear, for southern pine and California redwood under all load conditions, and for Douglas-fir and larch under wind and earthquake loadings. The limit shall be 15 psi for Douglas-fir and larch for other types of load. These values are subject to modification for duration of load.

TABLE 5.6.1.2

**BUTT JOINTS – TENSION OR FLEXURE**

Plywood Thickness (inches)	Length of Splice Plate (inches)	Maximum Stress (psi)			
		All STRUC. I Grades	Group 1	Group 2 and Group 3	Group 4
1/4	6				
5/16	8				
11/32 & 3/8 Sanded	10	1500	1200	1000	900
3/8 Unsanded	12				
15/32 & 1/2	14	1500	1000	950	900
19/32, 5/8	16	1200	800	750	700
23/32 & 3/4					

**5.5.7 Radial Compression**

The radial stress in compression shall not exceed the allowable stress in compression perpendicular to the grain except as modified for duration of load.

**5.6 Glued Plywood End Joints**

**5.6.1 End Joints for Tension or Bending**

End joints across the face grain shall be considered capable of transmitting the following stresses parallel with the face plies (normal duration of load).

*5.6.1.1 Scarf Joints and Finger Joints – Scarf joints 1 in 8 or flatter shall be considered as transmitting full allowable stress in tension or flexure. Scarf joints 1 in 5 shall be considered as transmitting 75% of the allowable stress. Scarf joints steeper than 1 in 5 shall not be used. Finger joints are acceptable, at design levels supported by adequate test data.*

*5.6.1.2 Butt Joints – When backed with a glued plywood splice plate on one side having its grain perpendicular to the joint, of a grade and species group equal to the plywood spliced, and being no thinner than the panel itself, joints may be considered capable of transmitting tensile or flexural stresses as in Table 5.6.1.2 (normal duration of loading). Strength may be taken proportionately for shorter splice-plate lengths.*

**5.6.2 End Joints for Compression**

End joints across the face grain may be considered as transmitting 100% of the compressive strength of the panels joined when conforming with the requirements of this Section (normal duration of load).

*5.6.2.1 Scarf Joints and Finger Joints – Slope no steeper than 1 in 5.*

*5.6.2.2 Butt Joints – Spliced as in Section 5.6.1.2, and with the splice lengths tabulated therein. Strength may be taken proportionately for shorter splice-plate lengths.*

### 5.6.3 End Joints for Shear

#### 5.6.3.1 Scarf Joints and Finger Joints –

Scarf joints along or across the face grain, with slope of 1 in 8 or flatter, may be designed for 100% of the shear strength of the panels joined. Finger joints are acceptable, at design levels supported by adequate test data.

5.6.3.2 Butt Joints – Butt joints, along or across the face grain, may be designed for 100% of the strength of the panels joined when backed with a glued plywood splice plate on one side, no thinner than the panel itself, of a grade and species group equal to the plywood spliced, and of a length equal to at least twelve times the panel thickness.

Strength may be taken proportionately for shorter splice-plate lengths.

#### 5.6.4 Combination of Stresses

Joints subject to more than one type of stress (for example, tension and shear), or to a stress reversal (for example, tension and compression), shall be designed for the most severe case.

#### 5.6.5 Permissible Alternate Joints

Other types of glued joints, such as tongue-and-groove joints, or those backed with lumber framing, may be used at stress levels demonstrated by acceptable tests.

### 5.7 Glued Lumber End Joints

#### 5.7.1 End Joints in “Structural Glued Laminated Timber”

In “Structural Glued Laminated Timber,” end joints shall comply with the requirements of ANSI A190.1 for

STRUCTURAL GLUED LAMINATED TIMBER. Allowable stresses shall be those of the latest edition of STANDARD SPECIFICATIONS FOR STRUCTURAL GLUED LAMINATED TIMBER OF SOFTWOOD SPECIES, AITC 117 or with approved EWS glued laminated timber combinations.

#### 5.7.2 Scarf and Finger Joints in Stress-Grade Lumber

5.7.2.1 Members Stressed Principally in Axial Tension – Slope of scarf joints shall not be steeper than 1 in 8 for dry conditions of use, nor 1 in 10 for wet conditions of use. They may then be considered to carry the full allowable tensile stress of the members glued. Finger joints are acceptable, at design levels supported by adequate test data.

5.7.2.2 Members Stressed Principally in Axial Compression – Slope of scarf joints shall not be steeper than 1 in 5 for dry conditions of use, nor 1 in 10 for wet conditions of use. They may then be considered to carry the full allowable compressive stress of the members glued. Finger joints are acceptable, at design levels supported by adequate test data.

#### 5.7.3 Butt Joints

Butt joints may be used in stress-grade lumber tension and compression members, in which case the effective cross-sectional area shall be computed by subtracting from the cross-sectional area the area of all laminations containing butt joints at a single cross section. In addition, laminations adjoining (actually touching) those containing butt joints

and themselves containing butt joints, shall be considered only partially effective if the spacing in adjoining laminations is less than 50 times the lamination thickness. The effective area of such adjoining laminations shall be computed by multiplying their gross area by the following percentages:

Butt-Joint Spacing (t = lamination thickness)	Effective Factor
30 t	90%
20 t	80%
10 t	60%

Butt joints spaced closer than 10 t shall be considered as occurring in the same section.

5.7.3.1 Tension – For butt joints in tension members or tension portions of members, the appropriate allowable stress in tension shall be multiplied by 0.8 at sections containing the joints.

#### 5.7.4 Compression Members – End Grain Bearing

5.7.4.1 Requirements for Butt Joints – Members in compression may be butted and spliced, provided there is adequate lateral support and the end cuts are accurately squared and parallel, and maintained in tight contact.

5.7.4.2 Allowable Stresses – Allowable stresses for bearing on end grain shall be as determined from the latest edition of the NATIONAL DESIGN SPECIFICATION FOR WOOD CONSTRUCTION, American Forest & Paper Association.

## APPENDIX A1

### Glossary of Terms

#### **AF&PA**

American Forest & Paper Association, Washington, D.C. A trade association of the wood industry. Maintains NATIONAL DESIGN SPECIFICATION FOR WOOD CONSTRUCTION.

#### **Air-Dry Moisture Content**

The equilibrium moisture content of wood for conditions under cover; this condition is usually taken as 12%.

#### **AITC**

The American Institute of Timber Construction, Englewood, Colorado. A trade association responsible for promotion of, and technical information relating to glued-laminated timber.

#### **APA**

APA – *The Engineered Wood Association*, Tacoma, Washington. A trade association organized for the purpose of quality inspection and testing of production, and for doing research upon and promoting the use of plywood and certain other wood-based structural panels. Major functions are: quality testing, applied and product research, and trade promotion.

#### **Back**

The back side of a plywood panel is that side of lower veneer grade when there is a difference.

#### **Butt Joint**

A straight joint in which the interface is perpendicular to the panel face. An end butt joint is perpendicular to the grain (face grain, if plywood).

#### **Centers**

Inner layers whose grain direction runs parallel to that of the outer plies. May be of parallel-laminated plies.

#### **Check**

A lengthwise separation of wood fibers, usually extending across the rings of annual growth. Caused chiefly by strains produced in seasoning.

#### **Class I, II**

Term used to identify different species-group combinations of B-B Plyform concrete-form panels.

#### **Construction**

Trade term used to refer to the layup of a plywood panel, for example, a “4-ply construction.”

#### **Crossband**

Inner layer whose grain direction runs perpendicular to that of the outer plies. Sometimes referred to as core.

#### **Equilibrium moisture content (also known as emc)**

The moisture content attained by wood moisture when it has reached equilibrium with the surrounding atmosphere. The equilibrium moisture content of wood is highly dependent on relative humidity, but essentially independent of temperature between 32° F and 100° F.

#### **EWS**

Engineered Wood Systems, Tacoma, Washington. A related corporation of APA – *The Engineered Wood Association* responsible for promotion of, and technical information relating to glued-laminated timber, I-joists and structural composite lumber.

#### **Face**

The face side of a panel is that side of higher veneer grade when there is a difference.

#### **Group or “Species Group”**

A collection of wood species of similar stiffness and strength, classified together for convenience. Species Group 1 is the stiffest and strongest. See Section 1.5.

#### **Inner Plies**

Plies other than face or back plies in a plywood panel.

#### **Layer**

A layer consists of one or more veneers laminated with grain direction parallel. Layers of plywood are oriented with the grain direction perpendicular to adjacent layers.

#### **Moisture Content of Wood**

The weight of the moisture in wood, expressed as a percentage of its oven-dry weight.

#### **Plugs**

Sound wood of various shapes, or synthetic material used to repair veneer defects.

#### **Ply**

A single thin sheet of wood in a plywood panel; a veneer.

#### **Repair**

Any patch, plug or shim placed in veneer or finished plywood panel.

#### **Shim**

A long narrow repair of wood or suitable synthetic not more than 3/16" wide.

#### **Span Rating**

A numerical designation used to describe maximum spans for APA RATED SHEATHING and APA RATED STURD-I-FLOOR panels. See Section 1.4.1.

#### **Species Group**

See “Group.”

#### **Touch sanding**

A sizing operation consisting of a light surface sanding in a sander. Frequently affects the face only, and so assumed in the section-property calculations for this Specification.

#### **Veneer**

Thin sheets of wood of which plywood is made; plies.

## APPENDIX A2

### Minimum Bending Radii

The following radii have been found to be appropriate minimums for mill-run panels of the thickness shown, bent dry. Shorter radii can be developed by selection for bending of areas free of knots and short grain, and/or by wetting or steaming. Exterior-type plywood should be used for such wetting or steaming. Panels to be glued should be redried before gluing. The radii given are minimums, and an occasional panel may develop localized fractures at these radii.

TABLE A2

#### MINIMUM BENDING RADII FOR PLYWOOD PANELS

Panel	Bending Radii (feet) for Panel Bent in Direction	
	Across Grain	Parallel to Grain
Thickness (inches)		
1/4	2	5
5/16	2	6
11/32 & 3/8	3	8
15/32 & 1/2	6	12
19/32 & 5/8	8	16
23/32 & 3/4	12	20

## APPENDIX A3

### Section Capacities for Span-Rated Plywood

When stresses are applied parallel to face grain, section capacities may be used for Span-Rated plywood in lieu of the product of effective section properties and allowable

design stresses. Table A3 is based on normal duration of load and capacities are subject to modification as specified in Section 3. Capacities are tabulated per foot of panel width without regard to panel thickness and, thus, may be quite conservative for some panels.

TABLE A3

Span Rating	$F_v t_s$ Shear-through the-Thickness Strength (lb/in.)	Stress Applied Parallel to Face Grain			
		EA Axial Stiffness (lb/ft)	EI Bending Stiffness (lb-in. <sup>2</sup> /ft)	$F_b K_S$ Bending Strength (lb-in./ft)	$F_s$ lb/Q Rolling Shear Strength (lb/ft)
<b>Unsanded Panels (APA RATED SHEATHING)</b>					
12/0	40.9	1,619,000	22,000	140	123
16/0	41.8	1,790,000	26,400	151	123
20/0	42.7	2,226,000	39,400	185	123
24/0	44.5	2,750,000	70,300	250	149
32/16	47.6	2,795,000	120,700	351	188
40/20	51.0	3,672,000	217,400	626	240
48/24	71.2	4,931,000	412,700	775	310
<b>Touch-Sanded Panels (APA RATED STURD-I-FLOOR)</b>					
16 oc	54.7	3,267,000	143,500	414	204
20 oc	65.2	3,337,000	201,000	481	257
24 oc	70.2	4,173,000	352,200	642	316
48 oc	134.2	8,186,000	1,139,000	1611	540

## APPENDIX A4

### References

#### **I. Supplements to This Publication**

Supplement 1, Design and Fabrication of Plywood Curved Panels.

Supplement 2, Design and Fabrication of Plywood-Lumber Beams.

Supplement 3, Design and Fabrication of Plywood Stressed-Skin Panels.

Supplement 4, Design and Fabrication of Plywood Sandwich Panels.

Supplement 5, Design and Fabrication of All-Plywood Beams.

#### **II. References**

##### **(listed in order of appearance)**

1. *Voluntary Product Standard PS 1-95 for Construction and Industrial Plywood.*

Available from APA – *The Engineered Wood Association.*

2. *Establishing Clear Wood Strength Values.* American Society for Testing and Materials Standard D 2555.

3. *Bending Strength and Stiffness of Plywood.* U.S.D.A., Forest Products Laboratory Research Note FPL-059.

4. *National Design Specification for Wood Construction.* American Forest & Paper Association.

5. *Relation of Strength of Wood to Duration of Load.* U.S.D.A., Forest Products Laboratory Research Report R-1916.

6. *Plywood – Preservative Treatment by Pressure Processes.* American Wood-Preservers' Association Standard C9.

7. *Lumber and Plywood for Permanent Wood Foundations – Preservative Treatment by Pressure Process.* American Wood-Preservers' Association Standard C22.

8. *Effect of Support Width on Plywood Deflection.* APA – *The Engineered Wood Association* Research Report Number 120.

9. *ANSI A190.1 for Structural Glued Laminated Timber.* Available from American National Standards Institute.

10. *Standard Specifications for Structural Glued Laminated Timber of Softwood Species.* American Institute of Timber Construction Standard AITC 117.

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