Plywood Design Fundamentals

CERTIFIED QUALITY QUALITÉ CERTIFIÉE
CAN PLY
EXTERIOR

CertiWood™

Over Five Decades of Service to the Plywood Industry

The CertiWood™ Technical Centre (formerly named the Canadian Plywood Association or CANPLY) is a non-profit, industry-funded association representing manufacturers of engineered wood products in Canada. Since the association's name change in 2005 from CANPLY to CertiWood™, plywood producing companies have retained the CANPLY trademark and continue to stamp their production with the well-known mark. The CANPLY stamp continues to serve as an assurance to buyers that the plywood is produced under CertiWood's exacting 3rd party quality auditing process and that it will perform in a satisfactory and predictable manner.

CANPLY plywood is manufactured by 6 companies belonging to CertiWood™ (member companies) operating in British Columbia and Alberta. Together, these companies operate 9 mills and produce over 90% of all structural, construction and industrial plywood manufactured in Canada. Member company plywood production is about 1.7 billion square feet (3/8" basis) annually. Approximately 90% is shipped to markets across Canada. The balance is exported to some 28 countries, among these: the United States, Japan, the United Kingdom and Germany.

Originally founded in 1950, CertiWood™ has a long history of service to its member companies and their customers. Today, CertiWood's purpose is, "To provide cost-effective certification, quality auditing and testing services to Canadian engineered wood products manufacturers".

CERTIFICATION MARKS

The registered certification marks shown below appear on CANPLY EXTERIOR Douglas Fir plywood (DFP), CANPLY EXTERIOR Canadian Softwood plywood (CSP) and CANPLY EXTERIOR Poplar Plywood manufactured by our members to meet the requirements of CSA O121, CSA O151 or CSA O153. CertiWood™ also certifies its Members' products to meet US and other international standards (see below).

Face Stamp on CANPLY EXTERIOR Plywood (Unsanded grades)

Licensed mill number of the CertiWood™ member

Indicates that this product is manufactured under CertiWood's Quality Certification Program.

Indicates that the plywood has been manufactured by a member of CertiWood™

Indicates a completely waterproof glue bond

Indicates species designation: DFP (Douglas Fir plywood), CSP (Canadian Softwood plywood), Aspen or Poplar plywood

Indicates the CSA standard governing manufacture

* DFP, CSP, ASPEN or POPLAR
**CSA O151, CSA O121 or CSA O153

Edge Stamp on CANPLY EXTERIOR Plywood (Sanded and Unsanded grades)

PLYCO CANADA BC xxx CANPLY EXTERIOR CSP GRADE

Indicates that the plywood has been manufactured by a CertiWood™ member and is quality certified

Indicates a completely waterproof glue bond

Panel grade

Indicates species designation: DFP (Douglas Fir plywood), CSP (Canadian Softwood plywood), Aspen or Poplar plywood

Licensed mill number of CertiWood™member (BC xxx, ABxxx).

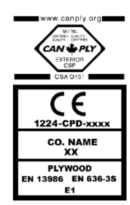
EASY T&G — This symbol identifies the patented tongue and groove profiles of CANPLY T&G products formerly known as COFI FLOOR & COFI ROOF.

COFI FORM — Face stamp on COFI FORM Douglas Fir plywood for concrete formwork.

INTERNATIONAL CERTIFICATION MARKS:

USA

JAPAN



EUROPEAN UNION

Plywood Design Fundamentals

1.0 INTRODUCTION

Information in this brochure pertains to CANPLY EXTERIOR Douglas Fir plywood, CANPLY EXTERIOR Canadian Softwood plywood, CANPLY EXTERIOR Aspen plywood and CANPLY EXTERIOR Poplar plywood manufactured in accordance with Canadian Standards Association Standards CSA O121 Douglas Fir Plywood, CSA O151 Canadian Softwood Plywood or CSA O153 Poplar Plywood by plywood manufacturers who are members of CertiWood™. CANPLY certification stamps, shown opposite, are on all CertiWood™ member products meeting the Association's Quality Certification Program.

Material for this brochure has been compiled from data developed by the CertiWood™ Technical Centre as well as from many other authoritative sources. However, information of a fundamental nature such as the derivation of formulas is not included since this brochure is intended for those familiar with the basic principles of engineering design.

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2.0 CANPLY EXTERIOR PLYWOOD

2.1 Panel Construction

CANPLY EXTERIOR plywood is an engineered panel built up from sheets of veneer glued together with a waterproof resin adhesive. The thickness and orientation of the plies determine the performance of the panel. The veneers are united under high temperature and pressure with a resin glue that is completely waterproof, making the plywood suitable for use under conditions of extreme exposure to moisture.

2.2 Sizes and Thicknesses

CANPLY EXTERIOR Plywood (DFP, CSP, Aspen and Poplar) is manufactured in a size of 1220 mm by 2440 mm, the metric equivalent of the familiar 4 ft by 8 ft panel. It is also available in a metric size of 1200 mm by 2400 mm. Net face widths for EASY T&G panels are given in Table 1.

CANPLY plywood is manufactured in a range of thicknesses from 6 mm to 31.5 mm as shown in Table 1. Panels manufactured in thicknesses from 22.5 mm to 31.5 mm are engineered to provide high load carrying capacities. They are subject to ply thickness limitations considerably more restrictive than those allowed by the basic product standards.

Table 1. Sizes and Thicknesses of CANPLY EXTERIOR Plywood

Thicknesses				Sizes
Sanded		Sheathing & Select		
6 mm	19 mm†	7.5 mm	20.5 mm†	***Lengths*** *Available up to 2500 mm* ***Widths*** *Available from 600 mm to 1250 mm*
8 mm	21 mm†	9.5 mm	22.5 mm†	
11 mm	24 mm†	11 mm†	25.5 mm†	
14 mm	27 mm†	12.5 mm†	28.5 mm†	
17 mm†	30 mm†	15.5 mm†	31.5 mm†	
		18.5 mm†		
All thicknesses are metric, but some approximate imperial dimensions eg 6 mm (1/4 in.) † Available as square edge or with EASY T&G edge.				*For EASY T&G panels, deduct 15 mm from the nominal width for net face coverage.*

NOTE: CANPLY EXTERIOR plywood panels are available in additional sizes and thicknesses on special order.

2.3 Species

Plywood marked CANPLY EXTERIOR may be designated as Douglas Fir (DFP), Canadian Softwood (CSP), Aspen or Poplar plywood.

CANPLY EXTERIOR Douglas Fir plywood is manufactured with faces of Douglas fir veneers. The inner plies and some backs may be of veneers of the selected coniferous species shown in Table 2. The permissible species for CANPLY EXTERIOR Canadian Softwood plywood are also shown in Table 2. For a complete list of allowable species in CANPLY Poplar plywood, please refer to the standard CSA O153.

2.4 Plywood Grades and Products

CertiWood™ members produce a wide range of CANPLY EXTERIOR plywood grades and products. Grade names in general are based on the quality of the veneers used for the face and back of the panel. CANPLY EXTERIOR plywood grades are shown in Table 3. A list of proprietary CANPLY EXTERIOR plywood products is given in Table 4.

2.5 Mill Specialties

Mill specialties are variations of the plywood grades and products shown in Tables 3 and 4. These panels are manufactured by a number of member companies and marketed under their own brand names. Mill specialities include patterned, overlaid, textured, brushed, embossed, striated, grooved and pre-finished panels for decorative use.

2.6 Overlaid Plywood

Plywood is also manufactured with overlays which improve the appearance and durability of the panel. The overlays are bonded to the face veneers of the plywood by heat and pressure. This process seals the overlay to the wood to form an inseparable bond stronger than the wood itself. The resin content of the overlay determines whether the final product is called Medium or High Density Overlaid plywood.

Medium Density (MDO)
The resin impregnated face presents a smooth uniform surface intended for high quality paint finishes. Some evidence of the underlying grain may appear. Overlay is produced in a natural buff colour and certain other colours.

Popular uses for Medium Density Overlaid plywood are flat, lap and bevel sidings; and sundecks, soffits and accent panels in residential construction. Other applications include boats, highway signs and many other commercial uses.

High Density (HDO)
The resin impregnated face is hard, smooth, and chemically resistant. No further finishing with paint or varnish is necessary. The overlay is usually produced in a whitish semi-opaque colour but other colours may be used by manufacturers for identification. Major uses for High Density Overlaid plywood include fine finish concrete formwork, storage bins, liquid tanks and signs.

2.7 Tongue and Groove (T&G) Plywood

T&G plywood has a factory-machined tongue along one of the long edges and a groove along the other. T&G panels interlock to ensure the effective transmission of loads across joints, eliminate differential deflection between adjoining panel edges and make blocking or the use of H-clips at longitudinal joints unnecessary.

CertiWood™ members manufacture two T&G panels, under one name -- EASY T&G. These panels have T&G edges specifically designed for roof and floor sheathing. Panel installation is fast and easy with these patented edge profiles, exclusive to CertiWood™ members.

2.8 Concrete Form Panels

All plywood bearing the registered certification mark CANPLY EXTERIOR is suitable for concrete formwork because it is manufactured with waterproof glue.

CANPLY EXTERIOR DFP is available in sanded and unsanded grades and in special high strength constructions. CANPLY EXTERIOR CSP is available in unsanded and lightly sanded grades. Sanded grades produce a smooth, wood grain finish valued by many architects. Unsanded grades are suitable for formwork where the appearance of the concrete is less important such as in sub-surface foundations.

CANPLY EXTERIOR plywood is also available edge sealed, treated with chemical release agents, and with resin impregnated cellulose fibre overlays. Overlays produce the highest quality concrete finish. They also help protect the plywood from oil and water, simplify form stripping and extend the service life of concrete forms.

COFI FORM PLUS and COFI FORM are special high-strength constructions of DFP panels designed specifically for use as concrete formwork. These panels are significantly stiffer than standard construction of DFP in wet service conditions because of stricter limits on species and ply thicknesses during manufacture. COFI FORM PLUS is the stiffest Douglas Fir panel manufactured by CertiWood™ members.

Table 2. Species permitted in CANPLY EXTERIOR Plywood

	CSA O121 DFP		CSA O151 CSP		CSA O151 ASPEN		CSA O153 POPLAR	
COMMON NAME	Faces & Backs	Inner Plies	Faces & Backs	Inner Plies	Faces & Backs	Inner Plies	Faces & Backs	Inner Plies
Douglas Fir	●	●		●		●		●
True fir *		●	●	●		●		●
Western white spruce*		●	●	●		●		●
Sitka spruce*		●	●	●		●		●
Lodgepole pine*		●	●	●		●		●
Western hemlock*		●	●	●		●		●
Western larch*		●	●	●		●		●
Trembling aspen		●		●	●	●	●	●
White birch		●	●	●		●		●
Balsam fir		●	●	●		●		●
Eastern spruce		●	●	●		●		●
Eastern white pine		●	●	●		●		●
Red pine		●	●	●		●		●
Jack pine		●	●	●		●		●
Ponderosa pine		●	●	●		●		●
Western white pine		●	●	●		●		●
Eastern hemlock		●	●	●		●		
Tamarack		●	●	●		●		●
Yellow cedar		●	●	●		●		●
Western red cedar			●	●		●		●
Balsam poplar		●		●		●	●	●
Black cottonwood		●		●		●	● **	● **

** Permitted on the backs of 6, 8, 11 and 14 mm Good One Side DFP*
*** Not permitted in sheathing grades*

Table 3. CANPLY EXTERIOR Standard Plywood Grades

Grade*	Product**	Veneer Grades**			Characteristics	Typical Applications
		Face	Inner Plies	Back		
Good Two Sides (G2S)	DFP	A	C	A	Sanded. Best appearance both faces. May contain neat wood patches, inlays or synthetic patching material.	Furniture, cabinet doors, partitions, shelving, concrete forms and opaque paint finishes
Sanded	Poplar					
Good One Side (G1S)	DFP	A	C	C	Sanded. Best appearance one side only. May contain neat wood patches, inlays or synthetic patching material.	Where appearance or smooth sanded surface of one face is important. Cabinets, shelving, concrete forms.
Select - Tight Face (SEL TF)	DFP	B***	C	C	Surface openings shall be filled and may be lightly sanded.	Underlayment and combined subfloor and underlayment. Hoarding. Construction use where sanded material is not required.
Select (SEL)	DFP Aspen Poplar CSP	B	C	C	Surface openings may be filled and may be lightly sanded.	
Sheathing (SHG)	DFP Aspen Poplar CSP	C	C	C	Unsanded. Face may contain limited size knots, knotholes and other minor defects.	Roof, wall and floor sheathing. Hoarding. Packaging. Construction use where sanded material is not required.
High Density Overlaid (HDO)	DFP Aspen Poplar CSP	B***	C	B***	Smooth, resin-fibre overlaid surface. Further finishing not required	Bins, tanks, boats, furniture, signs, displays, forms for architectural concrete.
Medium Density Overlaid (MDO) MDO 1 Side	DFP Aspen Poplar CSP	C***	C	C	Smooth, resin-fibre overlaid surface. Best paint base.	Siding, soffits, paneling, built-in fitments, signs, any use requiring a superior paint surface.
MDO 2 Sides	DFP Aspen Poplar CSP	C***	C	C***		

Table 4. CANPLY EXTERIOR Plywood Proprietary Products

Product*	Product Standard**	Grades**	Characteristics	Typical Applications
EASY T&G ROOF	DFP CSP	SHG or SEL	Milled with patented edge profile for easy installation and edge support without H-clips	Roof sheathing and decking for residential, commercial and industrial construction.
EASY T&G FLOOR	DFP CSP Aspen Poplar	SHG SEL SEL TF	Milled with a patented edge profile for fast, easy installation.	Floor and heavy roof sheathing for residential, commercial and industrial construction.
COFI FORM PLUS and COFI FORM	DFP (limits on thickness and species of face and inner plies)	SEL G1S G2S SPECIALTY HDO MDO	Special construction Douglas Fir panels with greater stiffness and strength providing improved properties particularly in wet service conditions. Available in regular sanded and unsanded grades and speciality grades with resin-fibre overlays. Also available with factory-applied release agent.	Concrete forms and other uses where wet service conditions or superior strength requirements are encountered.

* All grades and products including overlays bonded with waterproof resin glue.
** For complete veneer and panel grade descriptions see CSA O121 (DFP), CSA O151 (CSP) and CSA O153 (Poplar).
*** Indicates all openings are filled.

3.0 PHYSICAL AND MECHANICAL PROPERTIES

3.1 Symbols

The following symbols are used throughout this publication. Deviations from them, and additional nomenclature, are noted where they appear.

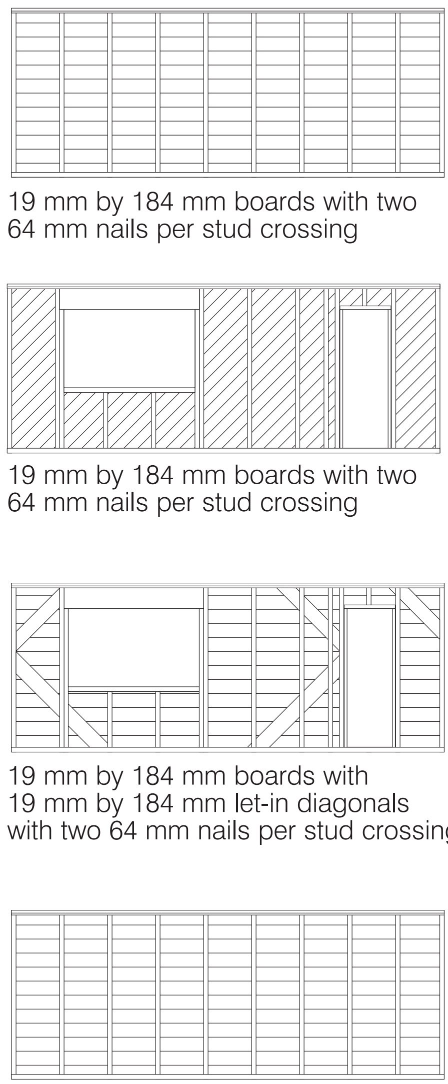
b	Width of member (mm)
b_b	Specified bending stiffness of plywood ($N \bullet mm^2 / mm$)
b_p	Width of plywood panel (mm)
EI	Bending stiffness of plywood expressed as the product of modulus of elasticity and moment of inertia
EA	Axial stiffness of plywood expressed as the product of modulus of elasticity and area
I	Moment of inertia about the neutral axis
k	Thermal conductivity (W/m°C)
K_D	Load duration factor (Table 16)
K_F	Factor for permanent wood foundations
K_S	Service condition factor (Table 17)
K_T	Treatment factor
ℓ	Span (mm)
m_p	Specified strength capacity of plywood in bending ($N \bullet mm/mm$)
R	Factored Reistance (N/mm)
R_T	Thermal resistivity (m°C/W)
RD	Relative density
t	Thickness of plywood (mm)
$t_{\perp}, t_{\|\|}$	Thickness of plies perpendicular to or parallel to span of plywood panel (mm)
T^o	Temperature (°C)
V_{pb}	specified strength capacity of plywood in planar shear (due to bending) (N/mm)
W	Heat flow rate
w	Specified total uniformly distributed load (kN/m^2)
X_J	Stress joint factor
α	Coefficient of thermal expansion
α_p	Coefficient of linear thermal expansion parallel to or perpendicular to face grain direction
α_t	Coefficient of thermal expansion for thickness
Δ	Deflection
Σ	Total
Φ	Resistance factor

3.2 Resistance to Splitting and Concentrated Loads

Plywood's cross-laminated construction results in a far greater resistance to splitting than solid wood since no plane of cleavage exists. Plywood also has the ability to withstand concentrated and impact loads that would dent or shatter other materials.

3.3 Resistance to Racking

Racking resistance is another term for the structural bracing or diaphragm action of plywood roof, wall, and floor sheathing. Specified strength capacities for diaphrams and shearwalls sheathed with plywood are contained in CSA O86 *Engineering Design in Wood.*



Wall section	Relative Rigidity	Relative Strength
19 mm by 184 mm boards with two 64 mm nails per stud crossing	1.0	1.0
19 mm by 184 mm boards with two 64 mm nails per stud crossing	1.0	1.3
19 mm by 184 mm boards with 19 mm by 184 mm let-in diagonals with two 64 mm nails per stud crossing.	1.5	2.2
6 mm plywood with 64 mm nails spaced 127 mm oc at all panel edges and 254 mm oc at intermediate studs	2.0	2.8

Note: Data from U.S. Forest Products Laboratory tests. Nailing patterns shown describe test conditions and are not recommended for construction purposes

Figure 1. Relative Rigidity and Strength of Wall Sections

3.4 Dimensional Stability

Plywood is subject to dimensional changes in response to fluctuations of ambient temperature and contact with liquids or vapours. Expansion in plywoods of balanced construction is slightly greater along the grain but much less across the grain than for solid wood.

The dimensional change, however, is approximately the same per unit of length in both directions because of the averaging influence of cross-bands. Change in thickness for all practical purposes is identical to that of solid wood in the radial direction.

Effect of Moisture

Plywood's cross-laminated construction provides superior dimensional stability in the plane of the panel. The swelling or shrinking of wood along the grain with changes in moisture content is small, being only about 1/20 to 1/40 of that across the grain. The tendency of individual veneers to swell or shrink crosswise, therefore, is greatly restricted by the relative longitudinal stability of the adjacent plies.

Expansion of a plywood panel that is free to move consists of a uniform restrained swelling across the full width or length, and a less restrained swelling at the edges. Edge swelling is independent of panel size, varies with the thickness of veneers having grain perpendicular to the direction of expansion and, for the same veneer thickness, is about twice as great for face plies as for inner plies.

The average coefficient of hygroscopic expansion in thickness is about 0.003 mm per millimetre of original thickness for each 1% change in moisture content.

Internal uniform dimension changes in a panel decrease as the percentage of panel thickness in plies having grain perpendicular to the direction of expansion or contraction decreases. Standard plywood constructions of four or more plies are well balanced and the perpendicular ply percentage, both across the width and along the length, seldom exceeds 60%. The average coefficient of hygroscopic expansion (or contraction) for these constructions is about 0.0002 mm per millimetre of length or width for each 10% change in equilibrium relative humidity; or 0.2% from oven-dry to complete saturation.

The approximate relationship between relative humidity (RH) and equilibrium moisture content (EMC) of plywood is:

RH (%)	EMC at 24°C (%)
10	2
20	4
30	6
40	7
50	9
60	11
70	13
80	16
90	20
100	28

In normal conditions of dry use, equilibrium relative humidity may vary between 40 and 80%, with corresponding moisture contents ranging from 7 to 16%. Total dimensional changes of a 1220 mm by 2440 mm panel exposed to this change in conditions may be expected to average about 1.0 mm across the width and 2.0 mm along the length.

Effect of Temperature

Plywood expands on heating and contracts on cooling. The rate of thermal expansion or contraction is practically independent of the temperature range involved, but is strongly influenced by the construction of the plywood. Thermal changes cause wood to expand about 10 times as much across the grain as it does parallel. By ignoring the influence of variations in moisture content and specific gravity, the average coefficient of linear thermal expansion α can be calculated for a temperature change of 1 °C from the following formulas:

For length and width:

$$\alpha_p \approx \left[40 - \frac{36\left(1 - \frac{t_\perp}{t}\right)}{1 - 0.92\,\frac{t_\perp}{t}} \right]$$

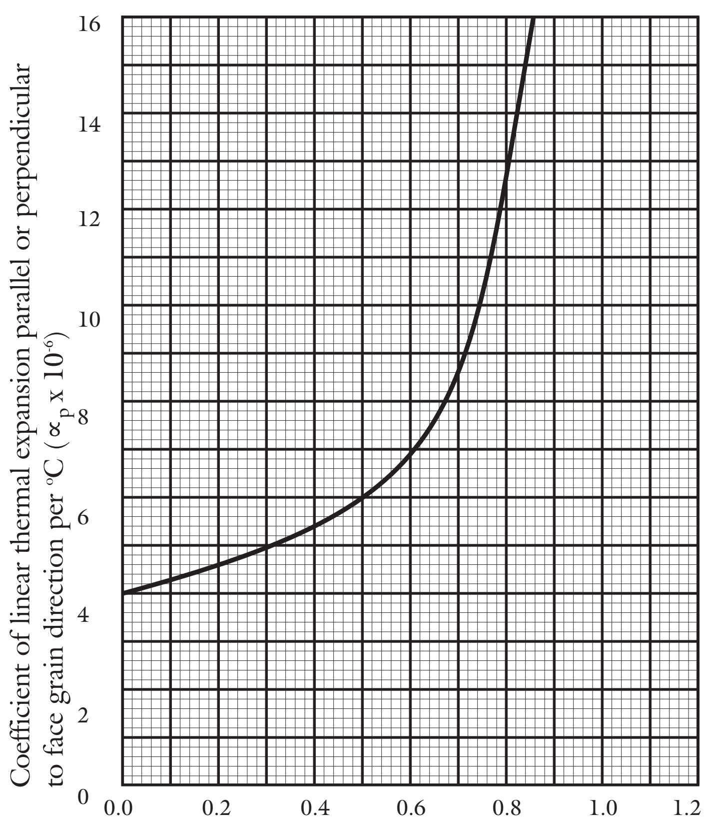
For thickness:

$$\alpha_t \approx 28 \times 10^{-6}$$

Values of α_p for various plywood constructions are presented in Figure 2.

Changes in panel dimension (length, width or thickness) due to a change in temperature can be calculated as:

Final dimension = Original dimension [1 + $\alpha(\Delta T)$]
where α = coefficient of thermal expansion (α_p or α_t).
ΔT = change in temperature (°C)



$\left(\frac{t_\perp}{t}\right)$ Ratio of thickness of plies perpendicular to the direction of expansion to total thickness of panel

Figure 2. Coefficients of Linear Thermal Expansion for Plywood of Various Constructions

3.5 Effect of Chemicals

Swelling of wood in concentrated aqueous solutions of phenol, resorcinol, pyrogallol, or formaldehyde; salts of zinc, lithium, calcium or magnesium; formic acid; liquid ammonia, formamide, n-butylamine, pyridine, and morpholene exceeds swelling in water by 20 to 30%. The shrinkage of wood containing aqueous solutes in less than that of water-swollen wood. Plywood may be expected to behave similarly to solid wood.

Organic acids and alcohols cause swelling slightly less than that caused by water. The effect of non-polar organic liquids such as petroleum, oils, creosote, benzene, toluene, carbon tetrachloride, ethylether, and dioxane is negligible.

Acid salts have a hydrolytic effect on wood if they are present in large concentrations. Fortunately, the concentrations used in preservative treatments of wood are sufficiently small so that the strength properties are not greatly affected under normal use conditions. No reduction in specified strengths is therefore necessary for plywood treated with preservatives. However, the specified strengths for plywood treated with fire-retardant salts and used in structural applications must be reduced according to the provisions of CSA O86.

Tests show that plywood treated with coal-tar creosote and preservative oils developed no reduction in bond strength of the plywood. Experience has also shown no adverse effect on the durability of the bond strength when CANPLY EXTERIOR waterproof glue plywood is pressure treated with water-borne salts preservatives.

Unpainted medium and high density resin-fibre overlays exhibit generally high resistance to chemical solutions. Table 5 summarizes the effects of representative reagents.

3.6 Thermal Resistance (Insulation Values)

The thermal resistance (RSI, or R_T based on Imperial values) of plywood is dependent on the specific gravity (SG) of the panel, and is affected by environmental conditions. Plywood's heat insulating properties are increased if the material has a lower specific gravity, or where panels have decreased moisture contents.

Thermal resistance values for plywood having an SG of 0.4 and at a moisture content (MC) of 7% are approximately 0.0087 RSI/mm (1.3 R/in), as presented for typical nominal thicknesses of plywood in Table 6. Values under other conditions, within an MC range from 0% to 40% and at or near room temperature can be estimated using the following formula:

$RSI = t / k$
where:
t = Panel Thickness
k = Thermal conductivity W/(m•°C) from Figure 3, or
$= SG\{0.201 + 0.004(MC)\} + 0.024$
SG = Specific Gravity (non-dimensional)
MC = Moisture content (%)

Table 5. Effects of Chemical Solutions on Resin-Fibre Overlays

Reagent	Effect on Overlay after 24 hours Contact with Reagent	
	High Density	Medium Density
Acetic Acid (10%)	No Effect	Slight swelling, roughening, softening and discolouration
Acetone	No Effect	Slight discolouration
Alkaline Solutions	Slight discolouration	Marked roughening, slight discolouration
Ammonium Hydroxide (10%)	Marked discolouration	Slight swelling, extreme roughening and discolouration
Detergent	No effect	Marked roughening, slight discolouration
Naptha (soap)	No effect	Slight swelling and softening. Marked roughening and discolouration
Hydrochloric Acid (10%)	No effect	Slight roughening, softening and discolouration
Sodium Chloride (10%)	No effect	Slight roughening
Sulphuric Acid (10%)	No effect	Slight swelling and roughening. Marked softening. Extreme discolouration.

Table 6. Thermal Resistance of Plywood

Plywood Thickness (mm)	Thermal Resistance	
	RSI (m²•°C/W)	R_T(Imperial)
7.5	0.06	0.4
9.5	0.08	0.5
12.5	0.11	0.6
15.5	0.13	0.8
18.5	0.16	0.9
20.5	0.18	1.0
22.5	0.19	1.1
25.5	0.22	1.3
28.5	0.25	1.4
31.5	0.27	1.6

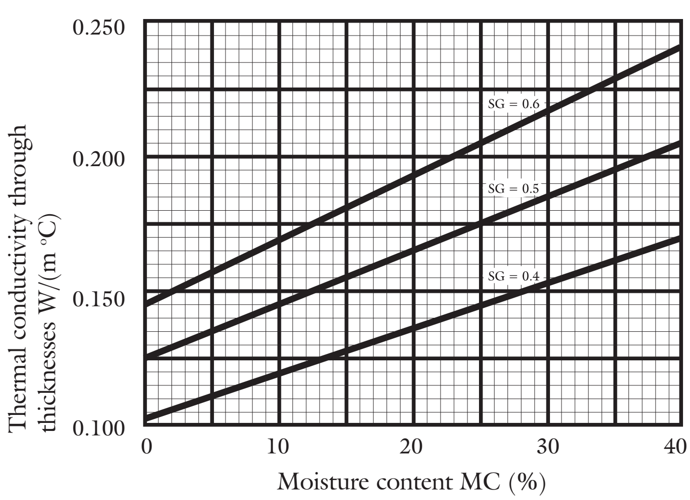


Figure 3. Thermal Conductivity of Plywood

3.7 Electrical Conductivity

At low moisture content, plywood is normally classified as an electrical insulator (dielectric), however its resistance to the passage of electrical current decreases as its moisture content increases.

3.8 Vapour Transmission (Permeance)

Plywood panels provide resistance to the flow of water vapour, and can be used as a vapour transmission retarder (VDR). VDRs are rated in terms of their permeance according to two classes. A Type I VDR has a permeance 14.4 metric perms (ng/(m^2•Pa•s)) or less and a Type II VDR has a permeance of 43.1 metric perms or less before aging and 57.5 perms or less after aging. Plywood can be considered a Type II VDR, with 9.5 mm thick plywood having a permeance of approximately 40 metric perms. Permeance can be reduced by coating plywood with aluminum paint or by application of overlays of low permeability.

3.9 Acoustical Properties

Conventional stud walls sheathed with 7.5 mm plywood (RD of 0.5) on both sides should reduce sound intensity by approximately 30 to 36 decibels at room temperature. Thicker panels are more effective sound insulators.

The sound absorption of 19 mm wood sheathing is approximately 0.10 between the frequencies of 100 to 4100 Hz and increases somewhat at higher frequencies. Plywood may be expected to behave similarly.

3.10 Cold Bend Radii

Table 7 gives cold bend radii for various thicknesses of plywood. The figures given are for plywood panels selected at random with no regard to defects such as knots, patches, and short grain. Without selection or soaking, a small percentage of panels bent to these radii may be expected to break. The selection of plywood with a minimum of defects will permit bending to smaller radii than those shown. These radii can be further reduced by soaking or steaming the panel prior to bending.

Table 7. Cold Bend Radii

Plywood Thickness (mm)	Bending Axis Parallel to Face Grain (m)	Bending Axis Perpendicular to Face Grain (m)
6, 7.5	0.7	1.5
8, 9.5	1.0	2.4
11, 12.5	2.4	3.6
14, 15.5	3.6	4.8
18.5, 19	4.8	6.0
20.5	5.8	7.0

These radii are theoretical values only and have not been verified experimentally.

3.11 Mass of Plywood

The mass of plywood primarily depends on the wood species, but is also affected by the in service moisture content. For practical design purposes, typical values range from 500 to 600 kg/m^3 for Douglas Fir plywood, and 400 to 500 kg/m^3 for Canadian Softwood plywood.

The mass for typical nominal thicknesses of plywood, assuming densities of 500 kg/m^3 for DFP and 450 kg/m^3 for CSP, are contained in Table 8.

Table 8. Mass of Plywood

Plywood Thickness (mm)	Average Mass (kg) for a 1220 x 2440 mm panel	
	DFP	CSP
7.5	11.2	10.0
9.5	14.1	12.7
12.5	18.6	16.7
15.5	23.1	20.8
18.5	27.5	24.8
20.5	30.5	27.5
22.5	33.5	30.1
25.5	38.0	34.2
28.5	42.4	38.2
31.5	46.9	42.2

3.12 Fire Performance

The fire performance data for plywood given in this section are from the National Building Code of Canada. Fire resistance data (Douglas Fir plywood) are shown in Table 9 and flame-spread ratings and smoke developed classifications are given in Table 10.

Table 9. Time Assigned to CANPLY Douglas Fir Plywood Used as Wallboard Membranes*

Plywood Thickness (mm)	Time (min.)
8, 9.5	5**
11, 12.5	10
14, 15.5	15
17, 18.5 and 19	20**

**Time shown is based on the ability of plywood to stay in place on the exposed side of the test assembly during fire tests.*

***This rating is extrapolated and should not be assumed in design or implemented in construction without the prior approval of the regulatory agency or authority having appropriate jurisdiction.*

Table 10. Assigned Flame-Spread Ratings and Smoke Developed Classifications*

Materials	Minimum Thickness (mm)	Flame-Spread/Smoke Developed**	
		Unfinished	Paint or Varnish not more than 1.3 mm thick; Cellulose Wallpaper not more than one layer
Douglas Fir Plywood made to CSA O121	11 6	150/100 150/100	150/300 150/100
Canadian Softwood Plywood made to CSA O151	11	150/100	150/300

** These data are based on all presently available evidence. Interpolation and extrapolation for other plywood thicknesses should not be done without prior approval from the appropriate regulatory agency or authority.*
*** These data are for plywoods without cellulose-resin overlays.*

3.13 Formaldehyde Emission

The phenolic resin adhesive used in CANPLY EXTERIOR plywood is polymerized (cured or hardened) during manufacture and becomes an inert substance with completely distinct characteristics from its individual components that include phenol and formaldehyde. Testing by various accredited organizations have shown formaldehyde levels associated with phenolic resin-bonded plywood to be extremely low, often below detectable levels (0.01 ppm). Further info is contained in CANPLY TechNote TN02.

4.0 STRENGTH PROPERTIES AND ENGINEERING DESIGN

4.1 General

Criteria for the structural design and appraisal of structures or structural elements made from wood or wood products is provided in CSA O86 *Engineering Design in Wood (Limit States Design).*

4.2 Principles of Limit States Design

General principles of limit states design are explained in Section 4, General Design, of CSA O86. Limit states design with plywood is explained in Section 7, Structural Panels. The limit states design method can be summarized as follows:

The design is carried out for strength limit states to assure that the effect of factored loads, determined by a structural analysis of the effect of the applicable types of loads and load factors, does not exceed the factored resistances calculated from specified strengths of materials adjusted by the appropriate factors affecting the specified strengths.

For serviceability limit states (such as deflection), design ensures that the effect of specified loads results in structural behavior that falls within the specified limits.

Factored Resistance (R) $\geq$ Factored Load Effect

It is recommended that Sections 4 and 7 of CSA O86 be studied and understood before carrying out engineering design with plywood.

4.3 Load Effects and Combinations

Specified loads must be factored to account for applicable load combinations.

Part 4 of the NBCC contains updated load effects and combinations.

4.4 Conditions and Factors Affecting Resistance

When calculating factored resistance, the specified strength of plywood shall be multiplied by the applicable modification factor and by a resistance factor. In the case of plywood, the following modification factors may apply and should be considered:

K_D = Load duration factor
K_S = Service condition factor
K_T = Treatment factor
X_J = Stress joint factor
K_F = Factor for permanent wood foundations

Modification factors are given and explained in Section 4.6. Applicability of modification factors and of the resistance factor is indicated for each type of property in Section 4.7. Values of the resistance factor Φ are also given in the same section.

4.5 Specified Strength Capacities

The specified strength, stiffness and rigidity capacities for regular grades of unsanded CANPLY EXTERIOR DFP and CSP are presented in Tables 13 and 14. These values are for ply thicknesses and species combinations yielding the lowest strength per panel construction and are identical to those published in CSA O86.

Other proprietary CANPLY products include EASY T&G, which are tongue and groove panels for floor and roof. Specified strength, stiffness and rigidity capacities for these products are presented in Table 15. Design values for COFI FORM/FORM PLUS, which are special high-strength panels typically specified for concrete from applications, are also available from CertiWood™.

The presented values are for a standard term duration of loading and dry service conditions. For conditions other than these, appropriate modification factors found in Tables 16 and 17 must be applied.

4.6 Modification Factors

Load Duration Factor (K_D)

The specified strength of plywood shall be multiplied by a load duration factor (K_D) as given in Table 16. Load duration factors are not applicable to tabulated stiffness or rigidity capacities.

Service Condition Factor (K_S)

The specified strength, stiffness or rigidity capacity of plywood shall be multiplied by a service condition factor (K_S) as given in Table 17.

Treatment Factor (K_T)

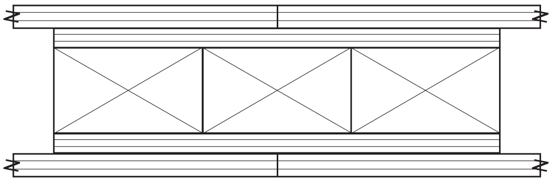
When plywood is impregnated with fire retardant or other strength reducing chemicals, strength and stiffness shall be modified in accordance with the requirements of Section 7 of CSA O86. For untreated and for preservative treated plywood K_T =1.0

Stress Joint Factor (X_J)

Figure 4 shows various types of joints commonly made using CANPLY EXTERIOR plywood.

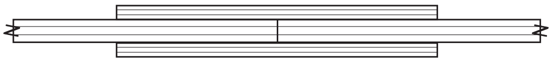
Butt Joints:
For length of splice plates perpendicular to the joint, the stress joint factors of butt joints across the face grain stressed in tension, compression, or shear through thickness shall be as given in Table 18. For butt joints in compression only, splice plates shorter than the minimum length shown in Table 18 may be used provided that the stress joint factor for compression is reduced in direct proportion to such reduction in length.

Splice plates stressed in shear shall have length in the direction perpendicular to the joint equal to 12 times the thickness of the butt jointed plywood, and shall have a width equal to the full depth or width of the panel between framing members. Splice plates shall be of a grade and thickness at least equal to the plywood being spliced.

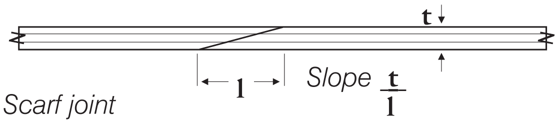


Butt joint with plywood splice plates, lumber backing for nailing

Single plywood splice plate



Double plywood splice plate



Scarf joint

Figure 4. Various Joint Types

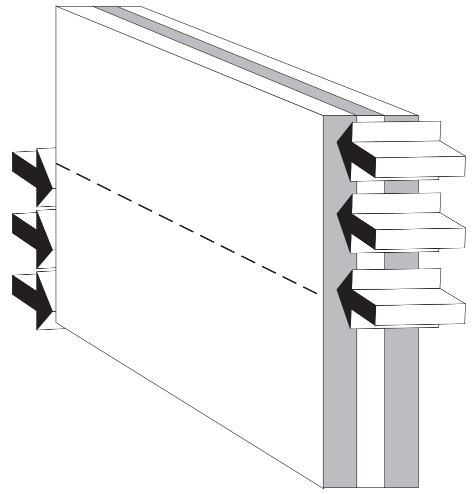
Scarf Joints:
The stress joint factors for scarf joints across the face grain stressed in tension, compression, or shear through thickness shall be as given in Table 19.

The slope of scarf shall not be steeper than 1:8 for scarf joints in shear, and shall not be steeper than 1:5 for scarf joints in tension, compression or bending.

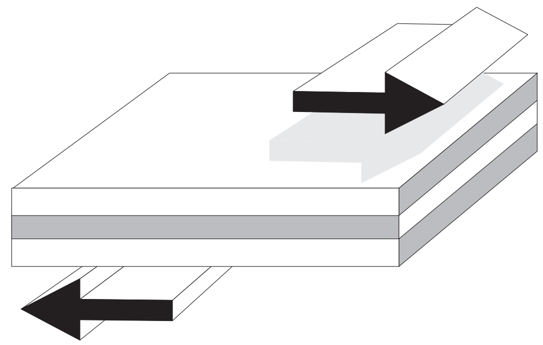
Joints Under Stress Combinations:
Plywood scarf and spliced butt joints subject to more than one type of stress or to a stress reversal should be designed for the most severe case.

Permanent Wood Foundation Factor (K_F)

For plywood in permanent wood foundations supported at intervals not exceeding 815 mm, the end use factor for panel bending and planar shear shall be K_F = 1.15. For all other properties, K_F = 1.00.



Shear through thickness



Planar shear

Figure 5. Shear Through Thickness and Planar Shear

4.7 Calculations of Plywood Resistance

Plywood is an orthotropic material and specified strength capacities used in calculations shall be those for the face grain orientation intended in the design.

Bending Strength

The factored bending resistance of a plywood panel in the plane perpendicular to the plane of the panel shall be taken as:

$M_r = \Phi M_p b_p$

where:

Φ = 0.95

$M_p = m_p (K_D K_S K_T K_F)$

m_p = Specified strength capacity in bending (N•mm/mm)

b_p = Width of plywood panel.

Bending Stiffness

The factored bending stiffness of a plywood panel in the plane perpendicular to the plane of the panel shall be taken as:

$B_{br} = \Phi B_b b_p$

where:

Φ = 1.00

$B_b = b_p (K_S K_T)$

b_b = Specified stiffness in bending (N•mm²/mm)

Bending on Edge

The factored bending resistance of plywood loaded on edge in the plane of a panel that is adequately braced to prevent lateral buckling shall be taken as:

$M_r = \Phi T_p d^2_p/6$

where:

Φ = 0.95

$T_p = t_p (K_D K_S K_T)$

t_p = Specified strength capacity in tension (N/mm)

d_p = Depth plywood panel in plane of bending (mm).

Shear

There are two distinctly different shear types in plywood design. One type of shear is that acting only on planes perpendicular to the surface of the panel (shear through thickness) for which the full cross-sectional area is considered. The other type of shear occurs in the plane of the plies and is termed planar shear, or shear in the plane of the plies. Both are illustrated in Figure 5. The term rolling shear is sometimes used in lieu of planar shear since it applies to shear within a plywood panel where the shearing force tends to roll the wood fibres in the ply at right angles to the direction of the shear force.

Planar Shear Due to Bending

The factored resistance in planar shear for plywood panels subjected to bending shall be taken as:

$V_{rp} = \Phi V_{pb} b_p$

where:

Φ = 0.95

$V_{pb} = v_{pb} (K_D K_S K_T K_F)$

v_{pb} = Specified strength capacity in planar shear (due to bending) (N/mm)

Planar Shear in Plywood Splice or Gusset Plate

The factored resistance in planar shear developed by a glued plywood splice or gusset plate or by the plywood splice plates at a plywood butt joint shall be taken as:

$V_{rp} = \Phi V_{pf} A_c$

where:

Φ = 0.95

$V_{pf} = v_{pf} (K_D K_S K_T)$

v_{pf} = Specified strength capacity in planar shear (due to in-plane forces) (MPa)

A_c = Contact area of splice or gusset plate on one side of joint (mm²)

Shear Due to Bending of Plywood on Edge

The factored resistance in shear through the thickness of plywood due to bending in the panel plane shall be taken as:

$V_r = \Phi V_p 2d_p/3$

where:

Φ = 0.95

$V_p = v_p (K_D K_S K_T)$

v_p = Specified strength capacity in shear-through-thickness (N/mm)

Shear-Through-Thickness in Plywood Splice or Gusset Plates

The factored shear-through-thickness resistance developed by a plywood splice or gusset plate shall be taken as:

$V_r = \Phi V_p L_G$

where:

Φ = 0.95

$V_p = v_p (K_D K_S K_T)$

v_p = Specified strength capacity in shear-through-thickness (N/mm)

L_G = Length of splice or gusset plate subjected to shear (mm).

Compression Parallel to Panel Edge

The factored compressive resistance parallel to a panel edge shall be taken as:

$P_r = \Phi P_p b_p$

where:

Φ = 0.95

$P_p = p_p (K_D K_S K_T)$

p_p = Specified strength capacity in compression (N/mm)

Tension Parallel to Panel Edge

The factored tensile resistance parallel to a panel edge shall be taken as:

$T_r = \Phi T_p b_n$

where:

Φ	= 0.95 (for all plywood thicknesses and number of plies except three and four ply construction stressed perpendicular to face grain)
Φ	= 0.60 (for three and four ply construction stressed perpendicular to face grain)
T_p	= $t_p\ (K_D\ K_S\ K_T)$
t_p	= Specified strength capacity in tension (N/mm)
b_n	= Net width of plywood panel after cutting of holes, etc. (mm).

Compressive Resistance Perpendicular to Face (Bearing)

The factored bearing resistance normal to plane of plies shall be taken as:

$Q_r = \Phi Q_p A_b$

where:

Φ	= 0.95
Q_p	= $q_p\ (K_D\ K_S\ K_T)$
q_p	= Specified strength capacity in bearing normal to plane of panel (MPa)
A_b	= Bearing area (mm^2)

4.8 Design Example

Design a heavy industrial floor deck exposed to wet service conditions. Edge support is to be provided by tongues and grooves. The live load, dead load and span are known. Determine the required thickness of EASY T&G Douglas Fir plywood.

Design Assumptions:

Live Load (uniformly distributed over three or more equal spans, all spans loaded) =17 kPa

Dead Load (uniformly distributed over three or more equal spans, all spans loaded) =2 kPa

Span (from centre to centre of supports) =407 mm

Maximum deflection of plywood between supports (Δ allowable) $=\ell/360$

EASY T&G Douglas Fir plywood applied with face grain across the supports

Wet service conditions:

Bending and Planar Shear K_S=0.8
Stiffness =0.85

Standard term duration of loading K_D=1.0

No chemical treatments K_T=1.0

Strength limit states design load factors α_L =1.50, α_D =1.25

Serviceability limit states design load factors α_L =1.00, α_D =1.00

Importance Category =Normal

Design Calculations:

Since loading is uniformly distributed, unit widths are employed in all calculations:

Specified Live Load (L) = ($17 kN/m^2$)(1.0m) =17 kN/m

Specified Dead Load (D) = ($2 kN/m^2$)(1.0m) =2 kN/m

Bending

$$
\begin{aligned}
M_{max} &\le M_r \\
0.1071\ w\ell^2 &\le \Phi\ M_p\ b_p \\
0.1071\ (1.5L + 1.25D)\ell^2 &\le \Phi\ m_p\ (K_D\ K_S\ K_T)b_p \\
0.1071\ (1.5 \times 17\ kN/m + 1.25 \times 2\ kN/m)(0.407\ m)^2 &\le 0.95 m_p\ (1.0 \times 0.8 \times 1.0)\ (1.0\ m) \\
m_p &\ge 0.654\ kN\ m/m = \underline{654\ N \bullet mm/mm}
\end{aligned}
$$

Planar Shear Due to Bending

$$
\begin{aligned}
V_{max} &\le V_{rp} \\
0.607\ w\ell &\le \Phi\ V_{pb}\ b_p \\
0.607\ (1.5L + 1.25D)\ell &\le \Phi\ v_{pb}\ (K_D\ K_S\ K_T)b_p \\
0.607\ (1.5 \times 17\ kN/m + 1.25 \times 2\ kN/m)(0.407\ m) &\le 0.95 v_{pb}\ (1.0 \times 0.8 \times 1.0)\ (1.0\ m) \\
v_{pb} &\ge 9.1\ kN/m = \underline{9.1\ N/mm}
\end{aligned}
$$

Deflection

$$
\begin{aligned}
\Delta_{max} &\le \Delta_{allow} \\
0.0069\ w\ell^4/B_{br} &\le \ell/360 \\
0.0069\ (L + D)\ell^4/\Phi B_b b_p &\le \ell/360 \\
0.0069\ (L + D)\ell^4/\Phi b_p(K_S\ K_T)b_p &\le \ell/360 \\
0.607\ (17\ kN/m + 2\ kN/m)(0.407\ m)^4/1.0\ b_b(0.85 \times 1.0)(1.0\ m) &\le 0.407\ m/360 \\
b_b &\ge 3.74\ kN\ m = \underline{3{,}740{,}000\ N \bullet mm^2/mm}
\end{aligned}
$$

Summary of Design Calculations

The calculated required specified strengths and stiffness are:

Specified Bending Strength $m_p \geq$ 654 N•mm/mm
Specified Planar Shear Strength $v_{pb} \geq$ 9.1 N/mm
Specified Bending Stiffness $b_b \geq$ 3,740,000 N•mm²/mm

From Table 15, the thinnest standard construction of EASY T&G Douglas Fir plywood required to provide the necessary strength in bending and planar shear and the stiffness necessary to contain deflection to within 1/360th of the span is 20.5 mm.

4.9 Load-Span Formulas

Tables 11 and 12 contain pre-calculated Factored Resistance (R) for plywood uniformly loaded (perpendicular to the plane of the panel) for typical support spacings and the maximum deflection requirements $\ell/180$, $\ell/270$ and $\ell/360$. Tabulated values assume loading over three or more spans, normal duration of load, dry service conditions and use the lowest values in Tables 13 and 14 for a given panel thickness.

The following standard engineering formulas, in conjunction with Table 13 and 14 capacities, may be used to calculate Factored Resistance.

Span governed by bending capacity:

$$R = \frac{8\Phi M_p}{\ell^2}$$ For single span and two equal spans

$$R = \frac{9.34\Phi M_p}{\ell^2}$$ For three or more equal spans

Span governed by planar shear capacity:

$$R = \frac{2.0\Phi V_{pb}}{\ell}$$ For single span

$$R = \frac{1.6\Phi V_{pb}}{\ell}$$ For two equal spans

$$R = \frac{1.65\Phi V_{pb}}{\ell}$$ For three or more equal spans

Span governed by deflection:

$$R = \frac{76.8 B_b \Delta}{\ell^4}$$ For single span

$$R = \frac{185 B_b \Delta}{\ell^4}$$ For two equal spans

$$R = \frac{145 B_b \Delta}{\ell^4}$$ For three or more equal spans

where:

Φ = 0.95
R = Factored Resistance (N/mm²)
M_p = $m_p (K_D K_S K_T K_F)$(N•mm/mm)
V_{pb} = $v_{pb} (K_D K_S K_T K_F)$(N•/mm)
B_b = $b_b (K_S K_T)$(N•mm²/mm)
ℓ = Support Spacing (mm)
Δ = Deflection (mm)

Note:
Unit widths are employed in all calculations.

4.10 Stressed Skin Panels and Plywood Web Beams

The procedures for design of glued stressed skin panels and glued and nailed plywood web beams are presented together with detailed design examples in *Design of Plywood Stressed Skin Panels* and *Design of Glued and Nailed Plywood Web Beams* available from CertiWood™.

The design of these structural components is governed in Canada by the provision of Section 8 of CSA O86 *Engineering Design in Wood (Limit States Design)*.

4.11 Design of Plywood Diaphragms

The design of plywood diaphragms and shear walls is governed in Canada by the provisions of Section 9 Shear Walls and Diaphragms of CSA O86 - *Engineering Design in Wood.*

4.12 Design of Concrete Formwork

The procedures for design of concrete formwork using CANPLY EXTERIOR plywood, including load-span graphs for a variety of uses are contained in CertiWood's publication *Concrete Formwork*.

4.13 Panel Effect

When a plywood panel is simply supported on all edges, the deflection and stresses are less than if the panel was simply supported on two opposite edges and under the same load. Information on the theoretical calculation of this panel effect can be found in the U.S. Forest Products Laboratory Report No. 1312, *Flat Plates of Plywood Under Uniform or Concentrated Loads*.

Tables 11 and 12 - Load-Span Information for DFP and CSP

Panel Thickness (mm)	Load Limited by	Factored Resistance, R (kPa) (1 kPa = 20.9 psf)																	
		DFP									CSP/Aspen								
		Face grain across supports						Face grain along supports			Face grain across supports						Face grain along supports		
		Support Spacing									Support Spacing								
		305 mm (12")	406 mm (16")	488 mm (19.2")	610 mm (24")	813 mm (32")	1220 mm (48")	305 mm (12")	406 mm (16")	610 mm (24")	305 mm (12")	406 mm (16")	488 mm (19.2")	610 mm (24")	813 mm (32")	1220 mm (48")	305 mm (12")	406 mm (16")	610 mm (24")
7.5	L/360	6.3	2.7	1.5	0.8			0.2			4.8	2.0	1.2	0.6			0.2		
	L/270	8.3	3.5	2.0	1.0			0.3			6.4	2.7	1.6	0.8			0.3		
	L/180	13	5.3	3.1	1.6			0.5			10	4.1	2.4	1.2			0.5		
	Bending	17	10	6.7	4.3			3.6			18	10	7.1	4.5			3.6		
	Shear	19	14	12	10			6.2			19	14	12	10			6.2		
9.5	L/360	12	5.1	2.9	1.5	0.6		0.4			8.7	3.7	2.1	1.1	0.5		0.4		
	L/270	16	6.8	3.9	2.0	0.8		0.5			12	4.9	2.8	1.4	0.6		0.5		
	L/180	24	10	5.8	3.0	1.3		0.8			17	7.4	4.2	2.2	0.9		0.8		
	Bending	26	15	10	6.4	3.6		4.9			26	15	10	6.4	3.6		4.9		
	Shear	20	15	13	10	7.5		6.7			20	15	13	10	7.5		6.7		
12.5	L/360	24	10	5.9	3.0	1.3	0.5	1.1	0.5		18	7.8	4.5	2.3	1.0	0.4	1.1	0.5	
	L/270	32	14	7.9	4.0	1.7	0.6	1.5	0.6		25	10	6.0	3.1	1.3	0.5	1.5	0.6	
	L/180	48	20	12	6.0	2.6	1.0	2.2	1.0		37	16	9.0	4.6	2.0	0.7	2.2	1.0	
	Bending	40	23	16	10	5.6	2.1	10	5.9		40	23	16	10	5.6	2.1	10	5.9	
	Shear	28	21	18	14	11	6.9	10	7.3		27	20	17	14	10	6.6	10	7.3	
15.5	L/360	43	18	10	5.3	2.3	0.8	6.1	2.6	1.0	33	14	8.0	4.1	1.7	0.7	6.1	2.6	1.0
	L/270	57	24	14	7.1	3.0	1.1	8.2	3.5	1.3	44	18	11	5.5	2.3	0.9	8.2	3.5	1.3
	L/180	85	36	21	11	4.5	1.7	12	5.2	1.9	65	28	16	8.2	3.5	1.3	12	5.2	1.9
	Bending	58	33	23	15	8.2	3.1	22	12	4.7	55	31	22	14	7.8	3.0	22	12	4.7
	Shear	34	25	21	17	13	8.2	19	14	9.0	34	25	21	17	13	8.2	19	14	9.0
18.5	L/360	65	28	16	8.2	3.5	1.3	18	7.8	2.9	51	22	12	6.4	2.7	1.0	18	7.8	2.9
	L/270	87	37	21	11	4.6	1.7	25	10	3.9	68	29	17	8.5	3.6	1.4	25	10	3.9
	L/180	131	55	32	16	6.9	2.6	37	16	5.9	102	43	25	13	5.4	2.0	37	16	5.9
	Bending	89	50	35	22	12	4.7	41	23	8.8	71	40	28	18	10	3.8	41	23	8.8
	Shear	44	33	27	22	16	11	26	19	12	43	32	27	21	16	10	26	19	12
20.5	L/360	82	35	20	10	4.4	1.6	27	11	4.3	65	28	16	8.2	3.5	1.3	27	11	4.3
	L/270	110	47	27	14	5.8	2.2	36	15	5.7	87	37	21	11	4.6	1.7	36	15	5.7
	L/180	165	70	40	21	8.7	3.3	54	23	8.6	131	55	32	16	6.9	2.6	54	23	8.6
	Bending	105	59	41	26	15	5.6	52	30	11	80	45	31	20	11	4.3	52	30	11
	Shear	43	32	27	21	16	10	29	22	14	43	32	27	21	16	10	29	22	14
22.5	L/360	108	46	26	14	5.7	2.2	36	15	5.7	80	34	19	10	4.2	1.6	31	13	5.0
	L/270	144	61	35	18	7.6	2.9	47	20	7.5	106	45	26	13	5.6	2.1	42	18	6.6
	L/180	216	92	53	27	11	4.3	71	30	11	159	68	39	20	8.4	3.2	63	27	10
	Bending	124	70	48	31	17	5.6	55	31	12	95	54	37	24	13	4.3	53	30	11
	Shear	48	36	30	24	18	12	36	27	17	46	35	29	23	17	11	35	26	17
25.5	L/360	156	66	38	20	8.3	3.1	53	22	8.4	112	48	27	14	5.9	2.2	48	20	7.7
	L/270	209	88	51	26	11	4.2	70	30	11	150	64	37	19	7.9	3.0	64	27	10
	L/180	313	133	76	39	17	6.2	105	45	17	225	95	55	28	12	4.5	97	41	15
	Bending	153	86	60	38	21	8.2	70	39	15	124	70	48	31	17	6.6	66	37	14
	Shear	57	42	35	28	21	14	40	30	19	51	39	32	26	19	12	40	30	19
28.5	L/360	199	84	49	25	11	4.0	80	34	13	142	60	35	18	7.5	2.8	73	31	12
	L/270	265	113	65	33	14	5.3	106	45	17	190	80	46	24	10	3.8	97	41	15
	L/180	398	169	97	50	21	7.9	159	68	25	284	121	69	36	15	5.7	145	61	23
	Bending	191	108	75	48	27	10	90	51	19	143	81	56	36	20	7.7	85	48	18
	Shear	57	42	35	28	21	14	47	36	23	57	42	35	28	21	14	45	34	22
31.5	L/360	256	109	62	32	14	5.1	105	45	17	199	84	49	25	11	4.0	95	40	15
	L/270	341	145	83	43	18	6.8	140	59	22	265	113	65	33	14	5.3	127	54	20
	L/180	512	217	125	64	27	10	210	89	34	398	169	97	50	21	7.9	191	81	30
	Bending	210	118	82	52	30	11	105	59	22	172	97	67	43	24	9.2	95	54	20
	Shear	67	50	42	33	25	16	51	39	25	62	46	39	31	23	15	51	38	25

Assumptions
1. Support spacing measured centre-to-centre
2. Three or more spans with full loading (two spans at 1220 mm with face grain across the supports and 610 mm with face grain along the supports)
3. Ks = 1.0; Kd = 1.0; Kt = 1.0

Table 13 - Specified Strength, Stiffness and Rigidity Capacities (per 1 mm width) for Unsanded Regular Grades of CANPLY EXTERIOR Douglas Fir Plywood (DFP) Certified to CSA O121

Nominal thickness (mm)	Number of plies	Bending Strength		Axial Tension Strength		Axial Compression Strength		Shear Through-Thickness Strength	Planar Shear Strength: Bending,		Planar Shear Strength: Shear in plane		Bending Stiffness		Axial Stiffness (in Tension or Compression)		Shear-Through-Thickenss Rigidity
		m_p		t_p		p_p		v_p	v_{pb}		v_{pf}		b_b = EI		b_a = EA		b_v
		(N·mm/mm)		(N/mm)		(N/mm)		(N/mm)	(N/mm)		(MPa)		(Nmm²/mm)		(N/mm)		(N/mm)
		Orientation of applied force relative to face grain															
		0°	90°	0°	90°	0°	90°	0°& 90°	0°	90°	0°	90°	0°	90°	0°	90°	0°& 90°
7.5	3	180	38	97	23	130	40	20	3.7	1.2	0.72	0.72	440,000	17,000	70,000	24,000	4,600
9.5	3*	270	51	97	27	130	46	24	3.9	1.3	0.55	0.72	840,000	27,000	70,000	28,000	5,500
12.5	3	520	110	170	38	210	66	34	6.3	1.9	0.72	0.72	2,100,000	79,000	120,000	39,000	7,800
12.5	4*	420	130	97	55	130	96	30	5.5	2.8	0.55	0.72	1,700,000	190,000	70,000	57,000	6,900
12.5	5	560	200	130	71	170	79	30	7.3	3.7	0.72	0.72	1,700,000	350,000	94,000	47,000	6,900
15.5	4	610	230	110	72	140	130	37	6.6	3.6	0.55	0.72	3,100,000	430,000	77,000	75,000	8,500
15.5	5*	770	280	130	71	170	79	36	9.4	4.9	0.72	0.72	3,000,000	630,000	94,000	47,000	8,400
15.5	6	730	310	130	71	170	79	36	6.9	4.1	0.55	0.55	3,000,000	760,000	94,000	47,000	8,400
18.5	5	980	460	150	100	190	120	43	9.0	5.0	0.55	0.55	4,600,000	1,300,000	110,000	69,000	9,800
18.5	6*	930	430	130	71	170	79	43	8.5	5.1	0.55	0.55	4,600,000	1,300,000	94,000	47,000	9,800
18.5	7	1,100	450	160	110	210	120	43	9.7	7.1	0.72	0.72	4,900,000	1,400,000	120,000	71,000	9,800
20.5	5	1,200	740	180	130	230	150	47	10	5.7	0.55	0.55	6,300,000	2,600,000	130,000	89,000	11,000
20.5	6	1,100	550	130	71	170	79	47	9.5	5.8	0.55	0.55	5,800,000	1,900,000	94,000	47,000	11,000
20.5	7	1,200	560	160	110	210	120	47	11	8.5	0.72	0.72	6,200,000	2,000,000	120,000	71,000	11,000
20.5	8	1,100	560	160	110	210	120	47	8.3	6.4	0.55	0.55	6,100,000	2,100,000	120,000	71,000	11,000
22.5	6	1,500	790	230	110	300	130	52	15	7.0	0.72	0.55	8,400,000	3,200,000	160,000	75,000	12,000
22.5	7*	1,300	640	170	110	210	130	51	12	9.8	0.72	0.72	7,600,000	2,500,000	120,000	75,000	12,000
22.5	8	1,400	580	160	110	210	120	51	9.3	7.2	0.55	0.55	8,000,000	2,500,000	120,000	71,000	12,000
22.5	9	1,500	730	200	140	250	160	51	12	8.8	0.72	0.72	8,300,000	3,100,000	140,000	95,000	12,000
25.5	7	1,700	950	210	160	270	180	57	13	11	0.72	0.72	11,000,000	4,300,000	150,000	110,000	13,000
25.5	8*	1,600	730	160	110	210	120	57	11	8.8	0.55	0.55	11,000,000	3,700,000	120,000	71,000	13,000
25.5	9	1,700	860	200	140	250	160	57	14	10	0.72	0.72	11,000,000	4,100,000	140,000	95,000	13,000
25.5	10	1,700	800	200	140	250	160	57	11	7.8	0.55	0.55	11,000,000	4,100,000	140,000	95,000	13,000
28.5	8	2,000	1,100	190	140	250	160	63	11	10	0.55	0.55	15,000,000	6,500,000	140,000	95,000	15,000
28.5	9*	2,000	1,000	200	140	250	160	63	16	12	0.72	0.72	14,000,000	5,700,000	140,000	95,000	15,000
28.5	10	2,000	940	200	140	250	160	63	12	9.2	0.55	0.55	15,000,000	5,600,000	140,000	95,000	15,000
28.5	11	2,100	1,200	230	180	300	200	63	15	12	0.72	0.72	15,000,000	6,400,000	160,000	120,000	15,000
31.5	8	2,700	1,600	240	190	320	210	71	13	11	0.55	0.55	22,000,000	10,000,000	180,000	120,000	16,000
31.5	9	2,400	1,500	230	190	300	210	69	17	13	0.72	0.72	19,000,000	9,400,000	170,000	120,000	16,000
31.5	10*	2,200	1,100	200	140	250	160	69	13	10	0.55	0.55	18,000,000	7,400,000	140,000	95,000	16,000
31.5	11	2,400	1,400	230	180	300	200	69	16	14	0.72	0.72	19,000,000	8,500,000	160,000	120,000	16,000
31.5	12	2,400	1,200	230	180	300	200	69	13	10	0.55	0.55	20,000,000	8,200,000	160,000	120,000	16,000

(1) For specified stiffness in bending on edge, use axial stiffness values.
(2) Tabulated values are based on dry service conditions and standard-term duration of load.
(3) Specified strength in bearing (normal to plane of panel) q_p = 4.5 MPa.
(4) Design values for high strength COFIFORM and COFIFORM PLUS concrete form panels are available from CertiWood
(5) All capacities are per 1 mm unit width
(6) Asterisk identifies panel with number of plies most commonly produced

Table 14 - Specified Strength, Stiffness and Rigidity Capacities (per 1 mm width) for Unsanded Regular Grades of CANPLY EXTERIOR Canadian Softwood Plywood (CSP) and Aspen plywood Certified to CSA O151

Nominal thickness (mm)	Number of plies	Bending Strength		Axial Tension Strength		Axial Compression Strength		Shear Through-Thickness Strength	Planar Shear Strength: Bending,		Planar Shear Strength: Shear in-plane		Bending Stiffness		Axial Stiffness (in Tension or Compression)		Shear-Through-Thickenss Rigidity
		m_p		t_p		p_p		v_p	v_{pb}		v_{pf}		b_b = EI		b_a = EA		b_v
		(N·mm/mm)		(N/mm)		(N/mm)		(N/mm)	(N/mm)		(MPa)		(Nmm²/mm)		(N/mm)		(N/mm)
		Orientation of applied force relative to face grain															
		0°	90°	0°	90°	0°	90°	0°& 90°	0°	90°	0°	90°	0°	90°	0°	90°	0°& 90°
7.5	3	190	38	83	23	93	40	18	3.74	1.2	0.72	0.72	340,000	17,000	55,000	24,000	3,400
9.5	3*	270	51	83	27	93	46	23	3.9	1.3	0.55	0.72	610,000	27,000	55,000	28,000	4,300
12.5	3	470	110	120	38	140	66	30	6.3	1.9	0.72	0.72	1,400,000	79,000	81,000	39,000	5,700
12.5	4*	420	130	83	55	93	96	30	5.3	2.8	0.55	0.72	1,300,000	190,000	55,000	57,000	5,700
12.5	5	450	200	120	71	130	79	30	7.3	3.7	0.72	0.72	1,400,000	350,000	79,000	47,000	5,700
15.5	4	600	230	89	72	99	130	38	6.6	3.6	0.55	0.72	2,300,000	430,000	59,000	75,000	7,100
15.5	5*	600	280	120	71	130	79	38	9.1	4.9	0.72	0.72	2,300,000	630,000	79,000	47,000	7,100
15.5	6	580	310	120	71	130	79	38	6.9	4.1	0.55	0.55	2,400,000	760,000	79,000	47,000	7,100
18.5	5	770	460	120	100	140	120	46	8.7	5.0	0.55	0.55	3,600,000	1,300,000	83,000	69,000	8,600
18.5	6*	740	430	120	71	130	79	46	8.3	5.1	0.55	0.55	3,600,000	1,300,000	79,000	47,000	8,600
18.5	7	840	450	150	110	170	120	46	9.7	7.1	0.72	0.72	3,900,000	1,400,000	100,000	71,000	8,600
20.5	5	900	740	150	130	170	150	51	9.9	5.7	0.55	0.55	4,600,000	2,600,000	100,000	89,000	9,500
20.5	6	840	550	120	71	130	79	51	9.3	5.8	0.55	0.55	4,600,000	1,900,000	79,000	47,000	9,500
20.5	7	960	560	150	110	170	120	51	11	8.5	0.72	0.72	4,900,000	2,000,000	100,000	71,000	9,500
20.5	8	900	560	150	110	170	120	51	8.3	6.4	0.55	0.55	4,800,000	2,100,000	100,000	71,000	9,500
22.5	6	1,000	720	200	100	220	120	54	14	6.8	0.72	0.55	5,600,000	2,800,000	130,000	69,000	10,000
22.5	7*	1,000	580	150	110	170	120	54	12	9.5	0.72	0.72	5,700,000	2,200,000	100,000	71,000	10,000
22.5	8	1,100	560	150	110	170	120	54	9.0	6.9	0.55	0.55	6,000,000	2,300,000	100,000	71,000	10,000
22.5	9	1,200	730	190	140	210	160	54	12	8.8	0.72	0.72	6,400,000	3,100,000	130,000	95,000	10,000
25.5	7	1,300	880	180	150	200	160	61	13	10	0.72	0.72	7,900,000	3,900,000	120,000	98,000	12,000
25.5	8*	1,300	690	150	110	170	120	61	10	8.4	0.55	0.55	8,000,000	3,400,000	100,000	71,000	12,000
25.5	9	1,400	810	190	140	210	160	61	13	9.7	0.72	0.72	8,400,000	3,700,000	130,000	95,000	12,000
25.5	10	1,400	920	190	140	210	160	61	10	7.8	0.55	0.55	8,800,000	4,400,000	130,000	95,000	12,000
28.5	8	1,500	950	160	130	180	140	68	11	9.7	0.55	0.55	10,000,000	5,400,000	110,000	85,000	13,000
28.5	9*	1,500	970	190	140	210	160	68	15	11	0.72	0.72	11,000,000	5,200,000	130,000	95,000	13,000
28.5	10	1,600	890	190	140	210	160	68	12	8.7	0.55	0.55	11,000,000	5,100,000	130,000	95,000	13,000
28.5	11	1,700	1,100	230	180	250	200	68	14	12	0.72	0.72	12,000,000	6,100,000	150,000	120,000	13,000
31.5	8	1,800	1,400	200	170	230	190	76	12	11	0.55	0.55	14,000,000	8,800,000	140,000	110,000	14,000
31.5	9	1,800	1,300	200	170	230	190	76	17	13	0.72	0.72	14,000,000	7,900,000	140,000	110,000	14,000
31.5	10*	1,800	1,000	190	140	210	160	76	13	10	0.55	0.55	14,000,000	6,700,000	130,000	95,000	14,000
31.5	11	1,900	1,300	230	180	250	200	76	16	13	0.72	0.72	15,000,000	7,700,000	150,000	120,000	14,000
31.5	12	1,900	1,200	230	180	250	200	76	12	9.9	0.55	0.55	15,000,000	7,500,000	150,000	120,000	14,000

(1) For specified stiffness in bending on edge, use axial stiffness values.
(2) Tabulated values are based on dry service conditions and standard-term duration of load.
(3) Specified strength in bearing (normal to plane of panel) q_p = 4.5 MPa.
(4) Design values for high strength COFIFORM and COFIFORM PLUS concrete form panels are available from CertiWood
(5) All capacities are per 1 mm unit width
(6) Asterisk identifies panel with number of plies most commonly produced

Table 15. Specified Strength Capacities per unit width for CANPLY EXTERIOR EASY T&G Plywood

Plywood Type	Plywood Product	Nominal Plywood Thickness (mm)	Number of Plies	Bending (m_p) N•mm/mm		Axial tension (t_p) N/mm		Axial compression (p_p) N/mm		Shear-through-thickness (v_p)	Planar Shear: Bending (v_{pb}) N/mm		Planar Shear: Shear in-plane (v_{pf}) MPa	
				Orientation of Applied Force Relative to Face Grain										
				0°	90°	0°	90°	0°	90°	0° & 90°	0°	90°	0°	90°
DFP	EASY T&G	11.0	3	410	85	150	34	190	60	30	5.6	1.7	0.72	0.72
		11.0	4	380	91	120	45	150	79	28	4.5	2.3	0.55	0.72
		12.5	4	470	150	120	58	160	100	31	5.2	2.9	0.55	0.72
		15.5	5	770	280	130	71	170	79	36	9.4	4.9	0.72	0.72
		18.5	5	1 300	460	200	110	260	120	45	11	5.7	0.72	0.72
		18.5	6	1 100	480	160	89	200	99	43	8.2	5.1	0.55	0.55
		18.5	7	1 100	450	160	110	210	120	47	9.7	7.1	0.72	0.72
		20.5	5	1 200	740	180	130	230	150	48	10	5.6	0.55	0.55
		20.5	6	1 200	610	150	130	200	150	47	9.2	5.8	0.55	0.55
		20.5	7	1 200	560	160	110	210	120	27	11	5.5	0.72	0.72
CSP or Aspen	EASY T&G	11.0	3	370	85	110	34	120	60	30	5.6	1.7	0.72	0.72
		12.5	4	430	150	90	58	100	100	38	5.2	2.9	0.55	0.72
		15.5	5	520	280	110	71	120	79	46	9.4	4.9	0.72	0.72
		18.5	5	880	460	160	110	180	120	46	11	5.7	0.72	0.72
		18.5	6	750	480	130	89	140	99	46	8.2	5.1	0.55	0.55
		18.5	7	740	450	140	110	160	120	51	9.7	7.1	0.72	0.72
		20.5	5	840	740	150	130	170	150	51	10	5.6	0.55	0.55
		20.5	6	850	610	120	130	140	150	51	9.2	5.8	0.55	0.55
		20.5	7	840	560	140	110	160	120	51	11	8.5	0.72	0.72

Notes:
1. *Specified Strength in bearing (normal to plane of plies) q_p=4.5MPa*
2. *Dry service conditions*
3. *Standard term duration of load*

Table 15. Specified Stiffness and Rigidity Capacities per unit width for CANPLY EXTERIOR EASY T&G Plywood (concluded)

Plywood Type	Plywood Product	Nominal Plywood Thickness (mm)	Number of Plies	Bending Stiffness (b_b =EI) N•mm²/mm		Axial Stiffness in tension or compression (b_a =EA) N/mm		Shear-Through-Thickness Rigidity (b_v) N/mm
				Orientation of Applied Force Relative to Face Grain				
				0°	90°	0°	90°	0° & 90°
DFP	EASY T&G	11.0	3	1 500 000	58 000	110 000	36 000	6 900
		11.0	4	1 400 000	110 000	86 000	47 000	6 500
		12.5	4	1 900 000	220 000	89 000	60 000	7 200
		15.5	5	3 000 000	630 000	95 000	47 000	8 400
		18.5	5	6 000 000	1 300 000	140 000	73 000	10 000
		18.5	6	5 300 000	1 500 000	110 000	59 000	9 800
		18.5	7	4 900 000	1 300 000	120 000	71 000	9 800
		20.5	5	6 300 000	2 600 000	130 000	89 000	11 000
		20.5	6	6 800 000	2 400 000	110 000	89 000	11 000
		20.5	7	6 200 000	2 000 000	120 000	71 000	11 000
CSP or Aspen	EASY T&G	11.0	3	1 000 000	58 000	71 000	36 000	5 000
		12.5	4	1 300 000	220 000	60 000	60 000	5 700
		15.5	5	2 000 000	630 000	72 000	47 000	7 100
		18.5	5	4 100 000	1 300 000	110 000	73 000	8 600
		18.5	6	3 600 000	1 500 000	84 000	59 000	8 600
		18.5	7	3 400 000	1 300 000	95 000	71 000	8 600
		20.5	5	4 300 000	2 600 000	100 000	89 000	9 500
		20.5	6	4 600 000	2 400 000	83 000	89 000	9 500
		20.5	7	4 300 000	2 000 000	95 000	71 000	9 500

Note: 1. Dry service conditions

Table 16. Load Duration Factor (K_D)

Duration of loading	K_D	Explanatory Notes
Short Term	1.15	Short term loading means that condition of loading where the duration of the specified loads is not expected to last more than seven days continuously or cumulatively throughout the life of the structure. Examples include wind loads, earthquake loads, falsework and formwork as well as impact loads.
Standard Term	1.00	Standard term means that condition of loading where the duration of specified loads exceeds that of short term loading, but it is less than permanent permanent loading. Examples include snow loads, live loads due to occupancy, wheel loads on bridges and dead loads in combination with all of the above.
Permanent	0.65	Permanent duration means that condition of loading under which a member is subject to more or less continuous specified load. Examples include dead loads plus live loads of such character that they are imposed on the members for as long a period of time as the dead loads themselves. Such loads include those usually occurring in tanks or bins containing fluids or granular material, loads on retaining walls subject to lateral pressure such as earth, floor loads where the specified load may be expected to be continuously applied such as those in buildings for storage of bulk materials. Loads due to fixed machinery should be considered permanent.

Notes:

1. *Duration of load may require professional judgement by the designer. Explanatory notes in this table provide guidance to designers about the types of loads and load combinations for which each modification factor should be applied to tabulated specified strengths, in accordance with CSA O86 Engineering Design in Wood.*

2. *For standard term loads where* **D** *is greater than* **L**, *the permanent load factor may be used, or the factor may be calculated as:*

$$K_D = 1.0 - 0.50 \log\left(\frac{D}{L}\right) \geq 0.65$$

where **L** *= specified live load*
D *= specified dead load*

3. *When the total specified load is made up of loads acting for different durations, the design shall be based on the most severe combination. The appropriate load duration factor shall be taken into account for each load combination.*

Table 17. Service Condition Factor (K_S)

Property to be Modified	Service Condition	
	Dry	Wet
Specified Strength	1.0	0.80
Specified Stiffness and Rigidity	1.0	0.85

Table 19. Stress Joint Factor (X_J) for Scarf Joints

Slope of Scarf	Tension	Compression	Shear
1:12	0.85	1.0	1.0
1:10	0.80	1.0	1.0
1:8	0.75	1.0	1.0
1:5	0.60	1.0	Not allowable

Table 18. Stress Joint Factor (X_J) for Butt Joints

Unsanded Plywood Thickness (mm)	Minimum Length of Splice Plate Perpendicular to Joint (mm)	Tension Splice Plate		Compression and Shear
		One Side	Both Sides	
7.5	200	0.67	0.85	1.0
9.5	300	0.67	0.85	1.0
12.5	350	0.67	0.85	1.0
15.5 to 20.5	400	0.50	0.85	1.0

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