Panel Design Specification

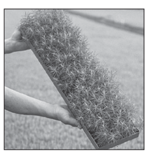
APA

WOOD
The Natural Choice

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

A few facts about wood.

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

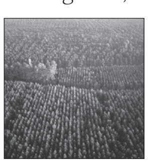


- ***Life Cycle Assessment shows wood is the greenest building product.*** A 2004 Consortium for Research on Renewable Industrial Materials (CORRIM) study gave scientific validation to the strength of wood as a green building product. In examining building products' life cycles – from extraction of the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

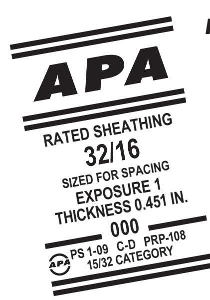
- ***Manufacturing wood is energy efficient.*** Wood products made up 47 percent of all industrial raw materials manufactured in the United States, yet consumed only 4 percent of the energy needed to manufacture all industrial raw materials, according to a 1987 study.

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

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



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



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

This Specification presents recommended design capacities and design methods for wood structural panels when used in building construction and related structures. Design information on other wood structural panel 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 structural panel certification bodies, 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) wood structural panels made in accordance with Voluntary Product Standard PS 1-09 or PS 2-10, promulgated by the United States Department of Commerce, and/or with APA manufacturing standards and 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 wood structural panels should bear the trademark of a certification body, such as APA – The Engineered Wood Association.

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

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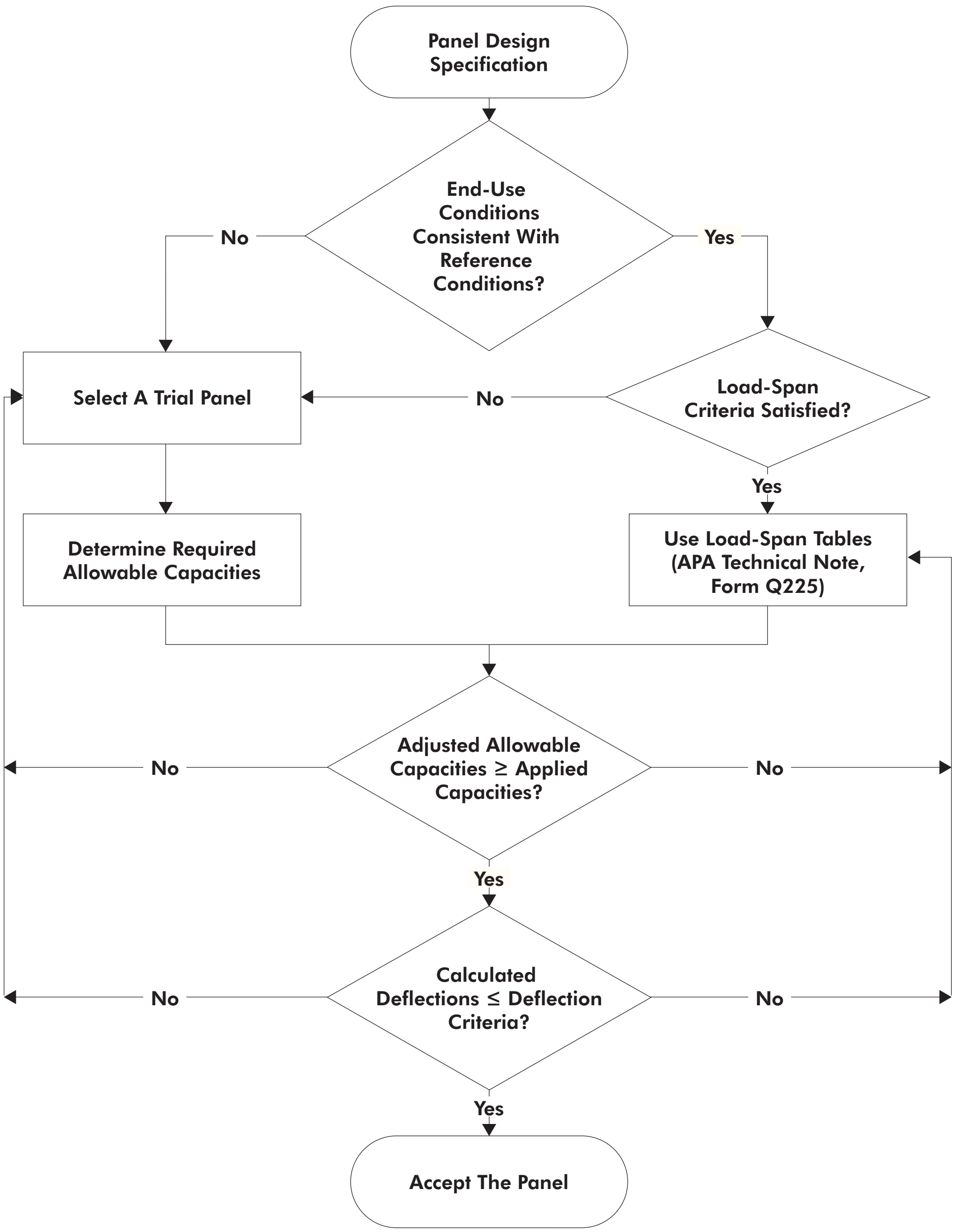

Panel Design Specification
End-Use Conditions Consistent With Reference Conditions?
No
Yes
Select A Trial Panel
No
Load-Span Criteria Satisfied?
Yes
Determine Required Allowable Capacities
Use Load-Span Tables (APA Technical Note, Form Q225)
Adjusted Allowable Capacities ≥ Applied Capacities?
No
No
Yes
Calculated Deflections ≤ Deflection Criteria?
No
No
Yes
Accept The Panel

PANEL DESIGN SPECIFICATION

1. INTRODUCTION

Wood structural panels available today respond to changes in wood resources, manufacturing, and construction trends, meet designer needs for excellent strength, and are light weight while using the only renewable building material. A wood structural panel is a panel product composed primarily of wood, which, in its end use, is essentially dependent upon certain structural and/or physical properties for successful performance in service. Such a product is manufactured to standards that clearly identify its intended end use. Today, wood structural panels include plywood and mat-formed panels such as oriented strand board (OSB). Composite panels containing a combination of veneer and wood-based material have also been produced.

In the early days of plywood manufacturing, every mill worked with several species only and nearly identical technology. Manufacturing techniques didn't vary much from mill to mill. To produce panels under prescriptive standards, a mill used wood of a certain species, peeled it to veneer of a prescribed thickness, then glued the veneers together in a prescribed manner using approved adhesives.

As technology changed, mills started using a broader range of species and different manufacturing techniques. With the development of U.S. Product Standard PS 1-66 for Softwood Plywood – Construction & Industrial, three existing plywood standards were combined into one. And, for the first time, span ratings for construction uses were incorporated into the standard. The span rating concept would later be used as a basis for the development of performance standards.

At the same time, there was a growing need to increase efficient use of forest resources. Working in cooperation with the U.S. Forest Service, the American Plywood Association (APA) (now *APA – The Engineered Wood Association*) tested panels manufactured with a core of compressed wood strands and traditional wood veneer on the face and back for use in structural applications. By using cores composed of wood strands, manufacturers were able to make more efficient use of the wood resource and use a broader range of species. These panels are called composite panels.

In the course of the research on composite panels, performance standards were developed that led to a system of performance rated panels. Soon, manufacturers were making wood structural panels composed entirely of wood strands. Most current production of these panels, intended for use in structural applications, is referred to as oriented strand board, or OSB.

1.1. Plywood

Plywood is the original wood structural panel. It is composed of thin sheets of veneer, or plies, arranged in layers to form a panel. Plywood always has an odd number of layers, each one consisting of one or more plies, or veneers.

In the manufacturing of plywood, a log is turned on a lathe and a long knife blade peels the veneer. The veneers are clipped to a suitable width, dried, graded, and repaired if necessary. Next the veneers are laid up in cross-laminated layers. Sometimes a layer will consist of two or more plies with the grain running in the same direction, but there will always be an odd number of layers, with the face layers typically having the grain oriented parallel to the long dimension of the panel.

Moisture-resistant adhesive is applied to the veneers that are to be laid up. Laid-up veneers are then put in a hot press where they are bonded to form panels.

Wood is strongest along its grain, and shrinks and swells most across the grain. By alternating grain direction between adjacent layers, strength and stiffness in both directions are maximized, and shrinking and swelling are minimized in each direction.

1.2. Oriented strand board

Panels manufactured of compressed wood wafers or strands have been marketed with such names as waferboard and oriented strand board. Today, virtually all mat-formed wood structural panels are manufactured with oriented strands, and are commonly called oriented strand board (OSB).

OSB is composed of compressed strands arranged in layers (usually three to five) oriented at right angles to one another, and bonded under heat and pressure with a moisture-resistant adhesive. The orientation of strands into directional layers achieves the same advantages of cross-laminated veneers in plywood. Since wood is stronger along the grain, the cross-lamination distributes wood's natural strength in both directions of the panel.

Most OSB sheathing panels have a non-skid surface on one side for safety on the construction site, particularly when used as sheathing on pitched roofs.

2. SELECTING PANELS

Wood structural panels are selected according to a number of key attributes. These attributes are identified in the APA trademark found on the panel. Examples are seen in Figure 1, and further explained in the paragraphs that follow.

2.1. Standards

Manufacturing standards for wood structural panels are primarily of two types: prescriptive or performance based. In the past, plywood standards have been primarily of the prescriptive type. The prescriptive standard approach provides a recipe for panel layup, specifying the species of veneer and the number, thickness and orientation of plies that are required to achieve panels of the desired nominal thickness and strength. An alternative approach is to utilize performance-based standards. Such standards specify performance levels required for common end uses rather than manufacturing aspects of construction. Performance standards permit oriented strand board and plywood to be rated similarly for uses in the construction market.

Another distinction between standards is whether they are consensus-based or proprietary. Consensus-based standards are developed following a prescribed set of rules that provide for input and/or review by people of varying interests following one of several recognized procedures. Other standards are of a proprietary nature and may be developed by a single company or industry group. Sometimes proprietary standards become the forerunners of consensus standards. This was the case with APA's proprietary standard PRP-108, Performance Standards and Qualification Policy for Wood Structural Panels, which became the foundation for the consensus-based Voluntary Product Standard PS 2, which was developed to achieve broader recognition of performance standards for wood structural panels.

2.1.1. Voluntary Product Standard PS 1

Voluntary Product Standard PS 1, Structural Plywood, is a consensus standard that originated in 1966 when it combined several preceding U.S. Commercial Standards, each covering a different species of plywood. While originating as a prescriptive standard, the 1983 version added performance-based provisions as an alternative method of qualifying sheathing and single-floor grades of plywood for span ratings. PS 1 continues to offer only prescriptive provisions for other panel grades such as a variety of sanded plywood grades. Consult with www.apawood.org for the latest version of PS 1.

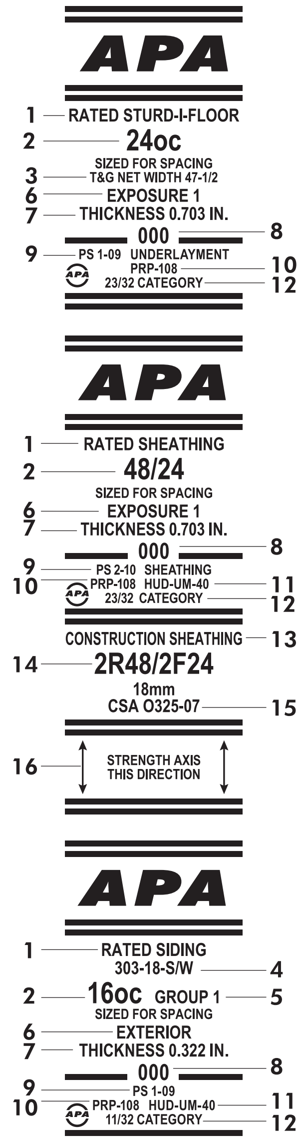
2.1.2. Voluntary Product Standard PS 2

Voluntary Product Standard PS 2, Performance Standard for Wood-Based Wood Structural Panels, was promulgated in 1992 as the first consensus-based performance standard for wood structural panels. The standard was based on APA's PRP-108.

PS 2 is not limited to plywood, but applies to all wood-based structural panels in general, regardless of composition. It covers sheathing and single-floor grades only, and includes performance criteria, qualification

FIGURE 1

TYPICAL TRADEMARKS



1 Panel grade
2 Span Rating
3 Tongue-and-groove
4 Siding face grade
5 Species group number
6 Bond classification
7 Decimal thickness designation (this value is generally at or near the lower tolerance specified in PS 1 or PS 2)
8 Mill number
9 Product Standard
10 APA's performance rated panel standard
11 HUD recognition
12 Performance Category
13 Panel grade, Canadian standard
14 Panel mark – Rating and end-use designation per the Canadian standard
15 Canadian performance rated panel standard
16 Panel face grain orientation indicator

requirements and test methods. Wood structural panels manufactured in conformance with PS 1 and PS 2 are recognized in all model building codes and most local codes in the United States. Also developed in concert with PS 2, with virtually identical provisions, was CSA-O325, Construction Sheathing, which is recognized in the National Building Code of Canada. Consult with www.apawood.org for the latest version of PS 2.

2.1.3. Proprietary standards

The prototype proprietary performance standard for wood structural panels is APA PRP-108, Performance Standards and Qualification Policy for Wood Structural Panels. The APA standard includes performance provisions for sheathing and single-floor grades, but also includes provisions for siding. Although PRP-108, promulgated in 1980, is quite mature, it remains in effect to take advantage of technical developments more expeditiously than would be possible with the rather time-consuming consensus process required by PS 2.

2.1.4. Thickness Designation and Performance Category

Up until 2008, the thickness of structural panels like plywood and OSB was designated and labeled by the panel's nominal thickness which was subject to a plus and minus tolerance specified in the Voluntary Product Standards PS 1 and PS 2. The tolerance on unsanded panel types used in construction is plus or minus 1/32 inch of the designated thickness. The tolerance on sanded grades of plywood is plus or minus 1/64 inch of the designated thickness. These thickness tolerances were applied at the time of manufacturing or at a standard dry condition since it is recognized that actual panel thickness may naturally change due to changes in panel moisture conditions.

Model codes, technical recommendations, designs and specifications have been based upon the use of these panel nominal thicknesses. However, packaging and labeling regulations adopted as state and local law specify that labeling of dimensions comply with standards developed by the National Conference on Weights and Measures. These regulations require dimensional labeling that is incompatible with the thickness tolerances specified in PS 1 and PS 2. To jointly comply with these regulations while maintaining the specifications within model codes and other existing specifications used in the construction industry, structural panels are now labeled with both a Performance Category and a decimal thickness designation. The decimal thickness designation is generally at or near the lower thickness tolerances permitted in PS 1 and PS 2.

The term "Performance Category" is defined within PS 1 and PS 2 as **a panel designation related to the panel thickness range that is linked to the nominal panel thickness designations used in the International Building Code (IBC) and International Residential Code (IRC). For purposes of labeling, abbreviations PERF CAT, CAT, or Category are permitted within the panel grade mark.** The 2012 IBC and IRC state that **the Performance Category value shall be used as the "nominal panel thickness" or "panel thickness" whenever referenced in the code.**

This publication widely uses the Performance Category as the panel designation. There are some places where traditional nominal thickness designations are used, and in those instances, they should be considered as equivalent to the Performance Category.

2.2. Veneer

Wood veneer is at the heart of a plywood panel. The veneer used is classified according to species group and grade requirements of PS 1.

2.2.1. Species groups

While plywood can be manufactured from nearly any wood species, under PS 1 over 70 species of wood are rated for use based on strength and stiffness. This grouping into five Groups is presented in Table 1. Strongest species are in Group 1; the next strongest in Group 2, and so on. The Group number that appears in the trademark on most non-span-rated panels – primarily sanded grades – is based on the species used for face and back veneers. Where face and back veneers are not from the same species Group, the higher Group number (the lower strength species) is used, except for sanded panels with Performance Category of 3/8 or less and Decorative panels of any thickness. These latter panels are identified by face species because they are chosen primarily for appearance and used in applications where structural integrity is not critical. Sanded panels with Performance Category greater than 3/8 are identified by face species if C or D grade backs are at least 1/8 inch and are no more than one species group number higher. Some species are used widely in plywood manufacture; others rarely. The specifier should check local availability if a particular species is desired.

TABLE 1

CLASSIFICATION OF SPECIES[a]

Group 1	Group 2	Group 2	Group 3	Group 4	Group 5
North American Species – Applicable to trees grown in North America					
Beech, American	Cedar, Port Orford	Pine	Alder, Red	Aspen	Basswood
Birch	Cypress	Pond	Birch, Paper	Bigtooth	Poplar,
Sweet	Douglas-fir[b]	Red	Cedar, Alaska	Quaking	Balsam
Yellow	Fir	Virginia	Fir, Subalpine	Cedar	
Douglas-fir[b]	Balsam	Western White	Hemlock, Eastern	Incense	
Larch, Western	California Red	Spruce	Maple, Bigleaf	Western Red	
Maple, Sugar	Grand	Black	Pine	Cottonwood	
Pine, Southern	Noble	Red	Jack	Eastern	
Loblolly	Pacific Silver	Sitka	Lodgepole	Black (W. Poplar)	
Longleaf	White	Sweetgum	Ponderosa	Pine	
Shortleaf	Hemlock, Western	Tamarack	Spruce	Eastern White	
Slash	Maple, Black	Yellow Poplar	Redwood	Sugar	
Tanoak			Spruce		
			Engelmann		
			White		
Non North American Species					
Apitong[c][d]	Lauan	Mengkulang[c]		Cativo	
Kapur[c]	Almon	Meranti, Red[c][e]			
Keruing[c][d]	Bagtikan	Mersawa[c]			
Pine	Mayapis				
Caribbean	Red Lauan				
Ocote	Tangile				
	White Lauan				

(a) Table 1 species classified in accordance with ASTM D2555 as discussed in Appendix A of *Voluntary Product Standard PS 1-09, Structural Plywood,* APA Form L870. The species groupings are only valid for species grown in the regions referenced in Appendix A of PS 1-09. (See Section 5.2.1. of PS 1-09 for additional information.)

(b) 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 Group 1 Douglas-fir. Douglas-fir from trees grown in the states of Nevada, Utah, Colorado, Arizona and New Mexico shall be classed as Group 2 Douglas-fir.

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

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

(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.

2.2.2. *Grades*

Veneer grades define veneer appearance in terms of natural unrepaired growth characteristics and allowable number and size of repairs that may be made during manufacture. See Table 2. The highest quality commonly available veneer grade is A. The minimum grade of veneer permitted in Exterior plywood is C-grade. D-grade veneer is used in panels intended for applications protected from long-term exposure to weather.

TABLE 2

VENEER GRADES

A	Smooth, paintable. Not more than 18 neatly made repairs, boat, sled, or router type, and parallel to grain, permitted. Wood or synthetic repairs permitted. May be used for natural finish in less demanding applications.
B	Solid surface. Shims, sled or router repairs, and tight knots to 1 inch across grain permitted. Wood or synthetic repairs permitted. Some minor splits permitted.
C Plugged	Improved C veneer with splits limited to 1/8-inch width and knotholes or other open defects limited to 1/4 x 1/2 inch. Wood or synthetic repairs permitted. Admits some broken grain.
C	Tight knots to 1-1/2 inches. Knotholes to 1 inch across grain and some to 1-1/2 inches if total width of knots and knotholes is within specified limits. Synthetic or wood repairs. Discoloration and sanding defects that do not impair strength permitted. Limited splits allowed. Stitching permitted.
D	Knots and knotholes to 2-1/2-inch width across grain and 1/2 inch larger within specified limits. Limited splits are permitted. Stitching permitted. Limited to Exposure 1 panels.

2.3. Panel grades

Wood structural panel grades are generally identified in terms of the veneer grade used on the face and back of the panel (e.g., A-B, B-C, etc.), or by a name suggesting the panel's intended end use (e.g., APA Rated Sheathing, APA Rated Sturd-I-Floor, etc.). See Table 3. Unsanded and touch-sanded panels, and panels with B-grade or better veneer on one side only, usually carry the trademark of a qualified inspection and testing agency (such as APA) on the panel back. Panels with both sides of B-grade or better veneer, or with special overlaid surfaces (such as High Density Overlay) usually carry the trademark on the panel edge.

2.3.1. *Unsanded*

Sheathing panels are unsanded since a smooth surface is not a requirement of their intended end use for subfloor, roof and wall applications. Sheathing panels are classified by span ratings, which identify the maximum recommended support spacings for specific end uses. Design capacities provided in 4.4. are on the basis of span ratings.

Structural I sheathing panels meet the requirements of sheathing grades as well as enhanced requirements associated with use in panelized roof systems, diaphragms, and shear walls (e.g., increased cross-panel strength and stiffness, and increased racking shear resistance).

2.3.2. *Touch-sanded*

Underlayment, Single Floor, C-D Plugged, and C-C Plugged grades require only touch sanding for "sizing" to make the panel thickness more uniform. Panels rated for single floor (combination subfloor-underlayment) applications are usually manufactured with tongue-and-groove (T&G) edge profiles, and are classified by span ratings. Single Floor panel span ratings identify the maximum recommended support spacings for floors. Design capacities provided in 4.4. are on the basis of span ratings. Other thinner panels intended for separate underlayment applications (Underlayment or C-C Plugged) are identified with a species Group number but no span rating.

2.3.3. *Sanded*

Plywood panels with B-grade or better veneer faces are always sanded smooth in manufacture to fulfill the requirements of their intended end use – applications such as cabinets, shelving, furniture, built-ins, etc. Sanded grades are classed according to Performance Category and the species group of the faces. Design capacities provided in 4.4. are based on Performance Category and assume Group 1 faces.

TABLE 3

GUIDE TO PANEL USE

Panel Grade	Description & Use	Common Performance Categories	Panel Construction OSB	Plywood
APA RATED SHEATHING EXP 1	Unsanded sheathing grade for wall, roof, subflooring, and industrial applications such as pallets and for engineering design with proper capacities.	5/16, 3/8, 7/16*, 15/32, 1/2, 19/32, 5/8, 23/32, 3/4	Yes	Yes
APA STRUCTURAL I RATED SHEATHING EXP 1	Panel grades to use where shear and cross-panel strength properties are of maximum importance.	3/8, 7/16*, 15/32, 1/2, 19/32, 5/8, 23/32, 3/4	Yes	Yes
APA RATED STURD-I-FLOOR EXP 1	Combination subfloor-underlayment. Provides smooth surface for application of carpet and pad. Possesses high concentrated and impact load resistance during construction and occupancy. Touch-sanded. Available with tongue-and-groove edges.	19/32, 5/8, 23/32, 3/4, 7/8, 1, 1-3/32, 1-1/8	Yes	Yes
APA UNDERLAYMENT EXP 1	For underlayment under carpet and pad. Touch-sanded. Available with tongue-and-groove edges for panels with Performance Categories of 19/32 or greater.	1/4, 11/32, 3/8, 15/32, 1/2, 19/32, 5/8, 23/32, 3/4	No	Yes
APA C-C Plugged EXT	For underlayment, refrigerated or controlled atmosphere storage rooms, open soffits and other similar applications where continuous or severe moisture may be present. Touch-sanded. Available with tongue-and-groove edges for panels with Performance Categories of 19/32 or greater.	1/2, 19/32, 5/8, 23/32, 3/4	No	Yes
APA Sanded Grades EXP 1 or EXT	Generally applied where a high quality surface is required. Includes APA A-A, A-B, A-C, A-D, B-B, B-C and B-D grades.	1/4, 11/32, 3/8, 15/32, 1/2, 19/32, 5/8, 23/32, 3/4	No	Yes
APA MARINE EXT	Superior Exterior plywood made only with Douglas-fir or Western Larch. Special solid-core construction. Available with MDO or HDO face. Ideal for boat hull construction.	1/4, 11/32, 3/8, 15/32, 1/2, 19/32, 5/8, 23/32, 3/4	No	Yes

*7/16 available in OSB only.

2.3.4. Overlaid

High Density Overlay (HDO) and Medium Density Overlay (MDO) plywood may or may not have sanded faces, depending on whether the overlay is applied at the same time the panel is pressed (one-step) or after the panel is pressed (two-step). For purposes of assigning design capacities provided in 4.4., HDO and MDO panels are assumed to be sanded (two-step) with Group 1 faces and B-grade veneer under the overlay.

2.4. Bond classifications

Wood structural panels may be produced in two bond classifications – Exterior and Exposure 1. The bond classification relates to adhesive bond, and thus to structural integrity of the panel.

Bond classification relates to moisture resistance of the glue bond and **does not** relate to fungal decay resistance of the panel. Fungal decay of wood products may occur when the moisture content exceeds approximately 20 percent for an extended period. Prevention of fungal decay is a function of proper design to prevent prolonged exposure to moisture, of material specification, of construction and of maintenance of the structure, or may be accomplished by pressure preservative treatment. See APA literature regarding decay and moisture exposure.

Aesthetic (nonstructural) attributes of panels may be compromised to some degree by exposure to weather. Panel surfaces may become uneven and irregular under prolonged moisture exposure. Panels should be allowed to dry, and panel joints and surfaces may need to be sanded before applying some finish materials.

2.4.1. Exterior

A bond classification for plywood suitable for repeated wetting and redrying or long-term exposure to weather or other conditions of similar severity.

2.4.2. Exposure 1

A bond classification for panels suitable for uses not permanently exposed to the weather. Panels classified as Exposure 1 are intended to resist the effects of moisture due to construction delays, or other conditions of similar severity. Exposure 1 panels are made with the same types of adhesives used in Exterior panels. However, because other compositional factors may affect bond performance, only Exterior panels should be used for long-term exposure to the weather. Exposure 1 panels may, however, be used where exposure to the outdoors is on the underside only, such as at roof overhangs. Appearance characteristics of the panel grade should also be considered.

C-D Exposure 1 plywood, sometimes called “CDX” in the trade, is occasionally mistaken as an Exterior panel and erroneously used in applications for which it does not possess the required resistance to weather. “CDX” should only be used for applications as outlined above.

2.5. Span ratings

Sheathing and Single Floor grades carry numbers in their trademarks called span ratings. These denote the maximum recommended center-to-center spacing of supports, in inches, over which the panels should be placed in construction applications. The span rating applies when the long panel dimension or strength axis is across supports, unless the strength axis is otherwise identified. Note that the floor span rating of “20” is intended for end-use spans of 19.2 inches.

2.5.1. Sheathing

The span rating on Sheathing grade panels appears as two numbers separated by a slash, such as 32/16, 48/24, etc. The left-hand number denotes the maximum recommended spacing of supports when the panel is used for roof sheathing with the long dimension or strength axis of the panel across three or more supports (two or more spans). The right-hand number indicates the maximum recommended spacing of supports when the panel is used for subflooring with the long dimension or strength axis of the panel across three or more supports. A panel marked 32/16, for example, may be used for roof sheathing over supports up to 32 inches on center or for subflooring over supports up to 16 inches on center.

Some roof sheathing maximum spans are dependent upon panel edge support. See Section 4.5.6. for more information.

Sheathing panels rated for use only as wall sheathing are usually identified as either Wall-24 or Wall-16. The numerical index (24 or 16) corresponds to the maximum wall stud spacing in inches. Wall sheathing panels are performance tested with the secondary axis (usually the short dimension of panel) spanning across supports, or studs. For this reason, wall sheathing panels may be applied with either the strength axis or secondary axis across supports. Design capacities for Wall-24 or Wall-16 are not covered in this specification due to the relatively small amount of production. These products should be designed based on the span rating unless the design capacities are provided by the panel manufacturer.

2.5.2. Single floor

The span rating on Single Floor grade panels appears as a single number. Single Floor panels are designed specifically for single-floor (combined subfloor-underlayment) applications and are manufactured with span ratings of 16, 20, 24, 32 and 48 oc. The span ratings for Single Floor panels, like those for Sheathing grade, are based on application of the panel with the long dimension or strength axis across three or more supports.

3. CODE PROVISIONS

Recommendations given in APA literature for construction applications are generally consistent with provisions given in the model building codes in the United States. However, most of the information herein has been expanded compared to the code provisions, to be more useful to designers.

The general APA recommendations apply primarily to conventional or non-engineered construction, but can also be considered conservative for engineered construction. On the other hand, for engineered construction, codes contain provisions for acceptance of engineering calculations, and design capacities given herein may be used. In many cases, calculations using values in this document will lead to higher allowable design loads for sheathing. This is because the general APA and code recommendations are based on minimum structural requirements or criteria of the performance standards, while the design capacities are based on actual characteristics of panels qualified under the performance standards. Since it would be difficult to manufacture a truly “minimum” panel with regard to all properties, panel characteristics meet or exceed requirements of the standards.

Regardless of any increase in allowable load based on calculations, always observe the maximum recommended span (e.g., span rating). Maximum span is established by test and is often controlled by concentrated load considerations.

4. MECHANICAL PROPERTIES

Wood structural panels can typically be incorporated into construction projects without the need for engineering design of the panels themselves. They lend themselves to tabular and descriptive presentation of design recommendations and provisions. Occasionally, however, there is a need to engineer panel applications that call for panel properties or capacities; or it may be necessary to evaluate specific panel constructions that yield superior mechanical properties compared to those that are the basis for general use recommendations.

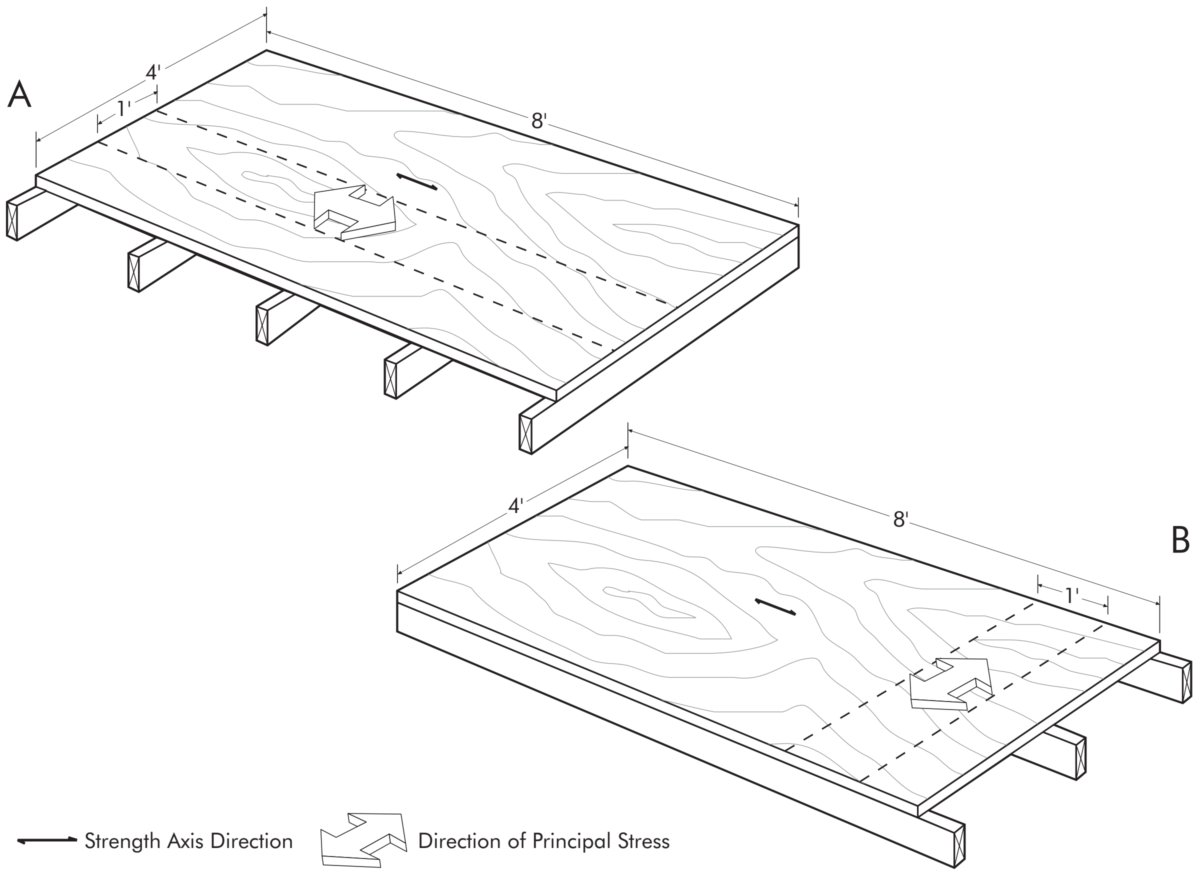
4.1. Strength axis

A feature of most wood structural panel types, primarily plywood and OSB, is that there is a strength axis associated with their manufacture. The layered construction of both products, in which layers are oriented 90 degrees from one another, creates dissimilar properties in the two principal directions. This is illustrated in Figure 2. The orientation of the face and back layer determines the direction of the strength axis.

The panel strength axis is typically in the long panel direction; that is, the panel is typically stronger and stiffer along the panel length than across the panel width. Specification of panel orientation, then, can be stated as “strength axis is perpendicular (or parallel) to supports” or, sometimes, “stress is parallel (or perpendicular) to the strength axis.” In the case of plywood, the strength axis is sometimes referred to as the face grain direction.

FIGURE 2

TYPICAL WOOD STRUCTURAL PANEL WITH STRENGTH AXIS DIRECTION PERPENDICULAR TO OR ACROSS SUPPORTS (A) AND PARALLEL TO SUPPORTS (B). Note the standard 4' x 8' size, strength axis direction, and representative portion of panel used in calculation of capacities for stress parallel (A) or perpendicular (B) to the strength axis.



4.2. Panel construction

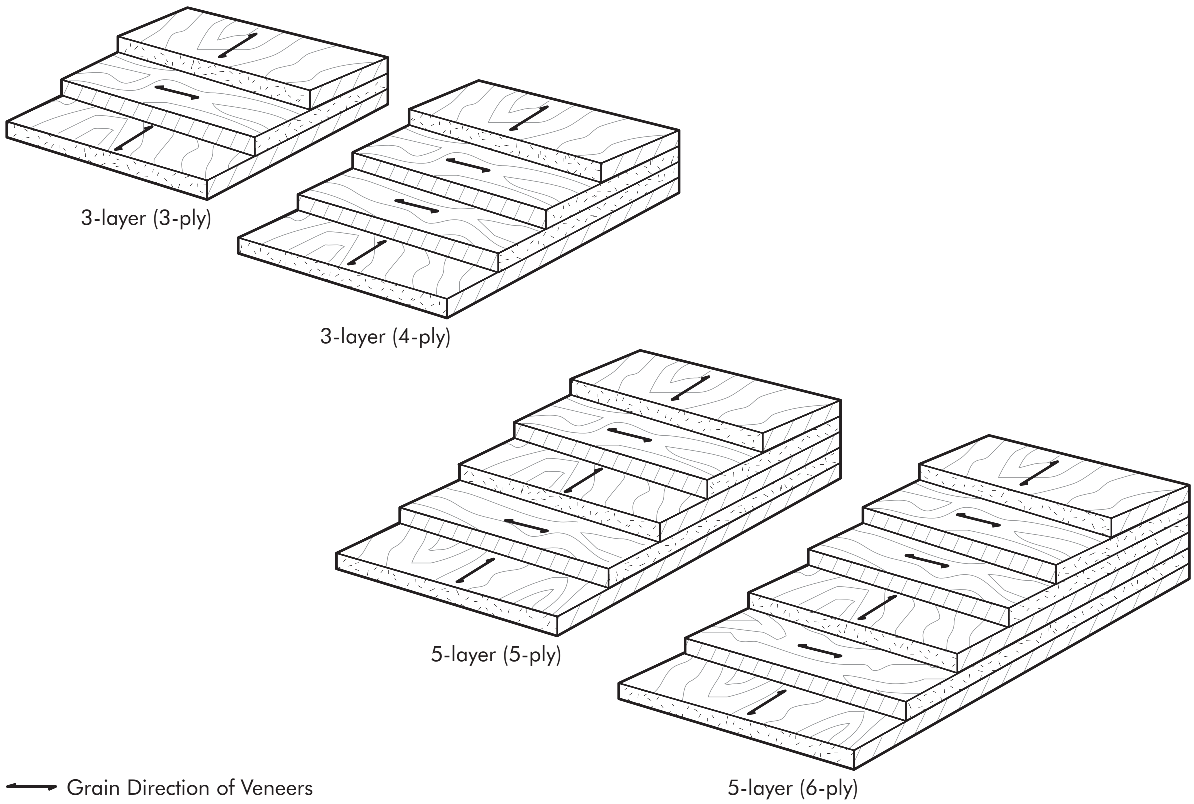
Plywood mills may use different layups for the same panel Performance Category and span rating to make optimum use of their raw material resources. Design calculations must take into account the direction in which the stresses will be imposed in the panel. If stresses can be expected in both directions, then both the parallel and perpendicular directions should be checked. For this reason, tabulated capacities are given for both directions.

Capacities parallel to the face grain of plywood are based on a panel construction that gives minimum values in that direction. (See Figure 3.) Capacities perpendicular to the face grain are usually based on a different panel construction that gives minimum values in that direction. Both values, therefore, are conservative. Capacities given for the two directions are not necessarily for the same panel construction.

Similar layers occur also in OSB manufacture. However, the layers are not defined and therefore cannot be specified. For this reason, ply-layer options are not tabulated for OSB.

FIGURE 3

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



4.3. Properties and stresses

Plywood properties have traditionally been separately tabulated as section properties and design stresses. These are multiplied together to obtain a capacity. In many cases the resulting capacity will be quite conservative. Design stresses are conservatively developed, taking into account grade factors and manufacturing factors, and then the data is statistically analyzed such that it represents the "low end" of possible values. The stress is then further adjusted by a load factor or, as some call it, a factor of safety.

At the same time, section properties are developed for virtually all possible layup combinations of veneer thickness and species. The lowest property value for a given panel thickness or span rating is then chosen for tabulation. The resulting capacity combines two already conservative values. In the 1990s, this procedure was largely replaced by direct publication of panel capacities. However, the section property and design stress technique is still used occasionally to analyze individual plywood layup variations.

4.4. Capacities

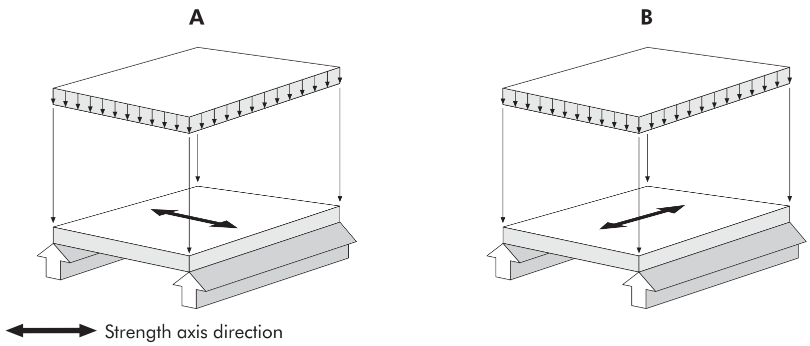
Panel design capacities listed in Tables 8 and 9 are minimum for grade and span rating or Performance Category. For Structural I panels, the tabulated capacities shall be permitted to be multiplied by the "Structural I Multiplier" factors given in the bottom of each property table. Since Table 9 gives capacities for sanded panels marked as species Group 1, Table 10 provides multipliers for sanded panel capacities that are identified as species Group 2, 3 or 4. The tabulated capacities are based on data from tests of panels bearing the APA trademark. To take advantage of these capacities and adjustments, the specifier must ensure that the correct panel is used in the final construction.

4.4.1. Panel flexure (flat panel bending)

Panel design capacities reported in Tables 8 and 9 are based on flat panel bending as measured by testing in accordance with ASTM D3043, Method C (large panel testing). See Figure 4.

FIGURE 4

STRUCTURAL PANEL IN BENDING – (A) STRESS PARALLEL TO STRENGTH AXIS AND (B) STRESS PERPENDICULAR TO STRENGTH AXIS



Stiffness (EI)

Panel bending stiffness is the capacity to resist deflection and is represented in bending equations as EI. The E is the modulus of elasticity of the material and the I is the moment of inertia of the cross section. Units of EI are lbf-in.^{2} per foot of panel width.

Strength (F_bS)

Allowable bending strength capacity is the design maximum moment, represented in bending equations as F_bS. Terms are the allowable extreme fiber stress of the material (F_b) and the section modulus (S). Units of F_bS are lbf-in. per foot of panel width.

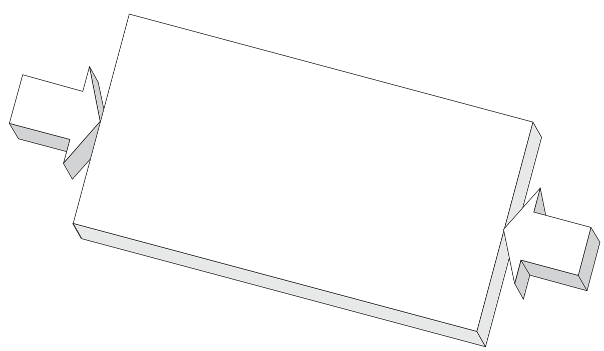
4.4.2. Panel axial strength

Tension (F_tA)

Allowable tension capacities are reported in Tables 8 and 9 based on testing in accordance with ASTM D3500, Method B. Tension capacity is given as F_tA, where F_t is the allowable axial tension stress of the material and A is the area of the cross section. Units of F_tA are lbf per foot of panel width.

FIGURE 5

STRUCTURAL PANEL WITH AXIAL COMPRESSION LOAD IN THE PLANE OF THE PANEL



Compression (F_cA)

Allowable compression capacities are reported in Tables 8 and 9 based on testing in accordance with ASTM D3501, Method B. Compression capacity is given as F_cA, where F_c is the allowable axial compression stress of the material, and A is the area of the cross section. Units of F_cA are lbf per foot of panel width. Axial compression strength is illustrated in Figure 5.

4.4.3. Panel axial stiffness (EA)

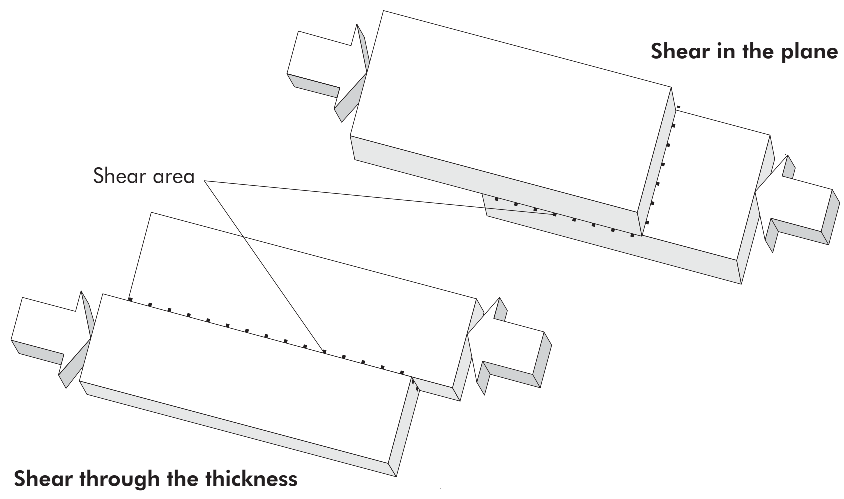
Panel axial stiffness is reported in Tables 8 and 9 based on testing in accordance with ASTM D3501, Method B. Axial stiffness is the capacity to resist axial strain and is represented by EA. The E is the axial modulus of elasticity of the material and A is the area of the cross section. Units of EA are lbf per foot of panel width.

4.4.4. Shear in the plane of the panel (Fs[Ib/Q])

Allowable shear in the plane of the panel (or interlaminar shear, sometimes called rolling shear in plywood) is reported in Tables 8 and 9 based on testing in accordance with ASTM D2718. Shear strength in the plane of the panel is the capacity to resist horizontal shear breaking loads when loads are applied or developed on opposite faces of the panel, as they are during flat panel bending. See Figure 6. The term F_s is the allowable interlaminar shear stress, while Ib/Q is the panel cross sectional shear constant. Units of F_s(Ib/Q) are lbf per foot of panel width.

FIGURE 6

TWO TYPES OF PANEL SHEAR: SHEAR THROUGH THE THICKNESS AND SHEAR IN THE PLANE OF THE PANEL



4.4.5. Panel shear through the thickness ($F_v t_v$)

Allowable shear through the thickness is the capacity to resist horizontal shear breaking loads when loads are applied or developed on opposite edges of the panel, such as they are in an I-joist web, and is reported in Tables 8 and 9. See Figure 6. Panel shear-through-the-thickness capacities are reported based on testing in accordance with ASTM D2719. Where additional support is not provided to prevent buckling, design capacities in Tables 8 and 9 are limited to sections 2 ft or less in depth. Deeper sections may require additional reductions. The term F_v is the allowable through-the-thickness shear stress, while t_v is the effective panel thickness for shear. Units of $F_v t_v$ are lbf per inch of shear-resisting panel length.

4.4.6. Panel rigidity through the thickness ($G_v t_v$)

Panel rigidity is reported in Tables 8 and 9 and is the capacity to resist deformation when under shear-through-the-thickness stress. Rigidity is represented by $G_v t_v$, where G_v is the modulus of rigidity and t_v is the effective panel thickness for shear. The units of $G_v t_v$ are lbf per inch of panel depth (for vertical applications). Multiplication of $G_v t_v$ by panel depth gives GA, used by designers for some applications.

4.4.7. Panel allowable bearing stress ($F_{c\perp}$)

Bearing stress is the compression stress perpendicular to the plane of the plies or to the surface of the panel. As compression load is applied to panels (such as by columns or by reactions at supports), bearing stress is induced through the bearing area. Panel bearing stress is based on testing in accordance with ASTM D143. The allowable bearing stress of APA wood structural panels is derived based on the load at a 0.04-in. deformation limit. A design bearing stress of 360 psi shall be used for wood structural panels under dry-use conditions where moisture content is less than 16 percent. Multiplying the allowable bearing stress by the bearing area gives the bearing capacity, $F_{c\perp}A$, in lbf.

A reduced design bearing stress may be appropriate where bearing deformation could affect load distribution or where total deformation of members must be closely controlled. The allowable panel bearing stress value at 0.02-inch deformation ($F_{c\perp 0.02"}$) can be chosen as 210 psi.

4.4.8. Fastener properties

Table 4 shows the specific gravity for wood structural panels that is equivalent to the specific gravity for solid-sawn lumber (also known as "equivalent specific gravity" or ESG) for fastener properties in dry service conditions where the equilibrium moisture content is less than 16 percent. The fastener properties when installed with wood structural panels can be determined using the ESG, in lieu of the lumber specific gravity (G), and the fastener design provisions provided in the NDS.

TABLE 4

EQUIVALENT SPECIFIC GRAVITY (ESG) FOR WOOD STRUCTURAL PANELS IN DRY SERVICE CONDITIONS

Loading Mode	Fasteners[a]	Plywood Group 1	Plywood Others	OSB
Withdrawal	Nails (Smooth- or Screw-Shank)	0.40	0.40	0.40
	Nails (Ring-Shank)	0.70	0.70	0.70
	Wood screws	0.45	0.45	0.45
Lateral	Dowel-type fasteners (nails, screws and bolts)[a]	0.50	0.42[b]	0.50

(a) For fastener diameter of 1/4 in. or less.

(b) Use 0.42 when species of the plies is not known. When species of the plies is known, specific gravity listed for the actual species and the corresponding dowel bearing strength may be used, or the weighted average may be used for mixed species.

4.4.8.1. Nail withdrawal strength

Under certain circumstances, such as strong gusts of wind or hurricanes, sheathing or siding may be loosened or detached as nails are withdrawn from the wood structural panels. Based on extensive testing conducted by APA in accordance with ASTM D1761, the equivalent specific gravity values for nail withdrawal strength with wood structural panels are listed in Table 4, which can be used to estimate the reference nail withdrawal strength from wood structural panels using Eq 1. The reference nail withdrawal strength shall be multiplied by all applicable adjustment factors (see Section 4.5 of this specification and Table 10.3.1 of the *National Design Specification for Wood Construction* (NDS)) to obtain adjusted nail withdrawal design values.

$$W = 1380\, G^{5/2}\, D \qquad [1]$$

Where:

W = reference nail withdrawal design value (lbf/in. penetration)

G = equivalent specific gravity (ESG) listed in Table 4

D = nail diameter (in.)

4.4.8.2. Wood screw withdrawal strength

Withdrawal strength of wood screws from wood structural panels depend on a number of variables, including the type and diameter of the screw, the specific gravity of the wood component, the effective penetration of the threaded portion of the screw, and moisture conditions. Wood screw withdrawal tests are conducted in accordance with ASTM D1761. The equivalent specific gravity values for wood screw withdrawal strength with wood structural panels are listed in Table 4, which can be used to estimate the reference wood screw withdrawal strength from wood structural panels using Eq. 2. The reference wood screw withdrawal strength shall be multiplied by all applicable adjustment factors (see Section 4.5 of this specification and Table 10.3.1 of the NDS) to obtain adjusted wood screw withdrawal design values.

$$W = 2850\ G^2\ D \qquad [2]$$

Where:

W = reference wood screw withdrawal design value (lbf/in. thread penetration)

G = equivalent specific gravity (ESG) listed in Table 4

D = wood screw diameter (in.)

4.4.8.3. Fastener lateral strength

Lateral strength of dowel-type fasteners from structural panels shall be calculated using the dowel bearing strength of wood structural panels as a function of the ESG listed in Table 4 and the yield limit equations provided in Table 11.3.1A of the NDS. The reference lateral strength shall be multiplied by all applicable adjustment factors (see Section 4.5 of this specification and Table 10.3.1 of the NDS) to obtain adjusted lateral design values.

4.4.8.4. Nailhead pull-through strength

A nailed sheathing-to-lumber joint may be limited by either nail withdrawal from the lumber or by nailhead pull-through strength of the wood structural panel. Nailhead pull-through resistance is affected by many factors, such as the nailhead diameter, and the thickness and specific gravity of the wood structural panel. Testing for the nailhead pull-through resistance is based on ASTM D1037. Reference *APA Technical Topic: Nailhead Pull-Through Strength of Wood Structural Panels,* Form TT-070 for more information.

4.5. Adjustments

Panel design capacities may be adjusted as required under the following provisions.

4.5.1. Duration of load (DOL)

Design capacities listed are based on "normal duration of load" as traditionally used for solid wood in accordance with U.S. Forest Products Laboratory Report R-1916, and successfully used for plywood for approximately 60 years. Adjustment factors for strength capacities (C_D) are shown in Table 5.

TABLE 5

LOAD DURATION FACTORS FOR WOOD STRUCTURAL PANELS

Time Under Load	DOL Adjustment Factor* (C_D)
Permanent	0.90
Normal	1.00
Two Months	1.15
Seven Days	1.25
Wind or Earthquake	1.60

*Adjustment for impact load does not apply to wood structural panels.

Creep

Wood structural panels under constant load will creep (deflection will increase) over time. For typical construction applications, panels are not normally under constant load and, accordingly, creep need not be considered in design. When panels will sustain permanent loads that will stress the product to one-half or more of its design strength capacity, allowance should be made for creep. Limited data indicates that under such conditions, creep may be taken into account in deflection calculations by applying the applicable creep adjustment factor (C_C) to panel stiffness, EI, as shown in Table 6.

See 4.5.2 for additional adjustments related to service moisture conditions, which for EI is cumulative with the creep adjustment.

TABLE 6

CREEP ADJUSTMENT FACTORS FOR WOOD STRUCTURAL PANELS

	Creep Adjustment Factor (C_c) for Permanent Loads	
Moisture Condition	Plywood	OSB
Dry	1/2	1/2
16% m.c. or greater	1/2	1/6

4.5.2. Service moisture conditions

Design capacities apply to panels under moisture conditions that are continuously dry in service; that is, where equilibrium moisture content is less than 16 percent. Adjustment factors for conditions where the panel moisture content in service is expected to be 16 percent or greater are shown in Table 7.

4.5.3. Elevated temperature

Capacities in Tables 8 and 9 apply at temperatures of 70°F and lower. Wood structural panel parts of buildings should not be exposed to temperatures above 200°F for more than very brief periods. However, between 70°F and 200°F, adjustments to capacity generally do not need to be made, because the need for adjustment of dry capacities depends upon whether moisture content will remain in the 12 to 15 percent range or whether the panel will dry to lower moisture contents as a result of the increase in temperature. If drying occurs, as is usually the case, 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 or higher 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 percent at 150°F, sustained relative humidity of around 80% would be required. The designer needs to exercise judgment in determining whether high temperature and moisture content occur simultaneously, and the corresponding need for temperature adjustment of capacities.

TABLE 7

MOISTURE CONTENT ADJUSTMENT FACTORS FOR WOOD STRUCTURAL PANELS

Capacity	Moisture Content Adjustment Factor (C_M)
Strength (F_bS, F_tA, F_cA, $F_s[Ib/Q]$, F_vt_v)	0.75
Stiffness (EI, EA, G_vt_v)	0.85
Bearing ($F_{c\perp}A$)	
Plywood	0.50
OSB	0.20
Nail withdrawal strength	0.75
Wood screw withdrawal strength and lateral strength for dowel-type fasteners (nails, screws and bolts) of 1/4 inch or less in diameter	NDS Table 10.3.3

4.5.4. Pressure treatment

Preservative treatment

Capacities given in this document apply, without adjustment, to plywood pressure-impregnated with preservative chemicals and redried in accordance with American Wood Protection Association (AWPA) Standard U1. OSB panels are currently recommended only for non-pressure applications of preservative treating in accordance with AWPA Standard T1.

Fire-retardant treatment

Discussion in this document does not apply to fire-retardant-treated structural panels. However, some general information on fire-retardant treated plywood roof sheathing is available in *APA Technical Note: Fire-Retardant-Treated (FRT) Plywood*, Form K320. For fire-retardant-treated plywood, all capacities and end-use conditions shall be in accordance with the recommendations and/or model code evaluation reports of the company providing the treating and redrying service.

TABLE 8

RATED PANELS DESIGN CAPACITIES

Span Rating	Stress Parallel to Strength Axis: Plywood 3-ply	Stress Parallel to Strength Axis: Plywood 4-ply	Stress Parallel to Strength Axis: Plywood 5-ply	Stress Parallel to Strength Axis: OSB	Stress Perpendicular to Strength Axis: Plywood 3-ply	Stress Perpendicular to Strength Axis: Plywood 4-ply	Stress Perpendicular to Strength Axis: Plywood 5-ply	Stress Perpendicular to Strength Axis: OSB
PANEL BENDING STIFFNESS, EI (lbf-in.²/ft of panel width)								
24/0	66,000	66,000	66,000	60,000	3,600	7,900	11,000	11,000
24/16	86,000	86,000	86,000	78,000	5,200	11,500	16,000	16,000
32/16	125,000	125,000	125,000	115,000	8,100	18,000	25,000	25,000
40/20	250,000	250,000	250,000	225,000	18,000	39,500	56,000	56,000
48/24	NA	440,000	440,000	400,000	NA	65,000	91,500	91,500
16 oc	165,000	165,000	165,000	150,000	11,000	24,000	34,000	34,000
20 oc	230,000	230,000	230,000	210,000	13,000	28,500	40,500	40,500
24 oc	NA	330,000	330,000	300,000	NA	57,000	80,500	80,500
32 oc	NA	NA	715,000	650,000	NA	NA	235,000	235,000
48 oc	NA	NA	1,265,000	1,150,000	NA	NA	495,000	495,000
Structural I Multiplier	1.0	1.0	1.0	1.0	1.5	1.5	1.6	1.6
PANEL BENDING STRENGTH, F_bS (lbf-in./ft of panel width)								
24/0	250	275	300	300	54	65	97	97
24/16	320	350	385	385	64	77	115	115
32/16	370	405	445	445	92	110	165	165
40/20	625	690	750	750	150	180	270	270
48/24	NA	930	1,000	1,000	NA	270	405	405
16 oc	415	455	500	500	100	120	180	180
20 oc	480	530	575	575	140	170	250	250
24 oc	NA	705	770	770	NA	260	385	385
32 oc	NA	NA	1,050	1,050	NA	NA	685	685
48 oc	NA	NA	1,900	1,900	NA	NA	1,200	1,200
Structural I Multiplier	1.0	1.0	1.0	1.0	1.3	1.4	1.5	1.5
PANEL AXIAL TENSION, F_tA (lbf/ft of panel width)								
24/0	2,300	2,300	3,000	2,300	600	600	780	780
24/16	2,600	2,600	3,400	2,600	990	990	1,300	1,300
32/16	2,800	2,800	3,650	2,800	1,250	1,250	1,650	1,650
40/20	2,900	2,900	3,750	2,900	1,600	1,600	2,100	2,100
48/24	NA	4,000	5,200	4,000	NA	1,950	2,550	2,550
16 oc	2,600	2,600	3,400	2,600	1,450	1,450	1,900	1,900
20 oc	2,900	2,900	3,750	2,900	1,600	1,600	2,100	2,100
24 oc	NA	3,350	4,350	3,350	NA	1,950	2,550	2,550
32 oc	NA	NA	5,200	4,000	NA	NA	3,250	3,250
48 oc	NA	NA	7,300	5,600	NA	NA	4,750	4,750
Structural I Multiplier	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
PANEL AXIAL COMPRESSION, F_cA (lbf/ft of panel width)								
24/0	2,850	4,300	4,300	2,850	2,500	3,750	3,750	2,500
24/16	3,250	4,900	4,900	3,250	2,500	3,750	3,750	2,500
32/16	3,550	5,350	5,350	3,550	3,100	4,650	4,650	3,100
40/20	4,200	6,300	6,300	4,200	4,000	6,000	6,000	4,000
48/24	NA	7,500	7,500	5,000	NA	7,200	7,200	4,300
16 oc	4,000	6,000	6,000	4,000	3,600	5,400	5,400	3,600
20 oc	4,200	6,300	6,300	4,200	4,000	6,000	6,000	4,000
24 oc	NA	7,500	7,500	5,000	NA	7,200	7,200	4,300
32 oc	NA	NA	9,450	6,300	NA	NA	9,300	6,200
48 oc	NA	NA	12,150	8,100	NA	NA	10,800	6,750
Structural I Multiplier	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Shaded cells are atypical APA panel constructions, as shown in Table 13.

TABLE 8 (Continued)

RATED PANELS DESIGN CAPACITIES

Span Rating	Stress Parallel to Strength Axis: Plywood 3-ply	Plywood 4-ply	Plywood 5-ply	OSB	Stress Perpendicular to Strength Axis: Plywood 3-ply	Plywood 4-ply	Plywood 5-ply	OSB
PANEL AXIAL STIFFNESS, EA (lbf/ft of panel width)								
24/0	3,350,000	3,350,000	3,350,000	3,350,000	2,900,000	2,900,000	2,900,000	2,500,000[a]
24/16	3,800,000	3,800,000	3,800,000	3,800,000	2,900,000	2,900,000	2,900,000	2,700,000[a]
32/16	4,150,000	4,150,000	4,150,000	4,150,000	3,600,000	3,600,000	3,600,000	2,700,000
40/20	5,000,000	5,000,000	5,000,000	5,000,000	4,500,000	4,500,000	4,500,000	2,900,000[b]
48/24	NA	5,850,000	5,850,000	5,850,000	NA	5,000,000	5,000,000	3,300,000[b]
16 oc	4,500,000	4,500,000	4,500,000	4,500,000	4,200,000	4,200,000	4,200,000	2,700,000
20 oc	5,000,000	5,000,000	5,000,000	5,000,000	4,500,000	4,500,000	4,500,000	2,900,000[b]
24 oc	NA	5,850,000	5,850,000	5,850,000	NA	5,000,000	5,000,000	3,300,000[b]
32 oc	NA	NA	7,500,000	7,500,000	NA	NA	7,300,000	4,200,000
48 oc	NA	NA	8,200,000	8,200,000	NA	NA	7,300,000	4,600,000
Structural I Multiplier	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
PANEL SHEAR IN THE PLANE, $F_s(Ib/Q)$ (lbf/ft of panel width)								
24/0	155	155	170	130	275	375	130	130
24/16	180	180	195	150	315	435	150	150
32/16	200	200	215	165	345	480	165	165
40/20	245	245	265	205	430	595	205	205
48/24	NA	300	325	250	NA	725	250	250
16 oc	245	245	265	205	430	595	205	205
20 oc	245	245	265	205	430	595	205	205
24 oc	NA	300	325	250	NA	725	250	250
32 oc	NA	NA	390	300	NA	NA	300	300
48 oc	NA	NA	500	385	NA	NA	385	385
Structural I Multiplier	1.4	1.4	1.4	1.0	1.4	1.4	1.0	1.0
PANEL RIGIDITY THROUGH THE THICKNESS, $G_v t_v$ (lbf/in. of panel depth)								
24/0	25,000	32,500	37,500	77,500	25,000	32,500	37,500	77,500
24/16	27,000	35,000	40,500	83,500	27,000	35,000	40,500	83,500
32/16	27,000	35,000	40,500	83,500	27,000	35,000	40,500	83,500
40/20	28,500	37,000	43,000	88,500	28,500	37,000	43,000	88,500
48/24	NA	40,500	46,500	96,000	NA	40,500	46,500	96,000
16 oc	27,000	35,000	40,500	83,500	27,000	35,000	40,500	83,500
20 oc	28,000	36,500	42,000	87,000	28,000	36,500	42,000	87,000
24 oc	NA	39,000	45,000	93,000	NA	39,000	45,000	93,000
32 oc	NA	NA	54,000	110,000	NA	NA	54,000	110,000
48 oc	NA	NA	76,000	155,000	NA	NA	76,000	155,000
Structural I Multiplier	1.3	1.3	1.1	1.0	1.3	1.3	1.1	1.0
PANEL SHEAR THROUGH THE THICKNESS, $F_v t_v$ (lbf/in. of shear-resisting panel length)								
24/0	53	69	80	155	53	69	80	155
24/16	57	74	86	165	57	74	86	165
32/16	62	81	93	180	62	81	93	180
40/20	68	88	100	195	68	88	100	195
48/24	NA	98	115	220	NA	98	115	220
16 oc	58	75	87	170	58	75	87	170
20 oc	67	87	100	195	67	87	100	195
24 oc	NA	96	110	215	NA	96	110	215
32 oc	NA	NA	120	230	NA	NA	120	230
48 oc	NA	NA	160	305	NA	NA	160	305
Structural I Multiplier	1.3	1.3	1.1	1.0	1.3	1.3	1.1	1.0

Shaded cells are atypical APA panel constructions as shown in Table 13.

(a) The value shall be permitted to be increased to 2,900,000 lbf/ft for the calculation of the bending stiffness (EI_{joist}) of prefabricated wood I-joists.

(b) The value shall be permitted to be increased to 4,500,000 lbf/ft for the calculation of the composite floor bending stiffness ($EI_{composite}$) of prefabricated wood I-joists.

TABLE 9

SANDED GROUP 1[(a)] PLYWOOD DESIGN CAPACITIES

Performance Category	Stress Parallel to Strength Axis			Stress Perpendicular to Strength Axis		
	A-A, A-C	Marine	Other	A-A, A-C	Marine	Other
PANEL BENDING STIFFNESS, EI (lbf-in.²/ft of panel width)						
1/4	15,000	15,000	15,000	700	980	700
11/32	34,000	34,000	34,000	1,750	2,450	1,750
3/8	49,000	49,000	49,000	2,750	3,850	2,750
15/32	120,000	120,000	120,000	11,000	15,500	11,000
1/2	140,000	140,000	140,000	15,500	21,500	15,500
19/32	205,000	205,000	205,000	37,500	52,500	37,500
5/8	230,000	230,000	230,000	48,500	68,000	48,500
23/32	320,000	320,000	320,000	90,500	125,000	90,500
3/4	355,000	355,000	355,000	115,000	160,000	115,000
7/8	500,000	500,000	500,000	185,000	260,000	185,000
1	760,000	760,000	760,000	330,000	460,000	330,000
1-1/8	985,000	985,000	985,000	490,000	685,000	490,000
Structural I Multiplier	1.0	1.0	1.0	1.4	1.0	1.4
PANEL BENDING STRENGTH, F_bS (lbf-in./ft of panel width)						
1/4	115	105	95	17	20	14
11/32	185	170	155	31	36	26
3/8	245	225	205	44	52	37
15/32	425	390	355	130	150	110
1/2	470	430	390	175	205	145
19/32	625	570	520	270	315	225
5/8	670	615	560	325	380	270
23/32	775	710	645	455	530	380
3/4	815	750	680	565	660	470
7/8	1,000	935	850	780	910	650
1	1,300	1,200	1,100	1,150	1,350	975
1-1/8	1,600	1,500	1,350	1,500	1,750	1,250
Structural I Multiplier	1.0	1.0	1.1	1.4	1.0	1.4
PANEL AXIAL TENSION, F_tA (lbf/ft of panel width)						
1/4	1,800	1,650	1,650	660	990	550
11/32	1,800	1,650	1,650	840	1,250	700
3/8	2,350	2,150	2,150	1,250	1,900	1,050
15/32	3,500	3,200	3,200	2,400	3,600	2,000
1/2	3,500	3,200	3,200	2,450	3,700	2,050
19/32	4,400	4,000	4,000	2,750	4,150	2,300
5/8	4,500	4,100	4,100	3,000	4,500	2,500
23/32	5,100	4,650	4,650	3,400	5,150	2,850
3/4	5,250	4,750	4,750	4,150	6,200	3,450
7/8	5,350	4,850	4,850	5,200	7,850	4,350
1	6,750	6,150	6,150	6,250	9,350	5,200
1-1/8	7,000	6,350	6,350	6,300	9,450	5,250
Structural I Multiplier	1.0	1.0	1.0	1.7	1.0	1.8

(a) See Table 10 for multipliers for other species Groups

TABLE 9 (Continued)

SANDED GROUP 1[(a)] PLYWOOD DESIGN CAPACITIES

Performance Category	Stress Parallel to Strength Axis			Stress Perpendicular to Strength Axis		
	A-A, A-C	Marine	Other	A-A, A-C	Marine	Other
PANEL AXIAL COMPRESSION F_cA (lbf/ft of panel width)						
1/4	1,710	1,550	1,550	605	990	550
11/32	1,710	1,550	1,550	715	1,150	650
3/8	2,200	2,000	2,000	1,050	1,700	950
15/32	3,300	3,000	3,000	2,050	3,350	1,850
1/2	3,300	3,000	3,000	2,100	3,400	1,900
19/32	4,150	3,750	3,750	2,350	3,850	2,150
5/8	4,200	3,800	3,800	2,600	4,250	2,350
23/32	4,800	4,350	4,350	2,900	4,750	2,650
3/4	4,900	4,450	4,450	3,500	5,750	3,200
7/8	5,000	4,550	4,550	4,500	7,400	4,100
1	6,350	5,750	5,750	5,350	8,750	4,850
1-1/8	6,550	5,950	5,950	5,400	8,800	4,900
Structural I Multiplier	1.0	1.0	1.0	1.8	1.0	1.8
PANEL AXIAL STIFFNESS, EA (lbf/ft of panel width)						
1/4	1,800,000	1,800,000	1,800,000	625,000	1,150,000	625,000
11/32	1,800,000	1,800,000	1,800,000	750,000	1,350,000	750,000
3/8	2,350,000	2,350,000	2,350,000	1,150,000	2,050,000	1,150,000
15/32	3,500,000	3,500,000	3,500,000	2,150,000	3,850,000	2,150,000
1/2	3,500,000	3,500,000	3,500,000	2,250,000	4,050,000	2,250,000
19/32	4,350,000	4,350,000	4,350,000	2,500,000	4,500,000	2,500,000
5/8	4,450,000	4,450,000	4,450,000	2,750,000	4,950,000	2,750,000
23/32	5,100,000	5,100,000	5,100,000	3,150,000	5,650,000	3,150,000
3/4	5,200,000	5,200,000	5,200,000	3,750,000	6,750,000	3,750,000
7/8	5,300,000	5,300,000	5,300,000	4,750,000	8,550,000	4,750,000
1	6,700,000	6,700,000	6,700,000	5,700,000	10,500,000	5,700,000
1-1/8	6,950,000	6,950,000	6,950,000	5,700,000	10,500,000	5,700,000
Structural I Multiplier	1.0	1.0	1.0	1.8	1.0	1.8
PANEL SHEAR IN THE PLANE, F_s(Ib/Q) (lbf/ft of panel width)						
1/4	105	135	105	105	135	105
11/32	145	190	145	145	190	145
3/8	165	215	165	165	215	165
15/32	220	285	220	220	285	220
1/2	235	305	235	235	305	235
19/32	290	375	290	290	375	290
5/8	310	405	310	310	405	310
23/32	350	455	350	350	455	350
3/4	360	470	360	360	470	360
7/8	425	555	425	425	555	425
1	470	610	470	470	610	470
1-1/8	525	685	525	525	685	525
Structural I Multiplier	1.3	1.0	1.3	1.4	1.0	1.4

(a) See Table 10 for multipliers for other species Groups

TABLE 9 (Continued)

SANDED GROUP 1[a] PLYWOOD DESIGN CAPACITIES

Performance Category	Stress Parallel to Strength Axis			Stress Perpendicular to Strength Axis		
	A-A, A-C	Marine	Other	A-A, A-C	Marine	Other
PANEL RIGIDITY THROUGH THE THICKNESS G_vt_v (lbf/in. of panel depth)						
1/4	24,000	31,000	24,000	24,000	31,000	24,000
11/32	25,500	33,000	25,500	25,500	33,000	25,500
3/8	26,000	34,000	26,000	26,000	34,000	26,000
15/32	38,000	49,500	38,000	38,000	49,500	38,000
1/2	38,500	50,000	38,500	38,500	50,000	38,500
19/32	49,000	63,500	49,000	49,000	63,500	49,000
5/8	49,500	64,500	49,500	49,500	64,500	49,500
23/32	50,500	65,500	50,500	50,500	65,500	50,500
3/4	51,000	66,500	51,000	51,000	66,500	51,000
7/8	52,500	68,500	52,500	52,500	68,500	52,500
1	73,500	95,500	73,500	73,500	95,500	73,500
1-1/8	75,000	97,500	75,000	75,000	97,500	75,000
Structural I Multiplier	1.3	1.0	1.3	1.3	1.0	1.3
PANEL SHEAR THROUGH THE THICKNESS, F_vt_v (lbf/in. of shear-resisting panel length)						
1/4	51	66	51	51	66	51
11/32	54	70	54	54	70	54
3/8	55	72	55	55	72	55
15/32	80	105	80	80	105	80
1/2	81	105	81	81	105	81
19/32	105	135	105	105	135	105
5/8	105	135	105	105	135	105
23/32	105	135	105	105	135	105
3/4	110	145	110	110	145	110
7/8	110	145	110	110	145	110
1	155	200	155	155	200	155
1-1/8	160	210	160	160	210	160
Structural I Multiplier	1.3	1.0	1.3	1.3	1.0	1.3

(a) See Table 10 for multipliers for other species Groups.

4.5.5. Panel size

Strength capacity in bending and tension are appropriate for panels 24 inches or greater in width. For panels less than 24 inches in width used in applications where failure could endanger human life, the following adjustment shall be made to capacity (x is the width, or dimension perpendicular to the applied stress, in inches):

When x is 24 inches or greater, then $C_s = 1.00$ [3]

When x is a minimum of 8 inches to a maximum of 24 inches, then $C_s = 0.25 + 0.0313x$ [4]

When x is less than or equal to 8 inches, then $C_s = 0.50$ [5]

Single strips less than 8 inches wide used in stressed applications shall be chosen such that they are relatively free of surface defects.

4.5.6. Panel Edge Support

For roof sheathing applications, additional panel edge support is recommended when panel widths are less than 24 inches. Specific recommendations are in *APA Technical Note: Panel Edge Support for Narrow-Width Roof Sheathing,* Form R275. Note that panel edge support may be required or recommended in applications subject to walking loads, such as floor or roof sheathing. See *APA Engineered Wood Construction Guide,* Form E30, for more information.

4.6. Section properties

Where required, geometric cross-sectional properties may be calculated by assuming a uniform rectangular cross section in conjunction with typical Performance Categories for a given span rating, Table 11. Computed rectangular (geometric) properties on a per-foot-of-panel-width basis are provided in Table 12.

Similarly, where design stress is required, design capacity may be divided by the applicable rectangular section property in Table 12.

TABLE 10

MULTIPLIERS FOR SANDED GROUP 2, 3 AND 4 PLYWOOD DESIGN CAPACITIES

Species Group	A-A, A-C	Marine	Other
PANEL BENDING STIFFNESS, EI (lbf-in.²/ft of panel width)			
2	0.83	NA	0.83
3	0.67	NA	0.67
4	0.56	NA	0.56
PANEL BENDING STRENGTH, F_bS (lbf-in./ft of panel width)			
2	0.70	NA	0.73
3	0.70	NA	0.73
4	0.67	NA	0.67
PANEL AXIAL TENSION, F_tA (lbf/ft of panel width)			
2	0.70	NA	0.73
3	0.70	NA	0.73
4	0.67	NA	0.67
PANEL AXIAL COMPRESSION, F_cA (lbf/ft of panel width)			
2	0.73	NA	0.71
3	0.65	NA	0.64
4	0.61	NA	0.62
PANEL AXIAL STIFFNESS, EA (lbf/ft of panel width)			
2	0.83	NA	0.83
3	0.67	NA	0.67
4	0.56	NA	0.56
PANEL SHEAR IN THE PLANE, F_s(Ib/Q) (lbf/ft of panel width)			
2	1.00	NA	1.00
3	1.00	NA	1.00
4	1.00	NA	1.00
PANEL RIGIDITY THROUGH THE THICKNESS, G_vt_v (lbf/in. of panel depth)			
2	0.83	NA	0.83
3	0.67	NA	0.67
4	0.56	NA	0.56
PANEL SHEAR THROUGH THE THICKNESS, F_vt_v (lbf/in. of shear-resisting panel length)			
2	0.74	NA	0.74
3	0.74	NA	0.74
4	0.68	NA	0.68

4.7. Uniform load computations

Computation of uniform-load capacity of wood structural panels shall be as outlined in this section for such applications as roofs, floors and walls. The design capacities are subject to adjustment as specified earlier in this document.

Three basic span conditions are presented for computing uniform-load capacities of wood structural panels. For normal framing practice and a standard panel size (4 x 8 ft), APA has used the following assumptions in computing recommendations for load-span tables. When the panel strength axis is across (perpendicular to) the supports, the three-span condition is assumed for support spacing up to and including 32 inches. The two-span condition is assumed for support spacing greater than 32 inches.

When the panel strength axis 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 when the support spacing is greater than 16 inches up to 24 inches, and a single span is assumed for spans greater than 24 inches.

To include the effects of support width in deflection and shear strength calculations, two-inch-nominal lumber framing is assumed for support spacings less than 48 inches. Four-inch-nominal lumber 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 wood structural panels over conventional lumber framing. Because it is assumed that no blocking is used, the formulas are for one-way "beam" action, rather than two-way "plate" action. The resulting loads are assumed to be applied to full-sized panels in standard sheathing-type applications. Loads are for the panels only, and in no way account for the design of the framing supports. Further consideration shall be given to concentrated loads, in compliance with local building codes and with maximum span recommendations of *APA – The Engineered Wood Association.*

TABLE 11

PERFORMANCE CATEGORY AND NOMINAL THICKNESS (in.) BY SPAN RATING

The predominant Performance Category for each span rating is highlighted in **bold** type.)

Span Rating	Performance Category										
	3/8	**7/16**	**15/32**	**1/2**	**19/32**	**5/8**	**23/32**	**3/4**	**7/8**	**1**	**1-1/8**
APA Rated Sheathing											
24/0	**.375**	.437	.469	.500							
24/16		**.437**	.469	.500							
32/16			**.469**	.500	.594	.625					
40/20					**.594**	.625	.719	.750			
48/24							**.719**	.750	.875		
APA Rated Sturd-I-Floor											
16 oc					**.594**	.625					
20 oc					**.594**	.625					
24 oc							**.719**	.750			
32 oc									**.875**	1.000	
48 oc											**1.125**

TABLE 12

PANEL SECTION PROPERTIES[(a)]

Performance Category	Approximate Weight[(b)] (psf)		Nominal Thickness t (in.)	Area A ($in.^2/ft$)	Moment of Inertia I ($in.^4/ft$)	Section Modulus S ($in.^3/ft$)	Statical Moment Q ($in.^3/ft$)	Shear Constant Ib/Q ($in.^2/ft$)
	Plywood	OSB						
3/8	1.1	1.2	.375	4.500	.053	.281	.211	3.000
7/16	1.3	1.4	.437	5.250	.084	.383	.287	3.500
15/32	1.4	1.5	.469	5.625	.103	.440	.330	3.750
1/2	1.5	1.7	.500	6.000	.125	.500	.375	4.000
19/32	1.8	2.0	.594	7.125	.209	.705	.529	4.750
5/8	1.9	2.1	.625	7.500	.244	.781	.586	5.000
23/32	2.2	2.4	.719	8.625	.371	1.033	.775	5.750
3/4	2.3	2.5	.750	9.000	.422	1.125	.844	6.000
7/8	2.6	2.9	.875	10.500	.670	1.531	1.148	7.000
1	3.0	3.3	1.000	12.000	1.000	2.000	1.500	8.000
1-1/8	3.3	3.6	1.125	13.500	1.424	2.531	1.898	9.000

See Section 6 for conversion factors.

(a) Properties based on rectangular cross section of 1-ft width.

(b) Approximate weight for calculating actual dead loads of the panel.

4.7.1. Uniform loads based on bending strength

The following formulas shall be used for computing loads based on design bending strength capacity (F_bS).

For a single span:

$$w_b = \frac{96\ F_bS}{\ell_1^2} \qquad [6]$$

For a two-span condition:

$$w_b = \frac{96\ F_bS}{\ell_1^2} \qquad [7]$$

For a three-span condition:

$$w_b = \frac{120\ F_bS}{\ell_1^2} \qquad [8]$$

Where:

w_b = uniform load based on bending strength (psf)
F_bS = design bending strength capacity (lbf-in./ft)
ℓ_1 = span (in., center-to-center of supports)

4.7.2. Uniform loads based on shear strength

The following formulas shall be used for computing loads based on design shear strength capacity (F_s[Ib/Q]).

For a single span:

$$w_s = \frac{24\ F_s(Ib/Q)}{\ell_2} \qquad [9]$$

For a two-span condition:

$$w_s = \frac{19.2\ F_s(Ib/Q)}{\ell_2} \qquad [10]$$

For a three-span condition:

$$w_s = \frac{20\ F_s(Ib/Q)}{\ell_2} \qquad [11]$$

Where:

w_s = uniform load based on shear strength (psf)
$F_s(Ib/Q)$ = design shear strength capacity (lbf/ft)
ℓ_2 = clear span (in., center-to-center of supports minus support width)

4.7.3. 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.

For a single span:

$$\Delta = \frac{w\ell_3^4}{921.6\ EI} \qquad [12]$$

For a two-span condition:

$$\Delta = \frac{w\ell_3^4}{2220\ EI} \qquad [13]$$

For a three-span condition:

$$\Delta = \frac{w\ell_3^4}{1743\ EI} \quad [14]$$

Where:

Δ = deflection (in.)
w = uniform load (psf)
EI = design bending stiffness capacity (lbf-in.^{2}/ft)
ℓ_3 = clear span + SW (in.)
SW = support-width factor, equal to 0.25 inch for two-inch-nominal lumber framing and 0.625 inch for four-inch-nominal lumber framing.

4.7.4. Uniform load

For uniform load based on a deflection requirement, compute bending deflection with a uniform load (w) equal to one psf. The allowable uniform load based on the allowable deflection is then computed as:

$$w_d = \frac{\Delta_{all.}}{\Delta} \quad [15]$$

Where:

w_d = uniform load based on deflection (psf)
$\Delta_{all.}$ = allowable deflection (in.)

4.8. Design examples showing use of capacity tables

Note: In these examples, panel type and construction are selected for illustrative purposes. Normally specification is by grade and span rating without regard to panel type, and calculations should assume the lowest capacities applicable to available types and constructions as given in Table 13 for the specified span rating.

TABLE 13

TYPICAL APA PANEL CONSTRUCTIONS[(a)]

	Plywood			
Span Rating	**3-ply**	**4-ply**	**5-ply**[(b)]	**OSB**
APA Rated Sheathing				
24/0	X			X
24/16				X
32/16	X	X	X	X
40/20	X	X	X	X
48/24		X	X	X
APA Rated Sturd-I-Floor				
16 oc				
20 oc		X	X	X
24 oc		X	X	X
32 oc			X	X
48 oc			X	X

(a) Constructions listed may not be available in every area. Check with suppliers concerning availability.

(b) Applies to plywood with 5 or more layers.

4.8.1. Example 1 – Conventional roof

A 4-ply plywood panel trademarked APA Rated Sturd-I-Floor 24 oc with tongue-and-groove edges was inadvertently installed over 4-in.-nominal roof supports 48 in. on center. The long dimension (strength axis) of the panel was placed perpendicular to supports. The local building code requires that the panel support a 25-psf snow load.

Bending Strength

From Table 8, a 4-ply plywood Rated Sturd-I-Floor 24 oc panel with stress applied parallel to the strength axis (long panel dimension perpendicular to supports) has a bending strength capacity (F_bS) of 705 lbf-in./ft. This capacity is adjusted by a duration-of-load factor (C_D) of 1.15 (see 4.5.1). This duration-of-load factor is normally associated with snow loads for roof structures. From 4.7, Eq. 7, a two-span condition is assumed.

$$w_b = \frac{96\ F_bS}{\ell_1^{\,2}} = \frac{96\ (705 \times 1.15)}{48^2} = 34 \text{ psf}$$

Shear Strength in the Plane

From Table 8, a 4-ply plywood Rated Sturd-I-Floor 24 oc panel with stress applied parallel to the strength axis has shear strength in the plane (F_s[Ib/Q]) of 300 lbf/ft. This capacity is adjusted by a duration-of-load factor (C_D) of 1.15 (see 4.5.1). From 4.7, Eq. 10,

$$w_s = \frac{19.2\ F_s(Ib/Q)}{\ell_2} = \frac{19.2\ (300 \times 1.15)}{(48 - 3.5)} = 149 \text{ psf}$$

Bending Stiffness

From Table 8, a Rated Sturd-I-Floor 24 oc panel with stress applied parallel to the strength axis has a dry stiffness capacity (EI) of 330,000 lbf-in.^{2}/ft. The deflection limit for live load is $\ell/240$. From 4.7, Eq. 13,

$$\Delta = \frac{w\ell_3^{\,4}}{2220\ EI} = \frac{1.0\ (48 - 3.5 + 0.625)^4}{2220 \times 330000} = 5.66 \times 10^{-3} \text{ in.}$$

From Eq, 15,

$$w_d = \frac{\Delta_{all.}}{\Delta} = \frac{48/240}{5.66 \times 10^{-3}} = 35 \text{ psf}$$

Bending strength controls (provides the lowest capacity) for this application. The bending strength capacity of 34 psf represents total load, from which dead load is subtracted to arrive at live load capacity. The bending stiffness capacity of 35 psf represents live load only. Here, if dead load (panel weight plus roofing) is no more than 9 psf, the 25 psf snow load capacity is achieved. The tongue-and-groove edges provide required edge supports.

4.8.2. Example 2 – Panelized roof

An oriented strand board (OSB) panel trademarked as APA Structural I Rated Sheathing 32/16 is to be used in a panelized roof system over 2-in.-nominal framing members 24 in. on center. The long panel dimension (strength axis) of the panel will be placed parallel to supports.

Bending Strength

From Table 8, an OSB Rated Sheathing 32/16 panel with stress applied perpendicular to strength axis (long panel dimension parallel to supports) has a bending strength capacity (F_bS) equal to 165 lbf-in./ft. This capacity is adjusted by a multiplier of 1.5 for OSB Structural I, and by a duration-of-load factor (C_D) of 1.15 (see 4.5.1.). From 4.7, Eq. 7, a two-span condition is assumed.

$$w_b = \frac{96\ F_bS}{\ell_1^{\,2}} = \frac{96\ (165 \times 1.5 \times 1.15)}{24^2} = 47 \text{ psf}$$

Shear Strength in the Plane

From Table 8, an OSB Rated Sheathing 32/16 panel with stress applied perpendicular to strength axis has shear strength in the plane ($F_s[Ib/Q]$) of 165 lbf/ft. This capacity is adjusted by a multiplier of 1.0 for OSB Structural I, and by a duration-of-load factor (C_D) of 1.15 (see 4.5.1.). From 4.7, Eq. 10,

$$w_s = \frac{19.2\ F_s(Ib/Q)}{\ell_2} = \frac{19.2\ (165 \times 1.0 \times 1.15)}{(24 - 1.5)} = 162 \text{ psf}$$

Bending Stiffness

From Table 8, an OSB Rated Sheathing 32/16 panel with stress applied perpendicular to strength axis has a dry stiffness capacity (EI) of 25,000 lbf-in.^{2}/ft. This capacity is adjusted by a multiplier of 1.6 for OSB Structural I. The deflection limit for live load is ℓ/240. From 4.7, Eq. 13,

$$\Delta = \frac{w\ell_3^4}{2220\ EI} = \frac{1.0\ (24 - 1.5 + 0.25)^4}{2220 \times (25000 \times 1.6)} = 3.02 \times 10^{-3} \text{ in.}$$

From Eq. 15,

$$w_d = \frac{\Delta_{all.}}{\Delta} = \frac{24/240}{3.02 \times 10^{-3}} = 33 \text{ psf}$$

4.8.3. Example 3 – Floor

A 5-ply plywood panel trademarked as APA Rated Sturd-I-Floor 24 oc is to be used in a floor system over supports 24 inches on center. The panels will be placed with the long panel dimension (strength axis) perpendicular to supports. Supports are 2-in.-nominal framing members. The capacity of the panel will be computed based on bending strength, shear strength in the plane and bending stiffness.

Bending Strength

From Table 8, a 5-ply plywood Rated Sturd-I-Floor 24 oc panel with stress applied parallel to the strength axis (long panel dimension perpendicular to supports) has a bending strength capacity (F_bS) of 770 lbf-in./ft. From 4.7, Eq. 8, a three-span condition is assumed.

$$w_b = \frac{120\ F_bS}{\ell_1^2} = \frac{120 \times 770}{24^2} = 160 \text{ psf}$$

Shear Strength in the Plane

From Table 8, a 5-ply plywood Rated Sturd-I-Floor 24 oc panel with stress applied parallel to the strength axis has shear strength in the plane ($F_s[Ib/Q]$) equal to 325 lbf/ft. From 4.7, Eq. 11,

$$w_s = \frac{20\ F_s(Ib/Q)}{\ell_2} = \frac{20 \times 325}{(24 - 1.5)} = 289 \text{ psf}$$

Bending Stiffness

From Table 8, a 5-ply plywood Rated Sturd-I-Floor 24 oc panel with stress applied parallel to the strength axis has a dry stiffness capacity (EI) of 330,000 lbf-in.^{2}/ft. The deflection limit for live load is ℓ/360. From 4.7, Eq. 14,

$$\Delta = \frac{w\ell_3^4}{1743\ EI} = \frac{1.0\ (24 - 1.5 + 0.25)^4}{1743 \times 330000} = 4.66 \times 10^{-4} \text{ in.}$$

From Eq. 15,

$$w_d = \frac{\Delta_{all.}}{\Delta} = \frac{24/360}{4.66 \times 10^{-4}} = 143 \text{ psf}$$

While the above calculations would indicate that this Sturd-I-Floor construction has a live load capacity of 143 psf (limited by bending stiffness), it is important to note that some structural panel applications are not controlled by uniform load. Residential floors, commonly designed for 40-psf live load, are a good example. The calculated allowable load is greatly in excess of the typical design load. This excess does not mean that floor spans for Sturd-I-Floor can be increased, but only that there is considerable reserve strength and stiffness for uniform loads. Recommended maximum spans for wood structural panel floors are based on deflection under concentrated loads, how the floor "feels" to passing foot traffic, and other subjective factors which relate to user acceptance. Always check the maximum floor and roof spans for wood structural panels before making a final selection for these applications.

5. REFERENCES

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Relation of Strength of Wood to Duration of Load, Report FPL R-1916, USDA Forest Products Laboratory, Madison, WI.

Performance Standard for Wood-Based Wood Structural Panels, Voluntary Product Standard PS 2, U.S. Department of Commerce, Washington, DC.

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6. CONVERSION FACTORS

Quantity	Multiply	By	To Obtain
Pressure/Stress	psi	6.895	kPa
	psi	6,895	N/m^2
Length	in.	25.40	mm
Panel Bending Stiffness Capacity (EI)	lbf-in.^{2}/ft of panel width	9.415	N-m^2/m
Panel Bending Strength Capacity (F_bS)	lbf-in./ft of panel width	0.3707	N-m/m
Panel Axial Tension Capacity (F_tA)	lbf/ft of panel width	14.59	N/m
Panel Axial Compression (F_cA)	lbf/ft of panel width	14.59	N/m
Panel Axial Stiffness Capacity (EA)	lbf/ft of panel width	14.59	N/m
Panel Shear in the Plane Capacity $F_s(Ib/Q)$	lbf/ft of panel depth	14.59	N/m
Panel Rigidity Through the Thickness (G_vT_v)	lbf/in. of panel length	1.216	N/m
Approximate Weight of Panel	psf	4.88	kg/m^2
Panel Area (A)	in.^{2}/ft of panel width	2.117	10^3 mm^2/m
Panel Section Modulus (S)	in.^{3}/ft of panel width	53.76	10^3 mm^3/m
Panel Moment of Inertia (I)	in.^{4}/ft of panel width	1.366	10^6 mm^4/m
Temperature	°F	t°C = (t°F – 32)/1.8	°C

ADDITIONAL INFORMATION

About APA – The Engineered Wood Association

APA – The Engineered Wood Association is a nonprofit trade association of and for structural wood panel, glulam timber, wood I-joist, structural composite lumber, and other engineered wood product manufacturers. Based in Tacoma, Washington, APA represents approximately 150 mills throughout North America, ranging from small, independently owned and operated companies to large integrated corporations.

Always insist on engineered wood products bearing the **mark of quality** – the *APA* or *APA EWS* trademark. Your APA engineered wood purchase is not only your highest possible assurance of product quality, but an investment in the many trade services that APA provides on your behalf. The Association's trademark appears only on products manufactured by member mills and is the manufacturer's assurance that the product conforms to the standard shown on the trademark.

For panels, that standard may be the Voluntary Product Standard PS 1-09 for Structural Plywood, Voluntary Product Standard PS 2-10, Performance Standards for Wood Structural Panels or APA PRP-108 Performance Standards and Qualification Policy for Structural-Use Panels. Panel quality of all APA trademarked products is subject to verification through APA audit.

APA's services go far beyond quality testing and inspection. Research and promotion programs play important roles in developing and improving construction systems using wood structural panels, glulam, I-joists, and structural composite lumber, and in helping users and specifiers to better understand and apply engineered wood products. For more information, please see the back cover.

Panel Design Specification

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

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