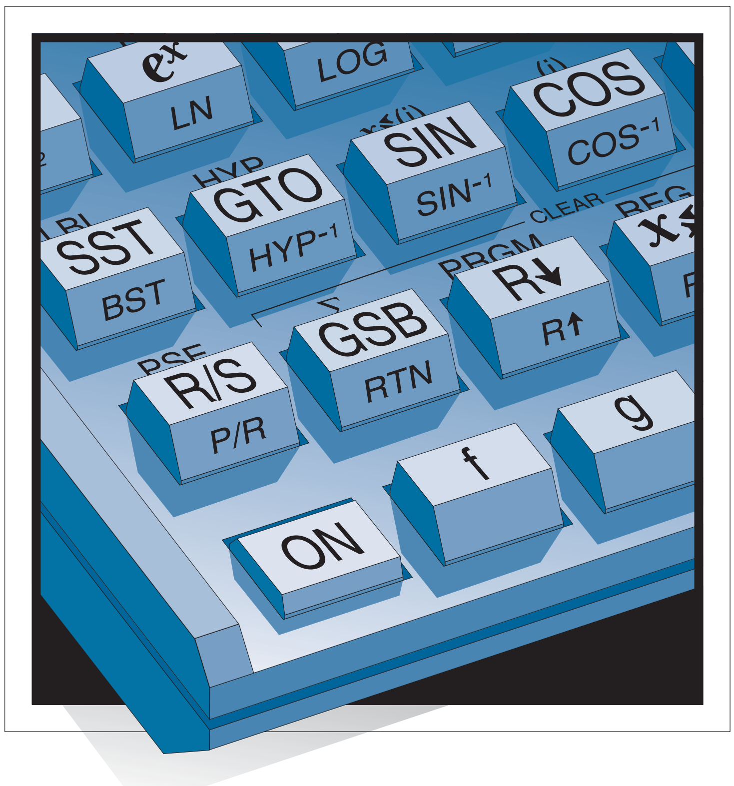
Panel Design Specification



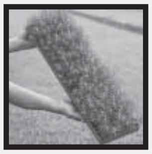
APA

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, recyclable, biodegradable resource that is easily manufactured into a variety of viable products.

A few facts about wood.

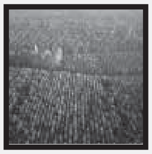
- ***We're growing more wood every day.*** Forests fully cover one-third of the United States' and one-half of Canada's land mass. American landowners plant more than two billion trees every year. In addition, millions of trees seed naturally. The forest products industry, which comprises about 15 percent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



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

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

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



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

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

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

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 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) wood structural panels made in accordance with Voluntary Product Standard PS 1-07 or PS 2-92, 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 *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.

Technical Services Division
APA – The Engineered Wood Association

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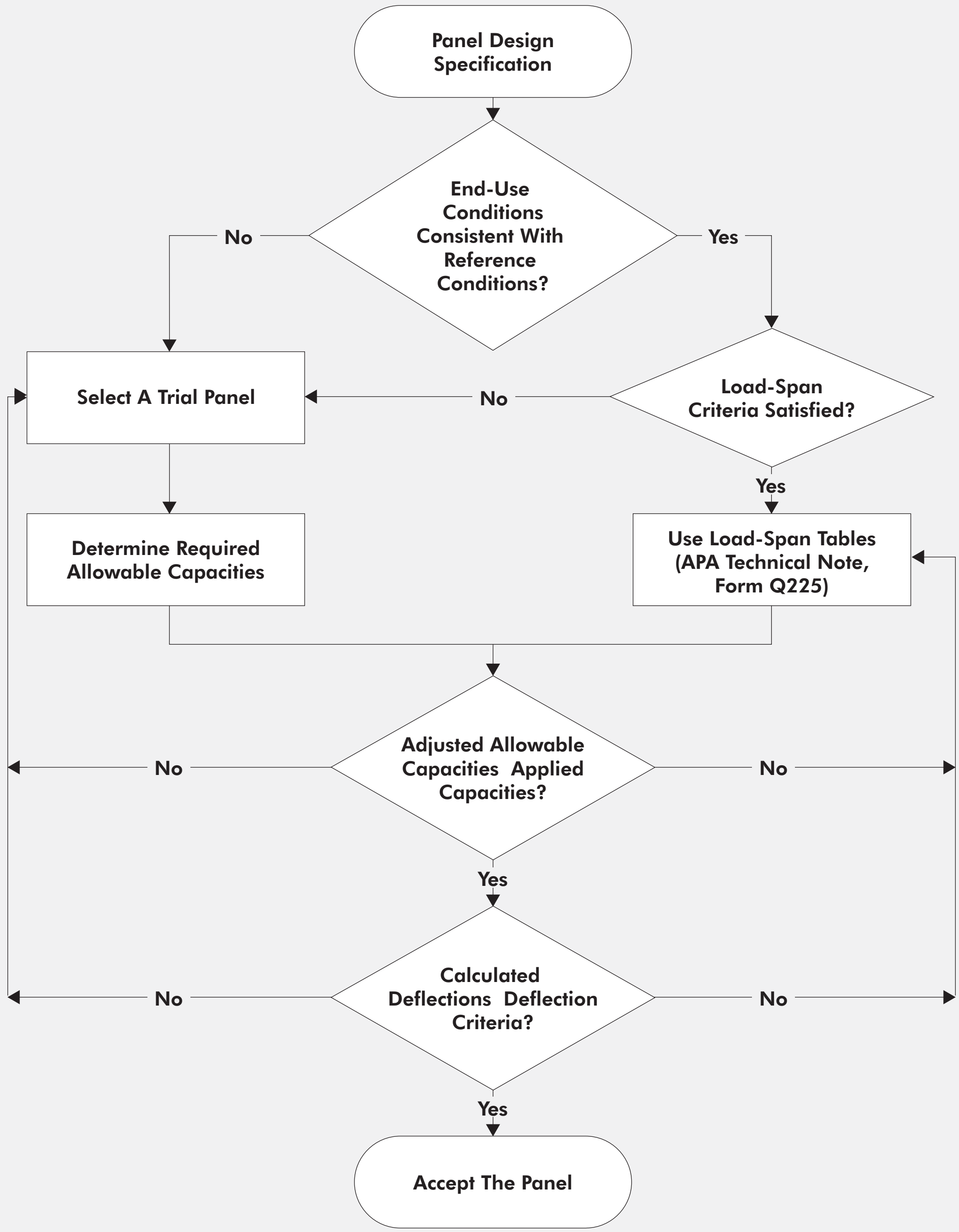
DESIGNER FLOWCHART



PANEL DESIGN SPECIFICATION

1. INTRODUCTION

Wood structural panels available today respond to changes in wood resources, manufacturing, and construction trends, meeting designer needs for excellent strength and light weight while using the only renewable building material. A wood structural panel, also referred to as a structural-use 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 manufacture, 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[1], 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 plywood manufacture, 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 or oriented wafers, 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. Whether a panel is composed of strands or wafers, most manufacturers orient the material to achieve maximum performance.

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.

1.3. Composite panels

COM-PLY® is an APA product name for composite panels that are manufactured by bonding layers of wood fibers between wood veneer. By combining reconstituted wood fibers with conventional veneer, COM-PLY panels allow for more efficient resource use while retaining the wood grain appearance on the panel face and back.

COM-PLY panels are manufactured in a three- or five-layer arrangement. A three-layer panel has a wood fiber core and veneer for face and back. The five-layer panel has a wood veneer crossband in the center and veneer on the face and back. When manufactured in a one-step pressing operation, voids in the veneers are filled automatically by the reconstituted wood particles or strands as the panel is pressed in the bonding process.

At the present time COM-PLY panels as described above are not being produced and therefore should not be specified.

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. A more recent development for wood structural panels is that of 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.

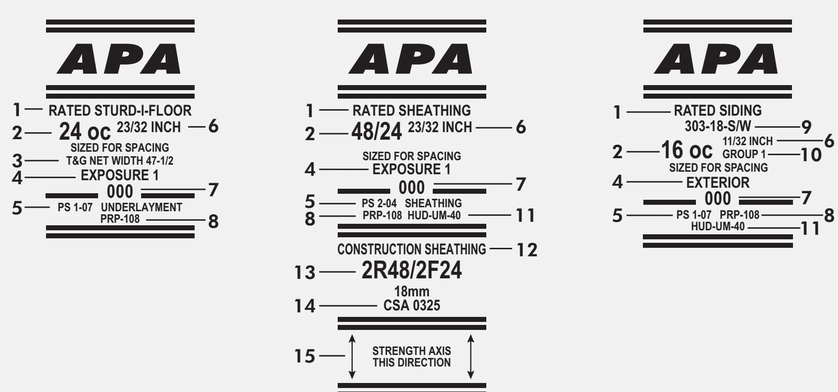
Another distinction between standards is whether they are consensus-based or proprietary. Consensus-based standards are developed following a prescribed set of rules that provide for input and/or review by people of varying interests following one of several recognized procedures. Other standards are 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 Structural-Use Panels[3], 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, Construction and Industrial Plywood[1], 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

FIGURE 1

TYPICAL TRADEMARKS



1 Panel grade
2 Span Rating
3 Tongue-and-groove
4 Bond classification
5 Product Standard
6 Thickness
7 Mill number
8 APA's performance rated panel standard
9 Siding face grade
10 Species group number
11 HUD recognition
12 Panel grade, Canadian standard
13 Panel mark – Rating and end-use designation per the Canadian standard
14 Canadian performance rated panel standard
15 Panel face orientation indicator

for span ratings. PS 1 continues to offer only prescriptive provisions for other panel grades such as a variety of sanded plywood grades.

2.1.2. Voluntary Product Standard PS 2

Voluntary Product Standard PS 2[2], Performance Standard for Wood-Based Structural-Use 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 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[12], Construction Sheathing, which is recognized in the National Building Code of Canada.

2.1.3. Proprietary standards

The prototype proprietary performance standard for wood structural panels is APA PRP-108, Performance Standards and Qualification Policy for Structural-Use 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.

2.2. 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

TABLE 1

CLASSIFICATION OF SPECIES

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

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

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

(c) 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.

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

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 3/8 inch [9.5 mm] thick 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 greater than 3/8 inch [9.5 mm] are identified by face species if C or D grade backs are at least 1/8 inch [3 mm] 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.

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 interior use or 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 inch. Knotholes to 1 inch across grain and some to 1-1/2 inch 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 or Interior panels.

Note: 1 inch = 25.4 mm.

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. 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 nominal

TABLE 3

GUIDE TO PANEL USE

Panel Grade	Description & Use	Common Nominal Thickness	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.	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.	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.

Note: 1 inch = 25.4 mm.

thickness and the species group of the faces, and design capacities provided in 4.4 are on that basis and assume Group 1 faces.

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), which is conservative, with Group 1 faces.

2.4. Bond classifications

Wood structural panels may be produced in three bond classifications – Exterior, Exposure 1, and Interior. The bond classification relates to adhesive bond, and thus to structural integrity of the panel. By far the predominant bond classifications are Exposure 1 and Exterior. Therefore, design capacities provided herein are on that basis.

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.

2.4.3. Other classifications

Panels identified as Interior and that lack further glueline information in their trademarks are manufactured with interior glue and are intended for interior applications only. Panels classed Interior were commonplace prior to the 1970s, but are not commonly produced today.

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.

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 [800 mm] on center or for subflooring over supports up to 16 inches [400 mm] on center.

Certain of the roof sheathing maximum spans are dependent upon panel edge support as recommended in APA literature.

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.

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 under carpet and pad 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, most panel characteristics actually 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 or composite panels, the strength axis is sometimes referred to as the face grain direction.

4.2. Panel construction

Plywood mills may use different layups for the same panel thickness 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 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.

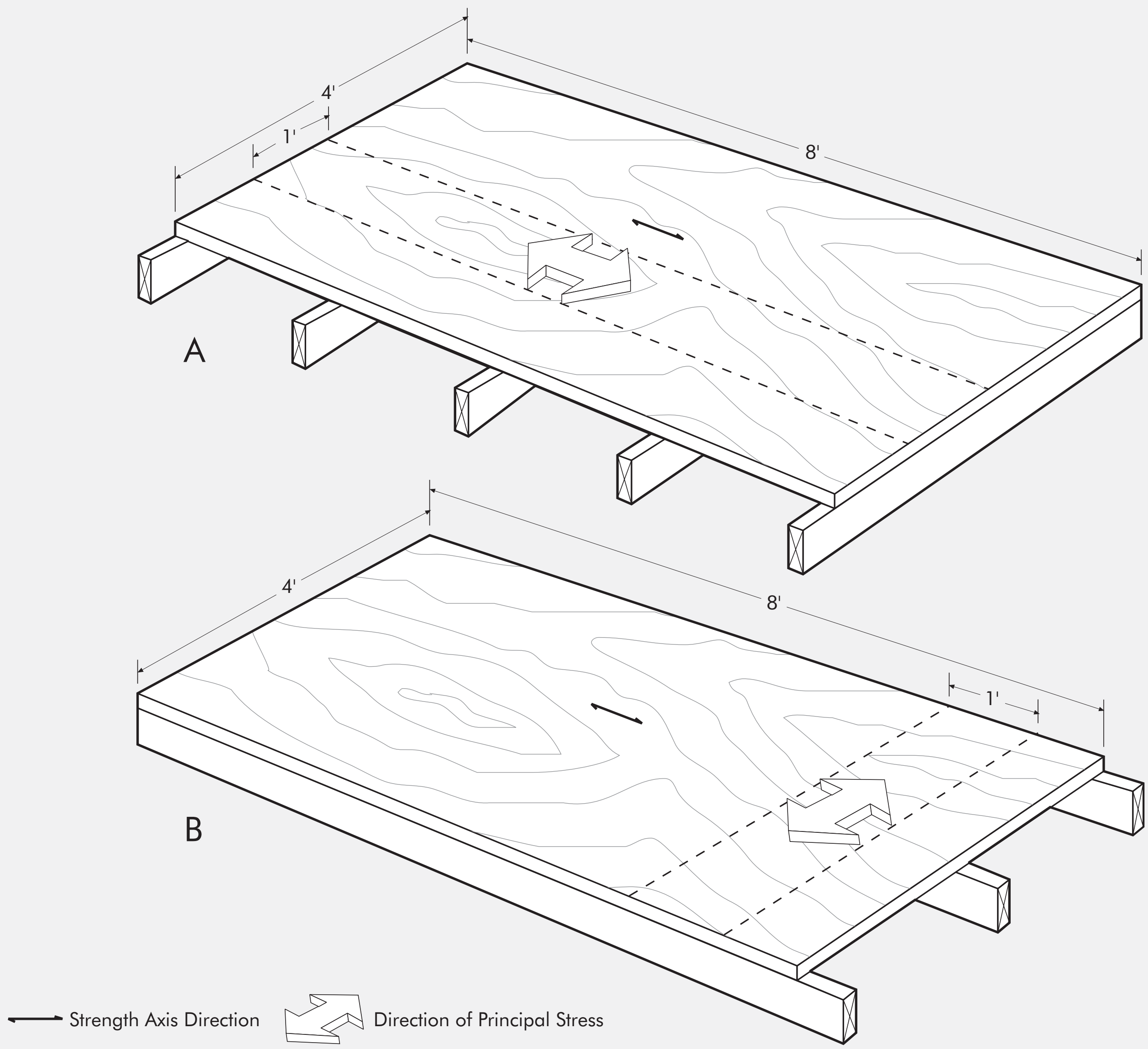
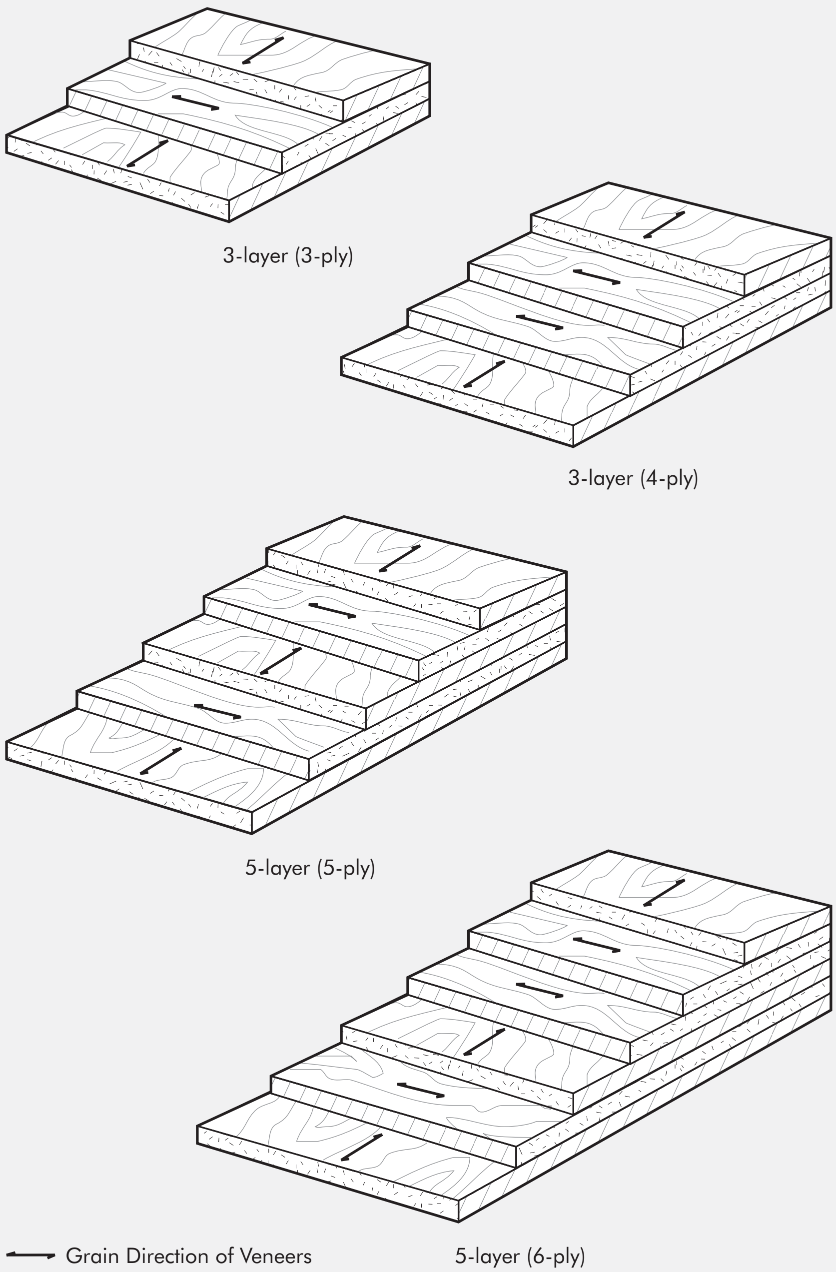


FIGURE 3

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, of course, 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 4A and 4B are minimum for grade and span rating or thickness. 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 4B gives capacities for sanded panels marked as species Group 1, Table 4C 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 insure that the correct panel is used in the final construction.

4.4.1. Panel flexure (flat panel bending)

Panel design capacities reported in Tables 4A and 4B are based on flat panel bending as measured by testing according to the principles of ASTM D 3043[4] Method C (large panel testing). See Figure 4.

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 lb-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 lb-in. per foot of panel width.

4.4.2. Panel axial strength

Tension (F_tA)

Allowable tension capacities are reported in Tables 4A and 4B based on testing according to the principles of ASTM D 3500[5] 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 lb per foot of panel width.

Compression (F_cA)

Allowable compression capacities are reported in Tables 4A and 4B based on testing according to the principles of ASTM D 3501[6] 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 lb 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 4A and 4B based on testing according to the principles of ASTM D 3501[6] 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 lb per foot of panel width.

4.4.4. Shear in the plane of the panel (F_s[lb/Q])

Allowable shear in the plane of the panel (or interlaminar shear, sometimes called rolling shear in plywood) is reported in Tables 4A and 4B based on testing according to the principles of ASTM D 2718[7]. 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 material stress, while lb/Q is the panel cross sectional shear constant. Units of F_s(lb/Q) are lb per foot of panel width.

4.4.5. Panel shear through the thickness

Panel shear-through-the-thickness capacities are reported based on testing according to the principles of ASTM D 2719[8]. See Figure 6.

Panel shear strength through the thickness (F_vt_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-beam, and is reported in Tables 4A and 4B. See Figure 6. Where additional support is not provided to prevent buckling, design capacities in Tables 4A and 4B are limited to sections 2 ft or less in depth. Deeper sections may require additional reductions. The term F_v is the allowable stress of the material, while t_v is the effective panel thickness for shear. Units of F_vt_v are lb per inch of shear-resisting panel length.

FIGURE 4

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

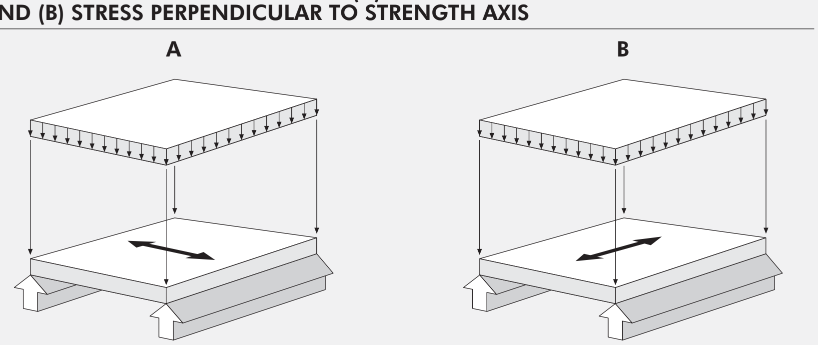


FIGURE 5

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

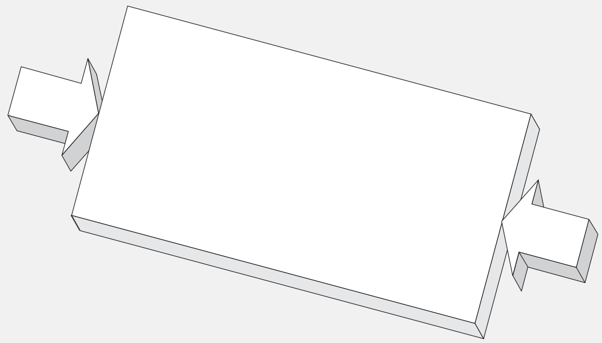
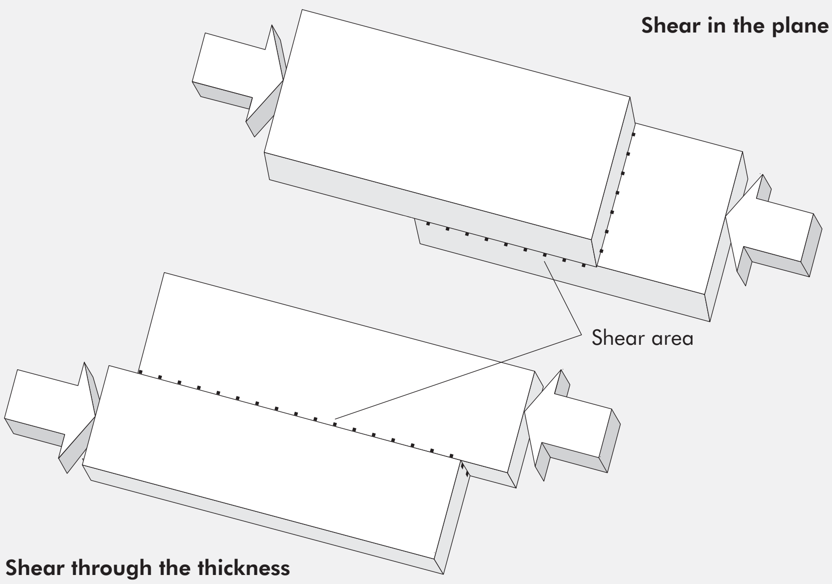


FIGURE 6

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



Panel rigidity through the thickness ($G_v t_v$)

Panel rigidity is reported in Tables 4A and 4B 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 lb 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.

4.4.6. 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. The allowable bearing stress of APA structural-use panels is derived based on the load at a 0.04-in. [1.0 mm] deformation limit. A design bearing stress of 360 psi [2.5 N/mm^2] shall be used for structural-use 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 pounds.

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. A conservative design value for 0.02-in. [0.5 mm] deformation can be chosen as 50 percent of the allowable bearing stress at 0.04-in. [1.0 mm] deformation. If necessary, use the following regression equation to derive the design value for 0.02-in. [0.5 mm] deformation:

$$F_{c\perp 0.02''} = 0.51F_{c\perp 0.04''} + 28$$

4.4.7 Dowel bearing strength

Dowel bearing strength is a component in fastener yield equations, as found in the National Design Specification (NDS) for Wood Construction[13]. The yield equations are also sometimes referred to as the European Yield Model (EYM). Dowel bearing strength is measured by testing according to the principles of ASTM D 5764[14].

Plywood trademarked Structural I or Marine grade can be taken as having a specific gravity of 0.50, based on the species limitations prescribed in PS 1. Plywood not identified as Structural I or Marine grade can be taken as having a specific gravity of 0.42, unless the species of plies is known, in which case the specific gravity listed for the actual species may be used. Dowel bearing strength of OSB listed below is conservative based on limited testing.

The table below summarizes dowel bearing strength of wood structural panels using terminology contained in the NDS.

Wood Structural Panel	Specific Gravity, G	Dowel Bearing Strength, F_e For Nailed Connections
Plywood		
Structural I, Marine	0.50	4,650 psi [32 MPa]
Other grades[(a)]	0.42	3,350 psi [23 MPa]
Oriented Strand Board		
All grades	0.50	4,650 psi [32 MPa]

(a) Use G = 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.

4.5. 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[9], and successfully used for plywood for approximately 40 years. Adjustment factors for strength capacities (C_D) are:

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 structural-use panels.
**Check local building code.

Creep

Wood-based 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 following adjustment factor (C_C) to panel stiffness, EI:

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

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

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 (C_m) are as follows:

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

TABLE 4A

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 BENDING STIFFNESS, EI (lb-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	440,000	440,000	440,000	400,000	29,500	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	330,000	330,000	330,000	300,000	26,000	57,000	80,500	80,500
32 oc	715,000	715,000	715,000	650,000	75,000	165,000	235,000	235,000
48 oc	1,265,000	1,265,000	1,265,000	1,150,000	160,000	350,000	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 (lb-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	845	930	1,000	1,000	225	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	640	705	770	770	215	260	385	385
32 oc	870	955	1,050	1,050	380	455	685	685
48 oc	1,600	1,750	1,900	1,900	680	815	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 (lb/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	4,000	4,000	5,200	4,000	1,950	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	3,350	3,350	4,350	3,350	1,950	1,950	2,550	2,550
32 oc	4,000	4,000	5,200	4,000	2,500	2,500	3,250	3,250
48 oc	5,600	5,600	7,300	5,600	3,650	3,650	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 (lb/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	5,000	7,500	7,500	5,000	4,800	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	5,000	7,500	7,500	5,000	4,800	7,200	7,200	4,300
32 oc	6,300	9,450	9,450	6,300	6,200	9,300	9,300	6,200
48 oc	8,100	12,150	12,150	8,100	6,750	10,800	10,800	6,750
Structural I Multiplier	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

TABLE 4A (Continued)

RATED PANELS DESIGN CAPACITIES

Span Rating	Stress Parallel to Strength Axis				Stress Perpendicular to Strength Axis			
	Plywood				Plywood			
	3-ply	4-ply	5-ply	OSB	3-ply	4-ply	5-ply	OSB
PANEL AXIAL STIFFNESS, EA (lb/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
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
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
48/24	5,850,000	5,850,000	5,850,000	5,850,000	5,000,000	5,000,000	5,000,000	3,300,000
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
24 oc	5,850,000	5,850,000	5,850,000	5,850,000	5,000,000	5,000,000	5,000,000	3,300,000
32 oc	7,500,000	7,500,000	7,500,000	7,500,000	7,300,000	7,300,000	7,300,000	4,200,000
48 oc	8,200,000	8,200,000	8,200,000	8,200,000	7,300,000	7,300,000	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(lb/Q) (lb/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	300	300	325	250	525	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	300	300	325	250	525	725	250	250
32 oc	360	360	390	300	630	870	300	300
48 oc	460	460	500	385	810	1,100	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, $G_v t_v$ (lb/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	31,000	40,500	46,500	96,000	31,000	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	30,000	39,000	45,000	93,000	30,000	39,000	45,000	93,000
32 oc	36,000	47,000	54,000	110,000	36,000	47,000	54,000	110,000
48 oc	50,500	65,500	76,000	155,000	50,500	65,500	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, $F_v t_v$ (lb/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	75	98	115	220	75	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	74	96	110	215	74	96	110	215
32 oc	80	105	120	230	80	105	120	230
48 oc	105	135	160	305	105	135	160	305
Structural I Multiplier	1.3	1.3	1.1	1.0	1.3	1.3	1.1	1.0

TABLE 4B

SANDED GROUP 1[(a)] PLYWOOD DESIGN CAPACITIES

Nominal Thickness (in.)	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 (lb-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 (lb-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 (lb/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 4C for multipliers for other species Groups.

TABLE 4B (Continued)

SANDED GROUP 1[a] PLYWOOD DESIGN CAPACITIES

Nominal Thickness (in.)	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 (lb/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 (lb/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(lb/Q) (lb/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 4C for multipliers for other species Groups.

TABLE 4B (Continued)

SANDED GROUP 1[a] PLYWOOD DESIGN CAPACITIES

Nominal Thickness (in.)	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 (lb/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 (lb/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 4C for multipliers for other species Groups.

4.5.3. Elevated temperature

Capacities in Tables 4A and 4B apply at temperatures of 70° F [21° C] and lower. Wood structural panel parts of buildings should not be exposed to temperatures above 200° F [93° C] for more than very brief periods. However, between 70° F [21° C] and 200° F [93° C] 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 [66° C] 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 [66° C], 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.

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 Preservers Association (AWPA) Standard C-9[10].

Due to the absence of applicable treating industry standards, OSB panels are not currently recommended for applications requiring pressure-preservative treating.

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 a bulletin[11] from *APA – The Engineered Wood Association*. 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.

4.5.5. Panel size

Strength capacity in bending and tension are appropriate for panels 24 inches [600 mm] or greater in width. For panels less than 24 inches [600 mm] 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):

When x is 24 inches [600 mm] or greater, then $C_s = 1.00$

When x is a minimum of 8 inches [200 mm] to a maximum of 24 inches [600 mm], then $C_s = 0.25 + 0.0313x$

When x is less than or equal to 8 inches [200 mm], then $C_s = 0.50$

Single strips less than 8 inches [200 mm] wide used in stressed applications shall be chosen such that they are relatively free of surface defects.

TABLE 4C

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

Species Group	A-A, A-C	Marine	Other
PANEL BENDING STIFFNESS, EI (lb-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 (lb-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 (lb/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 (lb/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 (lb/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) (lb/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 (lb/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 (lb/in. of shear-resisting panel length)			
2	0.74	NA	0.74
3	0.74	NA	0.74
4	0.68	NA	0.68

Also, additional panel edge support is recommended in applications subject to walking loads, such as floor or roof sheathing.

4.6. Section properties

Where required, geometric cross-sectional properties may be calculated by assuming a uniform rectangular cross section in conjunction with nominal panel thickness given in Table 5. Computed rectangular (geometric) properties on a per-foot-of-panel-width basis are provided in Table 6.

Similarly, where design stress is required, design capacity may be divided by the applicable rectangular section property in Table 6.

TABLE 5

NOMINAL THICKNESS BY SPAN RATING

(The nominal thickness is given. The predominant thickness for each span rating is highlighted in **bold** type.)

Span Rating	Nominal Thickness (in.)										
	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**

Note: 1 inch = 25.4 mm.

TABLE 6

PANEL SECTION PROPERTIES[(a)]

Nominal Panel Thickness (in.)	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 lb/Q ($in.^2/ft$)
3/8	1.1	.375	4.500	.053	.281	.211	3.000
7/16	1.3	.437	5.250	.084	.383	.287	3.500
15/32	1.4	.469	5.625	.103	.440	.330	3.750
1/2	1.5	.500	6.000	.125	.500	.375	4.000
19/32	1.8	.594	7.125	.209	.705	.529	4.750
5/8	1.9	.625	7.500	.244	.781	.586	5.000
23/32	2.2	.719	8.625	.371	1.033	.775	5.750
3/4	2.3	.750	9.000	.422	1.125	.844	6.000
7/8	2.6	.875	10.500	.670	1.531	1.148	7.000
1	3.0	1.000	12.000	1.000	2.000	1.500	8.000
1-1/8	3.3	1.125	13.500	1.424	2.531	1.898	9.000

Note: 1 inch = 25.4 mm; 1 psf = 4.88 kg/m^2; 1 $in.^2$/ft width = 2116.67 mm^2/m width; 1 $in.^3$/ft width = 53763 mm^3/m width; 1 $in.^4$/ft width = 1.3656x10^6 mm^4/m width.

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

(b) Approximate plywood weight for calculating actual dead loads. For OSB panels, increase tabulated weights by 10%.

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 [1200 x 2400 mm]), 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 [800 mm]. The two-span condition is assumed for support spacing greater than 32 inches [800 mm].

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 [400 mm], the two-span condition is assumed when the support spacing is greater than 16 inches [400 mm] up to 24 inches [600 mm], and a single span is assumed for spans greater than 24 inches [600 mm].

To include the effects of support width in deflection and shear strength calculations, two-inch-nominal [38 mm] lumber framing is assumed for support spacings less than 48 inches [1200 mm]. Four-inch-nominal [89 mm] lumber framing is assumed for support spacing of 48 inches [1200 mm] 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 should be given to concentrated loads, in compliance with local building codes and with maximum span recommendations of *APA – The Engineered Wood Association*.

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:

$$w_b = \frac{96\ F_bS}{\ell_1^{\,2}}$$

For a two-span condition:

$$w_b = \frac{96\ F_bS}{\ell_1^{\,2}}$$

For a three-span condition:

$$w_b = \frac{120\ F_bS}{\ell_1^{\,2}}$$

Where:

w_b = uniform load based on bending strength (psf)

F_bS = design bending strength capacity (lb-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[lb/Q]).

For a single span:

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

For a two-span condition:

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

For a three-span condition:

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

Where:

w_s = uniform load based on shear strength (psf)

$F_s(lb/Q)$ = design shear strength capacity (lb/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:

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

For a two-span condition:

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

For a three-span condition:

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

Where:

Δ = deflection (in.)

w = uniform load (psf)

EI = design bending stiffness capacity (lb-in.^{2}/ft)

ℓ_3 = clear span + SW (in.)

SW = support-width factor, equal to 0.25 inch [6.5 mm] for two-inch-nominal [38 mm] lumber framing and 0.625 inch [16 mm] for four-inch-nominal [89 mm] 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:

$$w_d = \frac{\Delta_{all.}}{\Delta}$$

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 7 for the specified span rating.

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 [89 mm] roof supports 48 in. [1200 mm] 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 [1200 N/m²] snow load.

Bending Strength

From Table 4A, 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 lb-in./ft [261 N•m/m]. This capacity is adjusted by a duration-of-load factor (C_D) of 1.15 (see 4.5.1). From 4.7, a two-span condition is assumed.

$$w_b = \frac{96\ F_bS}{\ell_1^{\,2}}$$

$$= \frac{96 \times (705 \times 1.15)}{48^2}$$

$$= 34 \text{ psf } [1628 \text{ N/m}^2]$$

Shear Strength in the Plane

From Table 4A, 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[lb/Q]) of 300 lb/ft [4378 N/m]. This capacity is adjusted by a duration-of-load factor (C_D) of 1.15 (see 4.5.1).

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

$$= \frac{19.2\ (300 \times 1.15)}{(48 - 3.5)}$$

$$= 149 \text{ psf } [7134 \text{ N/m}^2]$$

Bending Stiffness

From Table 4A, 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 lb-in.²/ft [3107 N•m²/m]. The deflection limit for live load is ℓ/240.

$$\Delta = \frac{w\ell_3^{\,4}}{2{,}220\ EI}$$

$$= \frac{1.0\ (48 - 3.5 + .625)^4}{2{,}220 \times 330{,}000}$$

$$= 5.66 \times 10^{-3} \text{ in.}$$

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

$$= 35 \text{ psf } [1676 \text{ N/m}^2]$$

Bending strength controls (provides the lowest capacity) for this application. The bending strength capacity of 34 psf [1628 N/m²] represents total load, from which dead load is subtracted to arrive at live load capacity. The bending stiffness capacity of 35 psf [1676 N/m²] represents live load only. Here, if dead load (panel weight plus roofing) is no more than 9 psf [431 N/m²], the 25 psf [1200 N/m²] 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 APA Structural I Rated Sheathing 32/16 is to be used in a panelized roof system over 2-in.-nominal [38 mm] framing members 24 in. [600 mm] on center. The long panel dimension (strength axis) of the panel will be placed parallel to supports.

Bending Strength

From Table 4A, 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 lb-in./ft [61.2 N•m/m]. 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). This duration-of-load factor is normally associated with snow loads for roof structures. From 4.7, a two-span condition is assumed.

$$w_b = \frac{96\ F_bS}{\ell_1^{\,2}}$$

$$= \frac{96\ (165 \times 1.5 \times 1.15)}{24^2}$$

$$= 47 \text{ psf } [2250 \text{ N/m}^2]$$

Shear Strength in the Plane

From Table 4A, an OSB Rated Sheathing 32/16 panel with stress applied perpendicular to strength axis has shear strength in the plane (F_s[lb/Q]) of 165 lb/ft [2408 N/m]. 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).

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

$$= \frac{19.2\ (165 \times 1.0 \times 1.15)}{(24 - 1.5)}$$

$$= 162 \text{ psf } [7757 \text{ N/m}^2]$$

Bending Stiffness

From Table 4A, an OSB Rated Sheathing 32/16 panel with stress applied perpendicular to strength axis has a dry stiffness capacity (EI) of 25,000 lb-in.^{2}/ft [235 N•m^2/m]. This capacity is adjusted by a multiplier of 1.6 for OSB Structural I. The deflection limit for live load is $\ell/240$.

$$\Delta = \frac{w\ell_3^{\,4}}{2{,}220\ EI}$$

$$= \frac{1.0\ (24 - 1.5 + .25)^4}{2{,}220 \times (25{,}000 \times 1.6)}$$

$$= 3.017 \times 10^{-3}\ \text{in.}$$

$$w_d = \frac{\Delta_{all.}}{\Delta} = \frac{24/240}{3.017 \times 10^{-3}}$$

$$= 33\ \text{psf}\ [1580\ \text{N/m}^2]$$

4.8.3. Example 3 – Floor

A 5-ply plywood panel marked APA Rated Sturd-I-Floor 24 oc is to be used in a floor system over supports 24 in. [600 mm] on center. The panels will be placed with the long panel dimension (strength axis) perpendicular to supports. Supports are 2-in.-nominal [38 mm] 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 4A, 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 lb-in./ft [285 N•m/m]. From 4.7, a three-span condition is assumed.

$$w_b = \frac{120\ F_bS}{\ell_1^{\,2}} = \frac{120 \times 770}{24^2}$$

$$= 160\ \text{psf}\ [7661\ \text{N/m}^2]$$

Shear Strength in the Plane

From Table 4A, 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[lb/Q]) equal to 325 lb/ft [4743 N/m].

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

$$= \frac{20 \times 325}{(24 - 1.5)}$$

$$= 289\ \text{psf}\ [13837\ \text{N/m}^2]$$

Bending Stiffness

From Table 4A, 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 lb-in.^{2}/ft [3107 N•m^2/m]. The deflection limit for live load is $\ell/360$.

$$\Delta = \frac{w\ell_3^{\,4}}{1{,}743\ EI}$$

$$= \frac{1.0\ (24 - 1.5 + .25)^4}{1{,}743 \times (330{,}000 \times 1.1)}$$

$$= 4.657 \times 10^{4}\ \text{in.}$$

$$w_d = \frac{\Delta_{all.}}{\Delta} = \frac{24/360}{4.657 \times 10^{-4}}$$

$$= 143\ \text{psf}\ [6847\ \text{N/m}^2]$$

While the above calculations would indicate that this Sturd-I-Floor construction has a live load capacity of 143 psf [6847 N/m^2] (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 [1900 N/m^2] 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.

To assist in ascertaining the availability of a specific panel type, the following table has been developed by APA.

TABLE 7

TYPICAL APA PANEL CONSTRUCTIONS[(a)]

Span Rating	Plywood			OSB
	3-ply	4-ply	5-ply[(b)]	
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.

5. REFERENCES

1. *Construction and Industrial Plywood,* Voluntary Product Standard PS 1, U.S. Department of Commerce, Washington, DC.

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

3. *Performance Standards and Qualification Policy for Structural-Use Panels,* PRP-108, *APA – The Engineered Wood Association,* Tacoma, WA.

4. *Methods of Testing Structural Panels in Flexure,* ASTM D 3043, American Society for Testing and Materials, Philadelphia, PA.

5. *Test Method for Structural Panels in Tension,* ASTM D 3500, American Society for Testing and Materials, Philadelphia, PA.

6. *Test Method for Testing Structural Panels in Compression,* ASTM D 3501, American Society for Testing and Materials, Philadelphia, PA.

7. *Test Method for Structural Panels in Planar Shear (Rolling Shear),* ASTM D 2718, American Society for Testing and Materials, Philadelphia, PA.

8. *Test Method for Structural Panels in Shear Through-the-Thickness,* ASTM D 2719, American Society for Testing and Materials, Philadelphia, PA.

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

10. *Plywood – Preservative Treatment by Pressure Process,* AWPA Standard C9, American Wood-Preservers' Association, Granbury, TX.

11. *Fire-Retardant-Treated Plywood,* Technical Bulletin TB-201, *APA – The Engineered Wood Association,* Tacoma, WA.

12. *Construction Sheathing, CAN/CSA-O325.0,* Canadian Standards Association, Toronto, ON, Canada.

13. *National Design Specification for Wood Construction,* American Forest & Paper Association, Washington, DC.

14. *Standard Method for Evaluating Dowel Bearing Strength of Wood and Wood-Base Products,* ASTM D 5764, American Society for Testing and Materials, Philadelphia, PA.

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

APA – THE ENGINEERED WOOD ASSOCIATION

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