Structural glued-laminated timber
Legal Notice for Standards

Canadian Standards Association (operating as “CSA Group”) develops standards through a consensus standards development process approved by the Standards Council of Canada. This process brings together volunteers representing varied viewpoints and interests to achieve consensus and develop a standard. Although CSA Group administers the process and establishes rules to promote fairness in achieving consensus, it does not independently test, evaluate, or verify the content of standards.

Disclaimer and exclusion of liability
This document is provided without any representations, warranties, or conditions of any kind, express or implied, including, without limitation, implied warranties or conditions concerning this document’s fitness for a particular purpose or use, its merchantability, or its non-infringement of any third party’s intellectual property rights. CSA Group does not warrant the accuracy, completeness, or currency of any of the information published in this document. CSA Group makes no representations or warranties regarding this document’s compliance with any applicable statute, rule, or regulation.

IN NO EVENT SHALL CSA GROUP, ITS VOLUNTEERS, MEMBERS, SUBSIDIARIES, OR AFFILIATED COMPANIES, OR THEIR EMPLOYEES, DIRECTORS, OR OFFICERS, BE LIABLE FOR ANY DIRECT, INDIRECT, OR INCIDENTAL DAMAGES, INJURY, LOSS, COSTS, OR EXPENSES, HOWEVER CAUSED, INCLUDING BUT NOT LIMITED TO SPECIAL OR CONSEQUENTIAL DAMAGES, LOST REVENUE, BUSINESS INTERRUPTION, LOST OR DAMAGED DATA, OR ANY OTHER COMMERCIAL OR ECONOMIC LOSS, WHETHER BASED IN CONTRACT, TORT (INCLUDING NEGLIGENCE), OR ANY OTHER THEORY OF LIABILITY, ARISING OUT OF OR RESULTING FROM ACCESS TO OR POSSESSION OR USE OF THIS DOCUMENT, EVEN IF CSA GROUP HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES, INJURY, LOSS, COSTS, OR EXPENSES.

In publishing and making this document available, CSA Group is not undertaking to render professional or other services for or on behalf of any person or entity or to perform any duty owed by any person or entity to another person or entity. The information in this document is directed to those who have the appropriate degree of experience to use and apply its contents, and CSA Group accepts no responsibility whatsoever arising in any way from any and all use of or reliance on the information contained in this document.

CSA Group is a private not-for-profit company that publishes voluntary standards and related documents. CSA Group has no power, nor does it undertake, to enforce compliance with the contents of the standards or other documents it publishes.

Intellectual property rights and ownership
As between CSA Group and the users of this document (whether it be in printed or electronic form), CSA Group is the owner, or the authorized licensee, of all works contained herein that are protected by copyright, all trade-marks (except as otherwise noted to the contrary), and all inventions and trade secrets that may be contained in this document, whether or not such inventions and trade secrets are protected by patents and applications for patents. Without limitation, the unauthorized use, modification, copying, or disclosure of this document may violate laws that protect CSA Group’s and/or others’ intellectual property and may give rise to a right in CSA Group and/or others to seek legal redress for such use, modification, copying, or disclosure. To the extent permitted by licence or by law, CSA Group reserves all intellectual property rights in this document.

Patent rights
Attention is drawn to the possibility that some of the elements of this standard may be the subject of patent rights. CSA Group shall not be held responsible for identifying any or all such patent rights. Users of this standard are expressly advised that determination of the validity of any such patent rights is entirely their own responsibility.

Authorized use of this document
This document is being provided by CSA Group for informational and non-commercial use only. The user of this document is authorized to do only the following:

If this document is in electronic form:
• load this document onto a computer for the sole purpose of reviewing it;
• search and browse this document; and
• print this document if it is in PDF format.

Limited copies of this document in print or paper form may be distributed only to persons who are authorized by CSA Group to have such copies, and only if this Legal Notice appears on each such copy.

In addition, users may not and may not permit others to
• alter this document in any way or remove this Legal Notice from the attached standard;
• sell this document without authorization from CSA Group; or
• make an electronic copy of this document.

If you do not agree with any of the terms and conditions contained in this Legal Notice, you may not load or use this document or make any copies of the contents hereof, and if you do make such copies, you are required to destroy them immediately. Use of this document constitutes your acceptance of the terms and conditions of this Legal Notice.
Standards Update Service

0122-16
January 2016

Title: Structural glued-laminated timber

To register for e-mail notification about any updates to this publication
• go to shop.csa.ca
• click on CSA Update Service

The List ID that you will need to register for updates to this publication is 2424251.

If you require assistance, please e-mail techsupport@csagroup.org or call 416-747-2233.

Visit CSA Group’s policy on privacy at www.csagroup.org/legal to find out how we protect your personal information.
0122-16
Structural glued-laminated timber

"A trade-mark of the Canadian Standards Association, operating as “CSA Group”
Contents

Technical Committee on Solid and Engineered Wood Products  3
Subcommittee on Glued-Laminated Timber  6
Preface  7

0 Introduction  8

1 Scope  8

2 Reference publications  9

3 Definitions  9

4 Classification  14
4.1 General  14
4.2 Member width  14

5 Materials  14
5.1 General requirements for laminating stock  14
5.2 Grading of laminating stock  15
5.2.1 All grades  15
5.2.2 Grades B to D  16
5.2.3 Grades B-F and T-1  16
5.3 Adhesives  17
5.3.1 General  17
5.3.2 Exterior grade glulam including marine, ground contact, and below-ground applications  17
5.3.3 Exterior grade glulam excluding marine, ground contact, and below-ground applications  17

6 Manufacturing  17
6.1 Lumber preparation  17
6.1.1 Moisture content  17
6.1.2 Surfacing  18
6.2 End joints  18
6.2.1 General  18
6.2.2 Production requirements  18
6.2.3 Spacing of end joints  19
6.3 Gluing  19
6.4 Assembly  20
6.5 Application of pressure  20
6.6 Setting  21
6.7 Pressure treatment  21
6.8 Final surfacing  21
6.8.1 General  21
6.8.2 Industrial grade  22
6.8.3 Commercial grade  22
6.8.4 Quality grade  22
6.8.5 Textured finishes (chainsaw, sandblasted, wirebrushed, combed, etc.) 23
6.8.6 Structural patching 23
6.9 Fire-resistance ratings 23
6.10 Orientation marking 23
6.11 Protection 23
6.12 Repairs 23

7 Quality control tests 24
7.1 General 24
7.2 Block shear test 24
7.2.1 General 24
7.2.2 Sample 24
7.2.3 Specimen 24
7.2.4 Test 24
7.2.5 Requirements 24
7.3 Vacuum-pressure cycle test 25
7.3.1 General 25
7.3.2 Face bond 25
7.3.3 End joint bond 26
7.4 End-joint test 26
7.4.1 General 26
7.4.2 Sample 27
7.4.3 Specimen 27
7.4.4 Test 27
7.4.5 Requirements 28
7.5 Modulus of elasticity test of NDT lumber 29
7.5.1 General 29
7.5.2 Sample 29
7.5.3 Specimen 29
7.5.4 Test 29
7.5.5 Requirements 29

Annex A (informative) — Metric/imperial conversions 43
Annex B (Normative) — Development of specified strengths and modulus of elasticity for structural glued laminated timber 45
# Technical Committee on Solid and Engineered Wood Products

<table>
<thead>
<tr>
<th>Name</th>
<th>Organization</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>R. Desjardins</td>
<td>FPInnovations, Québec, Québec</td>
<td>Chair</td>
</tr>
<tr>
<td>Y.H. Chui</td>
<td>University of New Brunswick, Fredericton, New Brunswick</td>
<td>Vice-Chair</td>
</tr>
<tr>
<td>P.M. Audet</td>
<td>Barrette Structural, Trois-Rivières, Québec</td>
<td>Associate</td>
</tr>
<tr>
<td>P. Da Silva</td>
<td>Boise Cascade Co., Dorval, Québec</td>
<td>Associate</td>
</tr>
<tr>
<td>C. Dagenais</td>
<td>FPInnovations, Québec</td>
<td>Associate</td>
</tr>
<tr>
<td>B. Di Lenardo</td>
<td>Canadian Construction Materials Centre, Ottawa, Ontario</td>
<td>Chair</td>
</tr>
<tr>
<td>K. Fargey</td>
<td>Western Archrib, Edmonton, Alberta</td>
<td>Associate</td>
</tr>
<tr>
<td>C.H. Frohlich</td>
<td>Guelph Utility Pole Co. Ltd, Guelph, Ontario</td>
<td>Associate</td>
</tr>
<tr>
<td>A.S. Garden</td>
<td>Canfor Wood Products Marketing Ltd., Vancouver, British Columbia</td>
<td>Associate</td>
</tr>
<tr>
<td>H. Griffin</td>
<td>Canadian Wood Council, Ottawa, Ontario</td>
<td>Associate</td>
</tr>
<tr>
<td>M. Humphries</td>
<td>Mott MacDonald Canada Ltd, Toronto, Ontario</td>
<td>Associate</td>
</tr>
</tbody>
</table>
K. Koo
FPIInnovations, Richmond Hill, Ontario
Associate

F. Lam
University of British Columbia, Vancouver, British Columbia
Category: Regulatory Authority/General Interest

D. Lavoie
Boise Cascade Co., Dorval, Québec
Category: Producer Interest

T.V. Leung
Thomas Leung Structural Engineering, Vancouver, British Columbia
Category: User Interest

C. Lum
FPIInnovations, Vancouver, British Columbia
Associate

D. Moses
Moses Structural Engineers Inc., Toronto, Ontario
Category: User Interest

N.J. Nagy
FeNICKS Enterprises, North Vancouver, British Columbia
Associate

M.S. Reid
Read Jones Christoffersen Ltd, Toronto, Ontario
Category: User Interest

A.K. Rozek
National Lumber Grades Authority (NLGA), Surrey, British Columbia
Category: Regulatory Authority/General Interest

A. Salenikovich
Université Laval, Québec, Québec
Category: Regulatory Authority/General Interest

G.C. Williams
Timber Systems Limited, Markham, Ontario
Category: User Interest

B. Yeh
APA The Engineered Wood Association, Tacoma, Washington, USA
Category: Producer Interest
L. Jula Zadeh
CSA Group,
Toronto, Ontario

Project Manager
Subcommittee on Glued-Laminated Timber

K. Fargey
Western Archrib,
Edmonton, Alberta

Chair

C. Dagenais
FPInnovations,
Québec, Québec

W. Downing
Structurlam Products Ltd.,
Penticton, British Columbia

J. Estok
DWB Consultants,
St-Sauveur, Québec

H. Griffin
Canadian Wood Council,
Ottawa, Ontario

P.M. Henry
C.Y. Loh Associates Ltd.,
Vancouver, British Columbia

R.B. Kullman
Robb Kullman Engineering LLP,
Saskatoon, Saskatchewan

F. Lam
University of British Columbia,
Vancouver, British Columbia

T.V. Leung
Thomas Leung Structural Engineering,
Vancouver, British Columbia

C.C. Williams
Timber Systems Limited,
Markham, Ontario

B. Yeh
APA The Engineered Wood Association,
Tacoma, Washington, USA

L. Jula Zadeh
CSA Group,
Toronto, Ontario

Project Manager
Preface


This Standard contains stress grades for Douglas Fir-Larch, Western Hemlock, Hem-Fir/Douglas Fir-Larch, Lodgepole Pine, Jack Pine, and Spruce. This Standard is intended to be used in conjunction with CSA O177, *Qualification code for manufacturers of structural glued-laminated timber*.

Changes to this edition include the following:

a) the grade combination for 16c-E Douglas fir/Larch glulam has been changed;
b) allowances have been made for the manufacturing glulam products that will have a 1 h and 2 h fire rating;
c) procedures to allow the use of edge-glued lamina in glulam have been approved;
d) requirements have been added to the Standard for vacuum pressure cycle testing of end joints;
e) the sampling requirements have been increased for the vacuum pressure cycle testing of face bonds and reduced for the block shear testing of face bonds;
f) a new grade combination for Douglas fir/Larch 24f-E and 24f-EX glulam, which was included in the 2009 revision of CSA O122, is part of this Standard; and
g) normative Annex B has been added, for the development of specified strengths and modulus of elasticity for glulam.

This Standard was prepared by the Subcommittee on Structural Glued-Laminated Timber, under the jurisdiction of the Technical Committee on Solid and Engineered Wood Products and the Strategic Steering Committee on Construction and Civil Infrastructure, and has been formally approved by the Technical Committee.

Notes:

1) *Use of the singular does not exclude the plural (and vice versa) when the sense allows.*

2) *Although the intended primary application of this Standard is stated in its Scope, it is important to note that it remains the responsibility of the users of the Standard to judge its suitability for their particular purpose.*

3) *This Standard was developed by consensus, which is defined by CSA Policy governing standardization — Code of good practice for standardization as “substantial agreement. Consensus implies much more than a simple majority, but not necessarily unanimity”. It is consistent with this definition that a member may be included in the Technical Committee list and yet not be in full agreement with all clauses of this Standard.*

4) *To submit a request for interpretation of this Standard, please send the following information to inquiries@csagroup.org and include “Request for interpretation” in the subject line:*

   a) define the problem, making reference to the specific clause, and, where appropriate, include an illustrative sketch;
   b) provide an explanation of circumstances surrounding the actual field condition; and
   c) where possible, phrase the request in such a way that a specific “yes” or “no” answer will address the issue.

   *Committee interpretations are processed in accordance with the CSA Directives and guidelines governing standardization and are available on the Current Standards Activities page at standardsactivities.csa.ca.*

5) *This Standard is subject to review five years from the date of publication. Suggestions for its improvement will be referred to the appropriate committee. To submit a proposal for change, please send the following information to inquiries@csagroup.org and include “Proposal for change” in the subject line:*

   a) Standard designation (number);
   b) relevant clause, table, and/or figure number;
   c) wording of the proposed change; and
   d) rationale for the change.
0122-16

Structural glued-laminated timber

0 Introduction

Structural glued-laminated timber is an engineered wood product requiring precise manufacturing at all stages of fabrication. The finished product cannot be readily tested except under laboratory conditions; therefore, quality control of manufacturing, as specified in this Standard, is necessary to ensure that glued-laminated timber (glulam) is in accordance with the properties specified in CSA O86.

CSA O177 provides a standard for determining the initial and continuing suitability of a plant’s personnel, equipment, and procedures to manufacture glulam in accordance with this Standard.

1 Scope

1.1 This Standard provides minimum requirements for the manufacture of glulam of those species specified in CSA O86. Storage, handling, and installation of products subsequent to manufacture are not covered by this Standard.

1.2 The design criteria for glulam manufactured in accordance with this Standard are covered in CSA O86. Requirements for the development of specified strengths and modulus of elasticity for glulam are provided in Annex B.

1.3 In this Standard, “shall” is used to express a requirement, i.e., a provision that the user is obliged to satisfy in order to comply with the standard; “should” is used to express a recommendation or that which is advised but not required; and “may” is used to express an option or that which is permissible within the limits of the Standard.

Notes accompanying clauses do not include requirements or alternative requirements; the purpose of a note accompanying a clause is to separate from the text explanatory or informative material.

Notes to tables and figures are considered part of the table or figure and may be written as requirements.

Annexes are designated normative (mandatory) or informative (non-mandatory) to define their application.

1.4 The values given in SI units are the units of record for the purposes of this Standard. The values given in parentheses are for information and comparison only.

Note: For conversion into yard/pound (imperial) equivalents, see Annex A.
2 Reference publications
This Standard refers to the following publications, and where such reference is made, it shall be to the edition listed below, including all amendments published thereto.

CSA Group
O80-15
Wood preservation

O86-14
Engineering design in wood

O112 Series-M1977 (withdrawn)
CSA Standards for wood adhesives

O112.7-M1977 (withdrawn)
Resorcinol and phenol-resorcinol resin adhesives for wood (room- and intermediate-temperature curing)

O112.9-10 (R2014)
Evaluation of adhesives for structural wood products (exterior exposure)

O177-06 (R2015)
Qualification code for manufacturers of structural glued-laminated timber

AWPA (American Wood-Preservers’ Association)
M4-11
Standard for the Care of Preservative-Treated Wood Products

NLGA (National Lumber Grades Authority)
Standard Grading Rules for Canadian Lumber, 2014

3 Definitions
The following definitions shall apply in this Standard:

Adhesive — a substance capable of holding material together by surface attachment.
Note: Synonymous with Glue.

Annual ring — the ring seen on the transverse section of a piece of wood, composed of earlywood and latewood and denoting 1 year of growth.

Appearance grade — a grade based on the appearance of the finished glued-laminated timber member.
Note: Except as noted in Clause 6.8.5, appearance grade has no influence on strength.

Assembly — pieces of wood that have been bonded together or placed together for bonding with adhesive.
Assembly time — the time interval between the spreading of the adhesive on the adherend and the application of heat or pressure, or both, to the assembly.

Note: For assemblies involving multiple layers or parts, the assembly time begins with the spreading of the adhesive on the first adherend.

Closed assembly time — the time between completion of assembly of the laminations for bonding before the application of pressure or heat, or both, to the assembly.

Open assembly time — the time between the spreading of the adhesive on the adherend(s) and the completion of the assembly of the parts for bonding before the application of pressure or heat, or both, to the assembly.

Automatic glue mixing equipment — equipment that mixes the components of the adhesive (i.e., hardener and resin) in the proper proportions and supplies the mixed adhesive to the spreading equipment just prior to application.

Billet — a block of glued-laminated timber.

Bond — the attachment at an interface between adhesive and laminations or the act of attaching laminations together by adhesive.

Bond line — the thin layer of adhesive between two surfaces.

Bow — the deviation of the wide faces of a piece from a straight line drawn from end-to-end of the piece, measured at the point of greatest distance from the straight line.

Check — a lengthwise separation of the wood that usually extends across the annual rings and results from stresses set up in the wood during seasoning.

Clamping — a method of holding components securely in place. Clamping can also be used as a method of applying pressure.

Clear wood — wood free of strength-reducing characteristics including but not limited to knots, knot holes, slope of grain steeper than defined limits, and torn grain.

Compression failure — the permanent deformation or fracture of wood cells by excessive compression forces parallel to grain. Compression failure can appear as fine wrinkles or minute lines visible on a surface in favourable light.

Compression wood — an abnormal wood usually formed in leaning trees and characterized by an unusually high proportion of apparent latewood in annual rings with a gradual transition from earlywood to latewood. Compression wood has a lifeless appearance, a darker colour when wet, and abnormally high shrinkage parallel to the grain.

Crook — the deviation of the narrow face (edge) of a piece from a straight line drawn from end-to-end of the piece, measured at the point of greatest distance from the straight line.

Cross-section — a section formed by a plane cutting a piece at right angles to both the narrow and wide faces.

Cup — the curve of the wide face across the width of a lamination, measured at the point of greatest distance from a straight line drawn from edge-to-edge of the piece.
Curing — converting an adhesive into a fixed or hardened state by chemical or physical action, usually accomplished by the action of heat or a catalyst, or both, in combination with pressure.

Decay — the deterioration of wood caused by the action of wood-destroying fungi, resulting in softening, loss of strength and weight, and possible change of texture and colour.

Delamination — the separation of layers in a laminate due to failure of the adhesive either in the adhesive itself or at the interface between the adhesive and the adherend.

Douglas Fir-Larch — the species group of Douglas Fir (Pseudotsuga menziesii Mirb. (Franco)) and Western Larch (Larix occidentalis (Nutt.)).

Earlywood — the less dense portion of an annual ring.

Edge — the narrower face of a piece or, when applied to a given face, the intersection of two adjacent faces.

End joint — a joint between the ends of two pieces that make up a lamination or part of a lamination.

Face — one of the four longitudinal surfaces of a piece, further designated as a wide face or narrow face.

Finger joint — an end joint between two pieces whose ends have been formed into a series of mating fingers through either the wide or narrow faces of the pieces.

Glue — a substance capable of holding material together by surface attachment.

Note: Synonymous with Adhesive.

Glued-laminated timber — see Structural glued-laminated timber.

Glulam — see Structural glued-laminated timber.

Grain — the direction, size, arrangement, appearance, or quality of the fibre in wood.

Raised grain — a condition where the harder latewood is raised above the softer earlywood but is not torn loose from the piece.

Slope of grain — the angle between the direction of the grain and the axis of the piece, expressed as a slope and measured over a distance sufficient to ensure that the determination of the slope is not influenced by short local deviations.

Torn grain — a condition where parts of the wood have been torn or broken out from below the dressed surface.

Hem-Fir — a species group of Western Hemlock (Tsuga heterophylla (Raf.) Sarg.) and Amabilis Fir (A. amabilis (Dougl.) Forg.).

Knife marks — the imprints or markings of the machine knives on the surface of the dressed lumber.

Knot — that portion of a branch or limb that has been surrounded by subsequent growth of the trunk or other portion of the tree.

Sound, tight knot — a knot that is free from decay, solid across its face, firmly embedded in the piece, and at least as hard as the surrounding wood.
Spike knot — a knot that has been cut lengthwise to the branch or diagonally across it.

Laminating stock — lumber to be used for laminating.

Lamination — a thin element of wood of appreciable width and length, consisting of one or more pieces that can be joined end to end.

Latewood — the denser portion of an annual ring.

Machine burn — the darkening of wood due to overheating by machine knives or rolls when pieces are stopped in a machine.

Member — a single structural element.

Moisture content — the weight of moisture in wood expressed as a percentage of its oven-dry weight.

Net thickness — the thickness after dressing.

Nominal dimensions — the approximate dimensions of the wood before it is dressed to actual size, used for convenience in defining size and computing quantities.

Nondestructive tested (NDT) lumber — lumber that has been sorted on the basis of an indicating property such as its bending stiffness.

Package — one or more members clamped together for curing.

Piece — a single board or plank, one or more of which may be used in a lamination.

Pine — for the purpose of this Standard, the species of Lodgepole Pine (Pinus Contorta) or Jack Pine (Pinus Banksiana).

Pitch pocket — a well-defined opening between annual rings that contains or has contained solid or liquid pitch.

Pitch streak — a local accumulation of resin in the form of a streak.

Pith — the small soft core in the structural centre of a log.

Pressure treatment — impregnation of the wood under pressure, in accordance with the CSA O80 Series.

Radio frequency curing equipment — equipment that uses radio frequency energy to cure the bond lines.

Sample — one or more units of product taken from a lot or batch or a portion of material taken from a member, in order to represent that lot, batch, or member for inspection purposes.

Scarf — a sloping cut made at the end of a piece for the purpose of joining pieces longitudinally into laminations.

Scarf joint — an end joint between two pieces whose ends have been scarfed.

Setting — the initial stages of curing (of adhesives).

Shake — a separation along the grain, the greater part of which occurs between the annual growth rings.
Skip — an area that has remained rough after a piece has been surfaced.

Softwood — wood from trees belonging to the botanical group Gymnosperms (i.e., conifers).

Specimen — a part, item, or the whole of a sample, taken as representative of a whole or a collection of items.

Split — a separation along the grain forming a crack or fissure that extends through the piece from one surface to another.

Spruce — for the purpose of this Standard, one or more of the following species of Spruce: Black Spruce (Picea Mariana), Englemann Spruce (Picea Englemanii), Red Spruce (Picea Rubens), and White Spruce (Picea Glauca).

Stain — a variation from the natural coloration of wood that is the result of fungi or other causes.

   Firm stain (or hard stain) — a stain that is not accompanied by softening or other disintegration of the wood.

Stress grade — a classification of glulam where combinations of laminating grades are arranged so they are suitable for resisting a particular type and magnitude of stress.

Structural glued-laminated timber — the wood product made by bonding, under pressure, graded laminating stock whose grain is essentially parallel and is in accordance with the requirements of this Standard.

Twist — warping in which one corner of the piece moves out of the plane of the other three. The amount of twist is determined by measuring the normal distance of one corner of the piece from the plane of the other three.

Vertically laminated beam — a beam manufactured such that the loads on the beam are intended to act in a plane parallel to the plane of the laminations.

Wane — the presence of bark or a lack of wood, for whatever cause, at the corner of a square-edged piece.

Warp — any deviation from a true or plane surface, including crook, bow, cup, or any combination of these.

Wood failure (per cent) — the area of wood fibre remaining at the bond line following completion of the specified shear test.

Note: Wood failure is determined by means of visual examination and is expressed to the nearest 5% of the test area.

Worm-holes, occasional small — holes not more than 6 mm in diameter, well scattered, and occurring in not more than 20% of the pieces.

Worm-holes, scattered pin — holes not more than 2 mm in diameter and not occurring in groups.
4 Classification

4.1 General
Glulam is classified according to stress grade (see Tables 4 to 8), service grade (see Clauses 5.3.2 and 5.3.3), and appearance grade (see Table 11), each of which is independent of the others.

4.2 Member width
Finished widths* of glulam are as follows:
a) 80 mm;
b) 105 mm;
c) 130 mm;
d) 175 mm;
e) 215 mm;
f) 225 mm;
g) 265 mm;
h) 275 mm;
i) 315 mm;
j) 365 mm;
k) 415 mm;
l) 465 mm; and
m) 515 mm.
* See Note 2) to Table A.1 for imperial equivalents.

5 Materials

5.1 General requirements for laminating stock

5.1.1 Lumber for all glulam shall be selected and graded in accordance with the requirements of Clause 5.2 and Table 2, except as otherwise permitted by Clause 5.1.3.

5.1.2 Nondestructive tested (NDT) lumber shall be used for glulam. NDT lumber shall meet all visual requirements of this Standard and the stiffness requirements of Tables 4 to 8.
Note: Manufacturers may choose to purchase NDT lumber (instead of testing each individual piece themselves) and should consult their third-party certification agency on manufacturing procedures, which will confirm that the requirements of Clause 7.5 are met.

5.1.3 Lumber for vertically laminated beams shall be joist and plank, structural light framing, or light framing, in accordance with the current NLGA Standard Grading Rules for Canadian Lumber.

5.1.4 Laminations shall be not greater than 50 mm in net thickness.
5.2 Grading of laminating stock

5.2.1 All grades

5.2.1.1
The visual grading of laminating stock shall be based on the worst face of the piece, except as noted in Clause 5.2.3.

5.2.1.2
Grading of laminating stock shall be based on the full length of the piece.

5.2.1.3
Pieces that are abnormally light in weight for the species shall be rejected as unsuitable laminating stock.

5.2.1.4
Pieces that have a moisture content higher than 15% shall be rejected.

5.2.1.5
When lumber to be used for laminating is re-sawn, the new size shall meet the original grade requirements. Laminations 38 mm in thickness that fulfill the requirements of Clauses 5.1 and 7.5 and are re-sawn to 19 mm in thickness, with the re-sawn pieces maintained adjacent to each other in their original orientation, shall be considered to comply with the grade of the original lamination.

5.2.1.6
When a member is to be re-sawn after laminating, each lamination shall be graded in relation to the final size of the member.

5.2.1.7
When two or more pieces are placed side by side to make up a lamination, the permissible knot sizes shall be based on the width of the individual pieces rather than the finished width of the member.

5.2.1.8
Knots shall be measured between lines enclosing the knot and parallel to the edges of the wide faces. If two or more knots are in line, i.e., partially or completely enclosed by the same parallel lines and separated lengthwise by less than 200 mm, the effective width of the knots shall be the distance between the two parallel lines that enclose the knots.

5.2.1.9
When two or more knots appear in the same cross-section of a piece (opposite each other on a face or edge), the sum of their sizes shall not exceed the maximum permitted knot size.

5.2.1.10
The following general grading requirements shall apply to all grades:

a) Compression failure is not permitted.

b) Compression wood — pronounced or severe compression wood is not permitted.

c) Crook — maximum 6 mm per 3.50 m is permitted.
d) Cup — maximum cup is permitted in accordance with Table 2.
e) Decay is not permitted.
f) Knots that project above the surface of wide faces are not permitted.
g) Machine marks — occasional knife marks and machine burns are permitted.
h) Pitch — occasional small pitch streaks not more than 1/12 of the width and 1/6 of the length of the piece are permitted. Pitch streaks occurring at any given cross-section shall not exceed 1/12 of the width of the piece. Pitch pockets approximately 3 mm wide with a length equal to the width of the piece are permitted when dry. A maximum of four pitch pockets are permitted in a 3.0 m length of piece, provided that no more than one pitch pocket occurs at any given cross-section, except for an occasional occurrence.
i) Shakes, checks, and splits — when parallel to the wide face of a lamination, shakes, checks, and splits are permitted if not deeper than 1/8 of the width nor longer than twice the width of the lamination. Through shakes, checks, and splits parallel to the edges are permitted for 1/2 of the length of the piece. Pitchy shakes are not permitted.
j) Skips are not permitted on the wide face of piece, except where a skip will later be removed by scarfing or end-trimming. Edge skips not exceeding 3 mm scant are permitted for the entire length of the piece.
k) Spike knots shall not displace more of the cross-section than would be displaced by the face knots permitted for each width and grade.
l) Stain — firm stain is permitted.
m) Torn grain is permitted except as restricted by Clauses 5.2.3.2 a) and 5.2.3.3 a).
n) Wane is permitted on pieces if its size is sufficiently small to permit its removal by scarfing, final surfacing, or trimming.
o) Warp, twist, or bow — maximum 12 mm per 3.50 m is permitted.
p) Worm holes — scattered pin or occasional small worm holes are permitted.

5.2.2 Grades B to D

In addition to the requirements of Clause 5.2.1, the following shall apply:
a) Knots — sound knots, tight knots, loose knots, or knot holes are permitted anywhere in the length or width of the piece, subject to Clause 6.2.2 f) and the size limitations of Table 3.
b) Slope of grain — general slope of grain anywhere in the length of the piece shall be in accordance with the values of Table 3, except that short local deviations may be disregarded.

5.2.3 Grades B-F and T-1

5.2.3.1 General

In addition to the requirements of Clauses 5.2.1 and 5.2.2, the requirements of Clauses 5.2.3.2 and 5.2.3.3 shall apply for Grades B-F and T-1.

5.2.3.2 Grade B-F

The following shall apply for Grade B-F:
a) Defects exceeding 10 mm, such as knots, knot holes, torn grain, and local deviations of slope of grain steeper than 1:16, shall not be permitted within 13 mm of the edge of the outer tension face lamination after finishing.
b) The outer face shall be free of cut-out inserts, except as permitted in Clauses 6.8.4.5 and 6.8.6.
5.2.3.3 Grade T-1
The following shall apply for Grade T-1:

a) Edge defects, such as knots, knot holes, local deviations of slope of grain steeper than 1:16, and
torn grain, shall not occupy more than 16% of the net cross-section.

b) When two or more knots appear within 200 mm along the length of a piece, the sum of all knot
sizes shall not exceed the maximum permitted knot size.

c) Maximum single strength-reducing characteristics (SRC) when not enclosed within the same lines
parallel to the edges of the wide faces shall be at least 600 mm apart along the length of the piece
measured centre-to-centre.

d) Clear wood:
   i) any cross-section of 200 mm in length that does not have an edge defect shall have at least
      2/3 clear wood free of strength-reducing characteristics and with a slope of grain no steeper
      than 1:16; and
   ii) any cross-section of 200 mm in length that has an edge defect shall have at least 3/4 clear
      wood free of strength-reducing characteristics and with a slope of grain no steeper than 1:16.

e) Pieces containing wide-ringed pith-associated wood at the end of the piece that occupies over 1/8
   of the cross-section shall be excluded. Wide-ringed pith-associated wood (or juvenile wood) shall
   be defined as wood fibre immediately surrounding the small soft core in the structural centre of a
   log with growth characteristics less dense than the average of the piece. This could be due to larger
   growth rings and/or a lower percentage of latewood compared to earlywood in the annual rings.

f) The outer face shall be free of cut-out inserts except as permitted in Clause 6.8.4.5 and as
   prescribed in Clause 6.8.6.

5.3 Adhesives

5.3.1 General
Adhesives for the face bonding and end joining of laminations shall be in accordance with Clause 5.3.2
or 5.3.3.

5.3.2 Exterior grade glulam including marine, ground contact, and below-ground
applications
Adhesives shall be in accordance with CSA O112.7 and shall meet the qualification requirements of
CSA O177.

5.3.3 Exterior grade glulam excluding marine, ground contact, and below-ground
applications
Adhesives shall be in accordance with CSA O112.9 and shall meet the qualification requirements of
CSA O177.

6 Manufacturing

6.1 Lumber preparation

6.1.1 Moisture content

6.1.1.1
Moisture content shall be measured at a depth of 1/4 to 1/5 of the thickness of the piece.
6.1.1.2
Laminating stock shall be seasoned to between 7% and 15% moisture content before final surfacing.

6.1.1.3
The moisture content range of pieces joined in a single lamination or of laminations assembled in a single member shall not exceed 5%.

6.1.1.4
The moisture content of the laminating stock at the time of gluing shall be between 7% and 15% for normal applications. Where glulam is distinctly specified for use under service conditions of low relative humidity, the maximum moisture content shall be 12%.

6.1.2 Surfacing

6.1.2.1
Surfaces of laminating lumber to be bonded shall be machine-finished to a uniformly smooth surface, but shall not be sanded.

6.1.2.2
The tolerance in thickness within a piece or within a lamination composed of two or more pieces shall be ± 0.40 mm.

6.1.2.3
If raised grain occurs on wide faces of pieces after final dressing, the lumber shall be resurfaced before gluing.

6.2 End joints

6.2.1 General
End joints shall be machine-cut and pressure-glued such that the end splice produced in an assembled member using production equipment shall meet the strength requirements of Clause 7.4.5. The configuration of the joint may be of any shape that meets the requirements of Clause 7.4.5.

6.2.2 Production requirements
To ensure consistency of results, the following requirements shall be met unless it can be shown by test that they do not apply to the process qualified under this Standard:

a) End joints shall be accurately machined, but not sanded, so that they are clean-cut without tearing, loosening, or crushing of fibres. Accuracy of machining shall be such that mating surfaces of end joints assembled under light pressure without adhesive do not permit the insertion of a feeler gauge 0.13 mm thick at any point in the joint.

b) Scarf joint longitudinal profile shall be checked by comparison with a standard steel profile gauge and shall not deviate from the specified pattern by more than 0.13 mm.

c) Scarf joints shall be restrained from sliding during clamping so that adequate pressure is maintained on all glued surfaces, and in no case shall a scarf slope be steeper than 1:8. A missing portion of a scarf tip shall not exceed the permissible knot size for the piece.

d) Assembled scarf joints shall be 0.13 to 0.51 mm greater in thickness than the thicker of the pieces that are end joined by the scarfing process.
e) Where finger joints are used, care shall be taken in the manufacturing process to prevent mismating or misalignment of the joints at the time of gluing. Sufficient side or face pressure shall be applied to align correctly the surfaces of the mating boards. The misalignment of finger joints cut perpendicular to the wide face shall not exceed 0.80 mm when measured between the planes of the wide faces of the mating pieces. The end pressure that is applied to the joint at the time of gluing shall be uniform and adequate for the type of joint and gluing process involved.

f) Finger joints shall be made of clear, sound portions of a piece that is free of pitch. A knot shall be separated from the root of a finger joint by a distance of at least three times its diameter. The width of missing or damaged fingers shall not exceed 1/3 of the permissible knot size for the piece for Grades C and D. Missing or damaged fingers are not permitted in the finished width of pieces of Grades B and B-F.

g) For Grades B, B-F, and T-1 end joints, both finger and scarf joints shall be made of portions of a piece free of local grain deviation.

6.2.3 Spacing of end joints

6.2.3.1
Except as provided for in Clauses 6.2.3.2 to 6.2.3.4, there is no restriction on the location of end joints.

6.2.3.2
For bending members, end joints located within the outer 1/8 of the total depth on the tension side(s) shall be spaced not less than 1.80 m apart in the same lamination, except as permitted by Clause 6.2.3.4. Joint spacing shall be measured from the centreline of the end-joint length.

6.2.3.3
For tension members, end joints shall be spaced not less than 1.80 m apart in the same lamination, except as permitted by Clause 6.2.3.4. Joint spacing shall be measured from the centreline of the end-joint length.

6.2.3.4
In bending or tension members where finger joints are spaced closer than 1.80 m in the same lamination, finger joints shall occur randomly within a finger joint run of single lumber size and species group. The total number of pieces of laminating stock less than 1.80 m in length shall not constitute more than 10% of the total number of pieces of laminating stock.

6.3 Gluing

6.3.1
Surfaces of laminations to be spread with adhesive shall be clean and free of oil, dust, and any other foreign matter that can be detrimental to gluing. When laminating lumber is treated with water-borne preservatives or fire retardants, laminations shall be re-dried and resurfaced before gluing.

6.3.2
The following shall be in accordance with the adhesive manufacturer’s recommendations:
   a) the application of adhesive, including mix proportions and quantity of spread;
   b) the temperature of the room, laminations, and adhesive;
   c) open and closed assembly times;
   d) the suitability of the adhesive mix for the species of wood being used;
e) gluing pressure; and
f) curing time.

6.4 Assembly

6.4.1
The assembly of laminating lumber into members shall be in accordance with the applicable
requirements of Tables 4 to 8 and Clause 6.4.2 for combinations of grades for the stress grade required.

6.4.2
In the haunches of arches and the peaks of pitched or tapered beams, Grade B laminations of the
number specified in Table 9 shall be placed adjacent to the material specified for the outer zone in
Table 6 on the convex side between the tangent points. The balance of the material in the built-up
section of the haunches or peaks shall be Grade C or better.

6.4.3
During manufacturing, laminations shall not be bent to a radius less than that given in Table 10.
Note: See Table A.2 for imperial equivalents.

6.4.4
When two or more pieces are required to make up the full width of a lamination, all longitudinal joints
in adjacent laminations shall be staggered at least 34 mm laterally and shall not have voids between
lamination edges that exceed 6 mm, except that in members greater than 225 mm, voids shall not
exceed 10 mm. Laminating stock may also be edge glued.

6.4.5
Where water can collect on the top face of a member in use, the top lamination shall be full width or, if
two or more pieces are used, the longitudinal joints, knot holes, and splits shall be caulked with non-
shrinking, waterproof filling material.

6.5 Application of pressure

6.5.1
The gluing pressure shall be in accordance with the adhesive manufacturer’s written recommendations,
but shall not be less than 0.70 MPa.

6.5.2
Pressure shall be applied uniformly over the entire area to be bonded, in accordance with the criteria in
Clause 6.5.1.

6.5.3
Application of pressure may start at any point but shall progress to an end or ends. The arrangement of
the pressure mechanism shall be such that misalignment of the laminations during or after application
of pressure is minimized.

6.5.4
Nailing shall not be used as a means of applying pressure.
6.5.5
The time taken to spread adhesive, apply pressure, and place the package in position for curing shall not exceed the limits of open and closed assembly times stated in the adhesive manufacturer’s written recommendations for the adhesive used.

6.6 Setting

6.6.1
When glued lumber under pressure has been placed in position for curing, the package shall remain under the required pressure and shall remain undisturbed until the bond has gained sufficient strength to permit handling and machining.

6.6.2
Curing time, temperature and relative humidity in the curing space, temperature of the bond line, and other pertinent controls shall be in accordance with the adhesive manufacturer’s written recommendations for the adhesive used.

6.7 Pressure treatment

6.7.1
The adhesive shall be compatible with the treating material whether treated laminating lumber is glued, or glulam is treated.

6.7.2
All boring, grooving, or other fabrication shall be completed before treatment wherever practicable, and any fabrication carried out after treatment that exposes untreated wood shall be locally treated in accordance with AWPA M4.

6.8 Final surfacing

6.8.1 General
Final surfacing shall be to the following tolerances at the time of manufacture:

a) width ± 2.0 mm;
b) depth ± 0.4 mm multiplied by the number of laminations, to a maximum tolerance of ± 6.0 mm;
c) camber or straightness: for members less than or equal to 6000 mm in length, the tolerance is ± 6 mm. For members over 6000 mm in length increase the tolerance by 3 mm for each additional 6000 mm of length or fraction thereof, to a maximum tolerance of 19 mm;

Notes:
1) The tolerances for camber or straightness do not allow for dead load.
2) The tolerances for camber and straightness are intended for use with straight or slightly cambered members, and do not apply to curved members such as arches.

d) squareness of cross-section at bearing points not more than 1:200 out of square;
e) exposed surfaces of members shall be finished in accordance with the requirements of Table 11;
f) replacement of surface defects of members shall be in accordance with the requirements of one of the appearance grades described in Clauses 6.8.2 to 6.8.4, using bonded inserts not more than 10 mm thick; and
g) end-joint tips in Grade B-F laminations shall be surfaced to zero tip thickness.
6.8.2 Industrial grade

6.8.2.1
Members may contain natural growth characteristics allowed in specific grades of laminating stock, as specified in Clause 5.2.1.10.

6.8.2.2
Sides shall be surfaced true to specified dimensions. Occasional planing misses may occur along individual laminations.

6.8.2.3
Wood inserts and filling shall not be required.

6.8.3 Commercial grade

6.8.3.1
Members may contain natural growth characteristics allowed in specified grades of laminating stock, as specified in Clause 5.2.1.10.

6.8.3.2
Sides shall be surfaced true to specified dimensions, free from squeezed-out adhesive, and sanded smooth. Planing misses along laminations shall be patched with replacement stock.

6.8.3.3
Loose knots, knot holes, and voids over 19 mm in diameter and on exposed surfaces shall be replaced by wood inserts or non-shrinking, waterproof filling material.

6.8.4 Quality grade

6.8.4.1
Members may contain natural growth characteristics allowed in specified grades of laminating stock, as specified in Clause 5.2.1.10.

6.8.4.2
Sides shall be surfaced true to specified dimensions, free from squeezed-out adhesive, and sanded smooth.

6.8.4.3
Tight knots and stains may appear on the finished surface.

6.8.4.4
Wane, pitch pockets, loose knots, knot holes, and voids on exposed surfaces shall be replaced by wood inserts or non-shrinking, waterproof filling material.

6.8.4.5
No wood shall be removed from Grade B-F laminations for the purpose of inserting replacement stock, except as permitted by Clause 6.8.6.
6.8.5 Textured finishes (chainsaw, sandblasted, wirebrushed, combed, etc.)
Where specified by the designer, a textured finish may be used. Textured finishes may change the finished widths and tolerances specified in this Standard. The designer shall compensate for any loss of cross-section and/or specified strength.

6.8.6 Structural patching
Previously undetected edge defects in Grade B-F laminations may be repaired by the insertion of structural patches meeting the following requirements:
   a) the structural patch material shall be clear, straight grained, and of any species from the species group, with approximately the same density and rate of growth;
   b) the structural patch shall be shaped as shown in Figure 1, with grain parallel to the axis of the member and with a scarf slope not steeper than 1:12;
   c) the manufacture of the patch, the dapped lamination, and the adhesive bond shall meet the requirements of Clause 5.3; and
   d) after removal of pressure clamps, the patch shall be planed down to provide feathered tips.

6.9 Fire-resistance ratings
Members manufactured to provide a one-hour fire rating shall be manufactured to the specified layup except that a core lamination shall be removed, the tension zone moved inward, and the equivalent of one additional 38 mm thickness outer tension lamination added. These members are permitted to be marked with a 1 h fire rating designation. Members manufactured to provide a two-hour fire rating shall be manufactured to the specified layup except that two core laminations shall be removed, the tension zone moved inward, and the equivalent of two additional 38-mm thickness outer tension laminations added. These members are permitted to be marked with a 2 h fire rating designation.

6.10 Orientation marking
The tops of beams shall be clearly identified to ensure correct orientation in the structure.

6.11 Protection
Members shall be protected from weather and mechanical injury while in the care of the manufacturer.

6.12 Repairs

6.12.1
Flaws in laminated members that are detected in the laminating plant may be repaired in the plant if, in the opinion of the plant structural engineer, such repair will render the member equivalent in strength to a member without such flaws. Repair methods shall be fully documented in plant manufacturing guidelines and supported by data from tests of shear strength and vacuum-pressure cycling for exterior grade. These tests shall be performed in accordance with Clauses 7.2 and 7.3.

6.12.2
Records shall be kept that identify the member, location, and type of flaw, as well as the date and method of repairs performed.
7 Quality control tests

7.1 General
Routine testing shall be performed to confirm that the quality of the manufactured product remains consistent. These tests shall be completed and the results approved by the manufacturer’s quality control organization prior to shipment of the material. Manufacturers shall maintain records of all routine tests.

7.2 Block shear test

7.2.1 General
At least six specimens shall be tested from a minimum of three packages produced per shift.

7.2.2 Sample
Specimens shall be selected to include outer, inner, and intermediate bond lines of a package. The sample is to include each adhesive and species combination produced on the shift. For packages in which the laminations are held on edge (i.e., vertically oriented bond lines), specimens shall be selected from the upper portion of the bond line.

7.2.3 Specimen
Specimens of Type A or B of Figure 2 or Type C of Figure 3 shall be cut from material allowed for at one or both ends of the member. Only specimens free from defects that will affect the gluing surfaces (such as knots or checks) shall be tested. The specimens shall be cut so that the grain direction is parallel to the direction of loading during the test. Care shall be taken in preparing the test specimens to ensure that the loaded surfaces are smooth, parallel to each other, and perpendicular to height. When sawing the bonded assembly into separate test specimens, care shall also be exercised when reducing the lengths of the laminations to 45 mm to ensure that the saw cuts extend to, but not beyond, the adhesive line.

Note: The objective is to prepare and test the specimen such that the force is applied parallel to bonded surfaces.

7.2.4 Test
The testing machine shall be capable of measuring the ultimate loads to within ± 5%. The specimens shall be placed in the shearing tool, so that the bond line lies along the shearing plane, and tested to failure at a rate not greater than 5 mm/min. Shear strength is calculated in megapascals (MPa) from the recorded ultimate load and the measured shear area, and the percentage wood failure is determined on the measured shear area. Wood failure shall be read by trained personnel and rounded to the nearest 5% of the test area.

Note: Trained personnel should be able to read single blocks from a standard set provided by a certification agency to within ± 15% and should be within ± 5% of the average for the set.

7.2.5 Requirements
The average shear strength of the specimens from each package tested shall exceed 3.5 times the specified strength in longitudinal shear for glulam of the species group tested for standard-term duration of load and dry service conditions as tabulated in CSA O86. The minimum shear strength shall exceed 1.75 times the specified strength in longitudinal shear. A maximum of one specimen per package may be excluded if, as a result of a grade defect not previously noted, that specimen’s shear strength is below the minimum strength requirement. The average wood failure of the specimens from each package shall be 80% or greater. A minimum of 95% of the specimens taken from any 20 consecutive
packages shall have 60% or greater wood failure. If a specimen value is less than 50% wood failure, a second specimen from the same bond line shall be tested. This second specimen shall have 80% or greater wood failure.

7.3 Vacuum-pressure cycle test

7.3.1 General
Manufacturers shall perform the vacuum-pressure cycle test at least once per production shift for end joints, and at least three times per shift for the face bond. Manufacturers shall perform qualification tests in accordance with CSA O177 for every change in adhesive.

7.3.2 Face bond

7.3.2.1 Sample
The test specimen(s) shall be taken from a minimum of three separate production members selected at random, except that the member shall be at least 150 mm in depth and at least one specimen shall be taken from each species/adhesive combination produced on a production shift.

7.3.2.2 Specimen
The test specimen(s) shall be 70 to 80 mm in length. Large cross-sections may be cut into smaller sections provided that the dimension of the specimen normal to the bond lines is not reduced to less than 150 mm and that the dimension at right angles is not reduced to less than 80 mm (see Figure 4). When cutting the specimen(s), the saw cuts, which shall be parallel to the bond lines, shall be midway between two bond lines in order to retain the original bond lines for testing. The end-grain surfaces of the test specimen(s) shall be cut smooth to facilitate inspection of the bond lines.

7.3.2.3 Test
The weight of each test specimen prior to conditioning shall be recorded to the nearest gram. The test specimen(s) shall be placed in an autoclave or pressure vessel, weighted down, and covered in water at a temperature of 18 to 27 °C. All test specimen(s) shall be separated such that all end-grain surfaces are exposed to the water. A vacuum of between 70 and 85 kPa shall be drawn and held for 30 min. The vacuum shall then be released and a pressure of 480 to 550 kPa shall be applied for 2 h. The test specimen(s) shall then be removed from the pressure vessel and placed in a drying oven. The test specimen(s) shall be dried in air at 65 to 75 °C. During the drying period, the test specimen(s) shall be placed approximately 50 mm apart and oriented with their end-grain surfaces parallel to the flow of air. The airflow rate and relative humidity shall be such that the specimen(s) are dried to within 12 to 15% of their original test weight within a period of 10 to 15 h. When the test specimen(s) have returned to within 12 to 15% of their original test weight, delamination shall be measured and recorded.

Note: Delamination should be measured immediately after removal of the specimens from the oven. If measurement is delayed, areas of poor bond can close up because the block core dries out to a state of equilibrium with the outer block surface, or the surface can pick up moisture.

7.3.2.4 Requirements
The total extent of delamination for a single bond line on the end-grain surfaces of the specimen shall not exceed 10% of the total length of that bond line. Delamination is measured along the glue lines and shall exclude knots, grade defects, and areas of wood failure away from the bond line.

Note: Once the test cycle is completed, the specimen may be chiselled apart at the bond line to further evaluate the quality of the glue bond.
7.3.3 End joint bond

7.3.3.1 Sample
The test specimen shall be taken from a production member selected at random, except that each species/adhesive combination produced on a production shift shall be included.

7.3.3.2 Specimen
End joints shall be cut to expose the entire end joint in section.

7.3.3.3 Test
The weight of each test specimen prior to conditioning shall be recorded to the nearest gram. The test specimen(s) shall be placed in an autoclave or pressure vessel, weighted down, and covered in water at a temperature of 18 to 27 °C. All test specimen(s) shall be separated such that all end-grain surfaces are exposed to the water. A vacuum of between 70 and 85 kPa shall be drawn and held for 30 min. The vacuum shall then be released and a pressure of 480 to 550 kPa shall be applied for 2 h. The test specimen(s) shall then be removed from the pressure vessel and placed in a drying oven. The test specimen(s) shall be dried in air at 65 to 75 °C. During the drying period, the test specimen(s) shall be placed approximately 50 mm apart and oriented with their end-grain surfaces parallel to the flow of air. The airflow rate and relative humidity shall be such that the specimen(s) are dried to within 12 to 15% of their original test weight within a period of 10 to 15 h. When the test specimen(s) have returned to within 12 to 15% of their original test weight, delamination shall be measured and recorded.

Note: Delamination should be measured immediately after removal of the specimens from the oven. If measurement is delayed, areas of poor bond can close up because the block core dries out to a state of equilibrium with the outer block surface, or the surface can pick up moisture.

7.3.3.4 Requirements
Delamination after one complete cycle shall not exceed 5% of the total bond line length. If delamination exceeds these values after one cycle, a second cycle shall be performed on the same specimens in which case the delamination shall not exceed 10%.

7.4 End-joint test

7.4.1 General
End joints shall be tested using either bending or tension tests.

Parametric or nonparametric statistical approaches may be used to determine the lower 5% tolerance limit. If parametric statistical approaches are used, evidence shall be provided to demonstrate that the parametric assumption is appropriate.

If laminating stock are edge-glued prior to end-jointing to make up the full width of a lamination (Clause 6.4.4), end joint of each piece across the width of the resulting edge-glued lamella is required to be individually tested. Specimen final width after rip-cutting the lamella along the edge-joint and edge surfacing shall follow Clause 7.4.3.
7.4.2 Sample

7.4.2.1 Scarf joints
For scarf joints, one joint shall be selected for each 1200 m of laminating stock, but no less than two joints shall be selected per work shift. The joint shall be made from Grade C or better laminations and manufactured as an addition to a package, with adequate pressure applied to the joint.

7.4.2.2 Finger joints
For finger joints, two joints shall be selected from Grade C or better laminations at the start of a production shift, and one joint shall be selected at the start of production after any change in lamination cross-section or species group. In addition, one joint shall be selected for every 200 joints produced, until the completion of the run. Edge glued lamination finger joint count is based on the full lamination width joint.

7.4.3 Specimen
Specimens may be edge surfaced to the following finished widths prior to testing:

<table>
<thead>
<tr>
<th>Lumber width, mm</th>
<th>Finished dimension, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>89</td>
<td>80</td>
</tr>
<tr>
<td>114</td>
<td>105</td>
</tr>
<tr>
<td>140</td>
<td>130</td>
</tr>
<tr>
<td>184</td>
<td>175</td>
</tr>
<tr>
<td>235</td>
<td>225</td>
</tr>
<tr>
<td>286</td>
<td>275</td>
</tr>
</tbody>
</table>

Specimens shall be prepared for the bending test as shown in Figure 5 or for the tension test as shown in Figure 6.

End-joint specimens used for the tension test shall be centred between grips spaced not closer than 610 mm apart.

7.4.4 Test

7.4.4.1
Specimens shall be tested to failure at a constant rate of loading that results in a time to failure of not less than 1 min. The accuracy of the load at failure shall be within ± 5%, as established by a prior calibration. Accuracy of the span shall be within 2 mm of the specified span.

7.4.4.2
For tension tests, the grips used to transmit the tensile load from the testing machine to the test specimen shall be designed so that
a) the specimen damage due to clamping will not affect the joint strength; and
b) the specimen slippage during load application is minimized.
7.4.5 Requirements

7.4.5.1 Bending test
The bending stress at failure [i.e., the Modulus of Rupture (MOR)] shall be determined and recorded for each test. For each consecutive group of 28 tests, the lower 5% tolerance limit MOR with 75% confidence shall be determined. MOR values for end joints shall be multiplied by the following factors:

<table>
<thead>
<tr>
<th>Lumber width, mm</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>89</td>
<td>1.00</td>
</tr>
<tr>
<td>114</td>
<td>1.00</td>
</tr>
<tr>
<td>140</td>
<td>1.00</td>
</tr>
<tr>
<td>184</td>
<td>1.05</td>
</tr>
<tr>
<td>235</td>
<td>1.10</td>
</tr>
<tr>
<td>286</td>
<td>1.14</td>
</tr>
</tbody>
</table>

Note: The lumber width factors given are based on the size factor for bending for glulam, as specified in CSA O86.

In the bending tests of end joints, the lower 5% tolerance limit MOR with 75% confidence shall exceed 1.45 times the specified strength in bending for the highest stress grade of glulam of the species group tested, for standard term duration of load and dry service conditions, as specified in CSA O86.

7.4.5.2 Tension test

7.4.5.2.1
The ultimate tensile stress (UTS) at failure shall be determined and recorded for each test. For each consecutive group of 28 tests, the lower 5% tolerance limit UTS with 75% confidence shall be determined. UTS values for end joints used in bending members shall be multiplied by the following factors:

<table>
<thead>
<tr>
<th>Lumber width, mm</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>89</td>
<td>1.00</td>
</tr>
<tr>
<td>114</td>
<td>1.00</td>
</tr>
<tr>
<td>140</td>
<td>1.00</td>
</tr>
<tr>
<td>184</td>
<td>1.05</td>
</tr>
<tr>
<td>235</td>
<td>1.10</td>
</tr>
<tr>
<td>286</td>
<td>1.14</td>
</tr>
</tbody>
</table>

Note: The lumber width factors given are based on the size factor for bending for glulam, as specified in CSA O86.

The above-noted factors shall not be applied to UTS values for end joints used in tension members.

7.4.5.2.2
For tension tests of end joints used in bending members, the lower 5% tolerance limit UTS with 75% confidence shall exceed 0.90 times the specified strength in bending for the highest stress grade of glulam of the species group tested, for standard term duration of load and dry service conditions, as specified in CSA O86.
7.4.5.2.3
For tension tests of end joints used in tension members, the lower 5% tolerance limit UTS with 75% confidence shall exceed 1.10 times the specified strength in tension at the net section for the highest stress grade of glulam of the species group tested, for standard term duration of load and dry service conditions, as specified in CSA O86.

7.4.5.3
After testing, each end-joint specimen shall be classified into one of the failure modes described in Table 1. The failure mode shall be recorded.

Note: The failure mode classification has no pass or fail criteria and is used to provide a historical record of the modes of failure. This information can be used when evaluating the performance of the end joint to determine whether any changes in the modes of failure have occurred over time.

7.4.5.4
Specimens that fail outside the joint length (Mode type 6 in Table 1) at stress values less than the specified minimums shall be disregarded, and an equal number of specimens shall be selected for re-testing.

7.5 Modulus of elasticity test of NDT lumber

7.5.1 General
For each size and species group run within a production shift, one specimen shall be tested at the beginning of each shift, one at the end, and additional specimens in between at intervals not exceeding 4 h.

7.5.2 Sample
Each specimen shall be randomly selected from production of NDT lumber.

7.5.3 Specimen
An individual piece of lumber shall constitute a specimen.

7.5.4 Test
Specimens shall be freely supported flatwise on rollers approximately 75 mm from their ends. One of the two rollers shall be swivel-mounted to permit rotation at right angles to the length. Deflection shall be determined at mid-span by a gauge reading accurate to 0.025 mm, and a load shall be applied at the same point by dead weight or other means accurate to within ± 1%. A suitable preload shall be applied and the gauge set to zero. A final load that does not induce a stress greater than 10.0 MPa in the specimen shall then be applied and the deflection read to the closest 0.025 mm. The modulus of elasticity shall be calculated from this deflection reading and the final load. Accuracy of the span shall be within 2 mm of the specified span.

Note: The intent of the pre-load is to ensure that the modulus of elasticity is calculated from the linear portion of the specimen’s load-deflection response.

7.5.5 Requirements
Of every 100 consecutive specimens tested, 95 shall have a modulus of elasticity greater than that specified for the stiffness grade.
Table 1
Failure mode classification
(See Clauses 7.4.5.3 and 7.4.5.4.)

<table>
<thead>
<tr>
<th>Mode type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mostly along the bond line surfaces of the joint profile; low wood failure</td>
</tr>
<tr>
<td></td>
<td>(less than 70%)</td>
</tr>
<tr>
<td>2</td>
<td>Mostly along the bond line surfaces of the joint profile; high wood failure</td>
</tr>
<tr>
<td></td>
<td>(greater than 70%)</td>
</tr>
<tr>
<td>3</td>
<td>Partially along the joint profile; some failure at the finger joint roots</td>
</tr>
<tr>
<td></td>
<td>(or scarf tip); good overall wood failure along the joint profile surfaces</td>
</tr>
<tr>
<td>4</td>
<td>Mostly at the finger joint roots (or scarf tip); high overall wood failure</td>
</tr>
<tr>
<td></td>
<td>but not along the joint profile</td>
</tr>
<tr>
<td>5</td>
<td>Either beginning at the joint (possibly due to a stress riser at the edge)</td>
</tr>
<tr>
<td></td>
<td>and progressing away from the joint through the wood section, or beginning</td>
</tr>
<tr>
<td></td>
<td>away from the joint and progressing to the joint</td>
</tr>
<tr>
<td>6</td>
<td>Away from the joint (not influenced by the joint); 100% wood failure</td>
</tr>
</tbody>
</table>

Note: See Figure 7.

Table 2
Maximum cup
(See Clauses 5.1.1 and 5.2.1.10.)

<table>
<thead>
<tr>
<th>Laminating stock thickness, mm</th>
<th>Maximum cup width, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Laminating stock width, mm</td>
</tr>
<tr>
<td>19</td>
<td>1.0 1.0 2.0</td>
</tr>
<tr>
<td>38</td>
<td>None 0.5 1.0</td>
</tr>
</tbody>
</table>
Table 3
Maximum permissible strength-reducing characteristics
(See Clause 5.2.2 and Table A.1.)

<table>
<thead>
<tr>
<th>Finished width of member, mm*</th>
<th>Knot or knot hole size, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grades B and B-F†</td>
</tr>
<tr>
<td>80</td>
<td>20</td>
</tr>
<tr>
<td>105</td>
<td>25</td>
</tr>
<tr>
<td>130</td>
<td>35</td>
</tr>
<tr>
<td>175</td>
<td>45</td>
</tr>
<tr>
<td>215</td>
<td>55</td>
</tr>
<tr>
<td>225</td>
<td>60</td>
</tr>
<tr>
<td>265</td>
<td>65</td>
</tr>
<tr>
<td>275</td>
<td>70</td>
</tr>
<tr>
<td>315</td>
<td>80</td>
</tr>
<tr>
<td>365</td>
<td>90</td>
</tr>
<tr>
<td>415</td>
<td>105</td>
</tr>
<tr>
<td>465</td>
<td>115</td>
</tr>
<tr>
<td>515</td>
<td>130</td>
</tr>
</tbody>
</table>

* See Note 2) to Table A.1 for imperial equivalents.
† The general slopes of grain are 1:16 for Grades B and B-F, 1:12 for Grade C, and 1:8 for Grade D.
Table 4
Minimum modulus of elasticity ($E$)* and visual grade requirements for Stress Grades 20f-E and 24f-E, MPa
(See Clauses 4.1, 5.1.2, and 6.4.1, and Table 6.)

<table>
<thead>
<tr>
<th>Zone</th>
<th>Visual Grade</th>
<th>20f-E Stress Grade</th>
<th>24f-E Stress Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Pine and/or Spruce</td>
<td>Douglas Fir-Larch</td>
</tr>
<tr>
<td>Within outer 1/8 compression</td>
<td>C</td>
<td>11 000</td>
<td>13 100</td>
</tr>
<tr>
<td>Remainder of outer 1/4 compression</td>
<td>D</td>
<td>9700</td>
<td>11 700</td>
</tr>
<tr>
<td>Inner 1/2 or less</td>
<td>D</td>
<td>No minimum</td>
<td>No minimum</td>
</tr>
<tr>
<td>Remainder of outer 1/4 tension</td>
<td>C</td>
<td>9700</td>
<td>11 700</td>
</tr>
<tr>
<td>Within outer 1/8 tension</td>
<td>B</td>
<td>11 000</td>
<td>13 100</td>
</tr>
<tr>
<td>Face lamination</td>
<td>B-F</td>
<td>11 000§</td>
<td>**</td>
</tr>
<tr>
<td>Douglas Fir-Larch</td>
<td></td>
<td>13 800</td>
<td>12 400</td>
</tr>
<tr>
<td>Hem-Fir and Douglas Fir-Larch‡</td>
<td></td>
<td>13 800</td>
<td>12 400</td>
</tr>
</tbody>
</table>

* Modulus of elasticity is for each piece of each lamination, as determined in Clause 7.5.4.
† Values for Western Hemlock shall be applicable to beams 608 mm or less in depth.
‡ The tension zones shall be Douglas Fir or Western Larch. Hem-Fir may be used in the inner and compression zones of this layup.
§ Grade B-F face lamination is not required for beams 608 mm or less in depth.
** Face lamination is the same visual grade and minimum lamination $E$ as the outer 1/8 tension zone.
Table 5
Minimum modulus of elasticity ($E^*$) and visual grade requirements for Stress Grade 24f-E, MPa
(See Clauses 4.1, 5.1.2, and 6.4.1.)

<table>
<thead>
<tr>
<th>Zone</th>
<th>Visual Grade</th>
<th>24f-E Stress Grade, Douglas fir/Larch</th>
<th>Minimum lamination E, MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within outer 1/8 compression</td>
<td>C</td>
<td></td>
<td>13 100</td>
</tr>
<tr>
<td>Remainder of outer 1/4 compression</td>
<td>D</td>
<td></td>
<td>11 000</td>
</tr>
<tr>
<td>Inner 1/2 or less</td>
<td>D</td>
<td></td>
<td>No minimum</td>
</tr>
<tr>
<td>Remainder of outer 1/4 tension</td>
<td>C</td>
<td></td>
<td>11 000</td>
</tr>
<tr>
<td>Remainder of 1/8 tension, or more</td>
<td>B</td>
<td></td>
<td>12 400</td>
</tr>
<tr>
<td>Outer 1/16 of tension, or more</td>
<td>T1</td>
<td></td>
<td>13 100</td>
</tr>
</tbody>
</table>

* Modulus of elasticity is for each piece of each lamination, as determined in Clause 7.5.4.
Table 6

Minimum modulus of elasticity ($E$)* and visual grade requirements for Stress Grades 20f-EX and 24f-EX, MPa
(See Clauses 4.1, 5.1.2, 6.4.1, and 6.4.2.)

<table>
<thead>
<tr>
<th>Zone††</th>
<th>Visual Grade</th>
<th>Pine and/or Spruce</th>
<th>Douglas Fir-Larch</th>
<th>Western Hemlock†</th>
<th>20f-EX Stress Grade</th>
<th>24f-EX Stress Grade</th>
<th>Hem-Fir and Douglas Fir-Larch‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top face lamination</td>
<td>B-F</td>
<td>11 000$§$</td>
<td>**</td>
<td>**</td>
<td>14 500</td>
<td>14 500</td>
<td></td>
</tr>
<tr>
<td>Within outer 1/8 (top)</td>
<td>B</td>
<td>11 000</td>
<td>13 100</td>
<td>11 700</td>
<td>14 500</td>
<td>13 800</td>
<td></td>
</tr>
<tr>
<td>Remainder of outer 1/4 (top)</td>
<td>C</td>
<td>9700</td>
<td>11 700</td>
<td>9700</td>
<td>12 400</td>
<td>12 400</td>
<td></td>
</tr>
<tr>
<td>Inner 1/2 or less</td>
<td>D</td>
<td>No minimum</td>
<td>No minimum</td>
<td>No minimum</td>
<td>No minimum</td>
<td>No minimum</td>
<td></td>
</tr>
<tr>
<td>Remainder of outer 1/4 (bottom)</td>
<td>C</td>
<td>9700</td>
<td>11 700</td>
<td>9700</td>
<td>12 400</td>
<td>12 400</td>
<td></td>
</tr>
<tr>
<td>Within outer 1/8 (bottom)</td>
<td>B</td>
<td>11 000</td>
<td>13 100</td>
<td>11 700</td>
<td>13 800</td>
<td>13 800</td>
<td></td>
</tr>
<tr>
<td>Bottom face lamination</td>
<td>B-F</td>
<td>11 000$§$</td>
<td>**</td>
<td>**</td>
<td>14 500</td>
<td>14 500</td>
<td></td>
</tr>
</tbody>
</table>

* Modulus of elasticity is for each piece of each lamination, as determined in Clause 7.5.4.
† Values for Western Hemlock shall be applicable to beams 608 mm or less in depth.
‡ The outer zones shall be Douglas Fir or Western Larch. Hem-Fir may be used in the inner zone.
§ Grade B-F face lamination is not required for beams 608 mm or less in depth.
** Face lamination is the same visual grade and minimum lamination $E$ as the outer 1/8 tension zone.
†† Where outer zones are specifically located as being permanently in compression, the compression zone requirements of Table 4 may be used in these locations.
### Table 7
Minimum modulus of elasticity ($E$)* and visual grade requirements for Stress Grade 24f-EX, MPa
(See Clauses 4.1, 5.1.2, and 6.4.1.)

<table>
<thead>
<tr>
<th>Zone</th>
<th>Visual Grade</th>
<th>24f-EX Stress Grade, Douglas fir/Larch</th>
<th>Minimum lamination $E$, MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outer 1/16 of tension, or more</td>
<td>T1</td>
<td>24f-EX Stress Grade, Douglas fir/Larch</td>
<td>13 100</td>
</tr>
<tr>
<td>Remainder of 1/8 tension, or more</td>
<td>B</td>
<td>12 400</td>
<td></td>
</tr>
<tr>
<td>Remainder of outer 1/4 compression</td>
<td>C</td>
<td>11 000</td>
<td></td>
</tr>
<tr>
<td>Inner 1/2 or less</td>
<td>D</td>
<td>No minimum</td>
<td></td>
</tr>
<tr>
<td>Remainder of outer 1/4 tension</td>
<td>C</td>
<td>11 000</td>
<td></td>
</tr>
<tr>
<td>Remainder of 1/8 tension, or more</td>
<td>B</td>
<td>12 400</td>
<td></td>
</tr>
<tr>
<td>Outer 1/16 of tension, or more</td>
<td>T1</td>
<td>13 100</td>
<td></td>
</tr>
</tbody>
</table>

* Modulus of elasticity is for each piece of each lamination, as determined in Clause 7.5.4.

### Table 8
Minimum modulus of elasticity ($E$) and visual grade requirements for Stress Grades 11c, 12c-E, 16c-E, 14t-E, and 18t-E, MPa
(See Clauses 4.1, 5.1.2, and 6.4.1.)

<table>
<thead>
<tr>
<th>Stress Grade</th>
<th>Zone</th>
<th>Visual Grade</th>
<th>Minimum $E$, MPa</th>
<th>Pine and/or Spruce</th>
<th>Western Hemlock</th>
</tr>
</thead>
<tbody>
<tr>
<td>11c</td>
<td>All</td>
<td>D</td>
<td>No minimum</td>
<td>No minimum</td>
<td>No minimum</td>
</tr>
<tr>
<td>12c-E</td>
<td>All</td>
<td>C</td>
<td>N/A</td>
<td>9700</td>
<td>N/A</td>
</tr>
<tr>
<td>16c-E</td>
<td>All</td>
<td>C</td>
<td>11 000</td>
<td>N/A</td>
<td>9700</td>
</tr>
<tr>
<td>14t-E</td>
<td>Outer zone 1</td>
<td>B</td>
<td>N/A</td>
<td>10 700</td>
<td>N/A</td>
</tr>
<tr>
<td>*</td>
<td>Inner</td>
<td>C</td>
<td>N/A</td>
<td>10 700</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Outer zone 2</td>
<td>B</td>
<td>N/A</td>
<td>10 700</td>
<td>N/A</td>
</tr>
<tr>
<td>18t-E</td>
<td>Outer zone 1</td>
<td>B</td>
<td>13 800</td>
<td>N/A</td>
<td>11 700</td>
</tr>
<tr>
<td>*</td>
<td>Inner</td>
<td>C</td>
<td>13 800</td>
<td>N/A</td>
<td>11 700</td>
</tr>
<tr>
<td></td>
<td>Outer zone 2</td>
<td>B</td>
<td>13 800</td>
<td>N/A</td>
<td>11 700</td>
</tr>
</tbody>
</table>

* “Outer zones” are the two zones at the outer 1/5 of the cross-section. The “inner zone” is the middle 3/5 of the cross-section.

Notes:
1) Laminations that overlap two zones shall be the higher of the two grades assigned to these zones.
2) N/A = not applicable for this species group.
### Table 9
**Number of Grade B laminations required for built-up sections of arch haunches and pitched beam peaks**
(See Clause 6.4.2.)

<table>
<thead>
<tr>
<th>Member</th>
<th>Lamination thickness, mm</th>
<th>Number of laminations</th>
<th>Applies to</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pitched beams</td>
<td>38</td>
<td>1</td>
<td>Roof slopes 2:12 or flatter</td>
</tr>
<tr>
<td>Pitched beams</td>
<td>38</td>
<td>2</td>
<td>Roof slopes steeper than 2:12</td>
</tr>
<tr>
<td>Arches</td>
<td>38</td>
<td>2</td>
<td>5–24 laminations</td>
</tr>
<tr>
<td>Arches</td>
<td>38</td>
<td>3</td>
<td>25–32 laminations (at tangent points)</td>
</tr>
<tr>
<td>Arches</td>
<td>19</td>
<td>2</td>
<td>11–16 laminations (at tangent points)</td>
</tr>
<tr>
<td>Arches</td>
<td>19</td>
<td>3</td>
<td>17–32 laminations (at tangent points)</td>
</tr>
<tr>
<td>Arches</td>
<td>19</td>
<td>4</td>
<td>33–38 laminations (at tangent points)</td>
</tr>
</tbody>
</table>

### Table 10
**Minimum radius of curvature***
(See Clause 6.4.3.)

<table>
<thead>
<tr>
<th>Lamination thickness, mm</th>
<th>Minimum radius of curvature, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tangent end†</td>
</tr>
<tr>
<td>38 standard</td>
<td>8400</td>
</tr>
<tr>
<td>19 standard</td>
<td>2800</td>
</tr>
<tr>
<td>35 non-standard</td>
<td>7400</td>
</tr>
<tr>
<td>32 non-standard</td>
<td>6300</td>
</tr>
<tr>
<td>29 non-standard</td>
<td>5600</td>
</tr>
<tr>
<td>25 non-standard</td>
<td>4600</td>
</tr>
<tr>
<td>16 non-standard</td>
<td>2300</td>
</tr>
<tr>
<td>13 non-standard</td>
<td>1800</td>
</tr>
<tr>
<td>10 non-standard</td>
<td>1200</td>
</tr>
<tr>
<td>6 non-standard</td>
<td>800</td>
</tr>
</tbody>
</table>

* See Table A.2 for imperial equivalents.
† The tangent end requires a straight length of finished lamination beyond the tangent point of not less than 32 times the lamination thickness.
### Table 11

**Appearance grade requirements**

(See Clauses 4.1 and 6.8.1.)

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Industrial</th>
<th>Commercial</th>
<th>Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laminations may contain natural growth characteristics in specified grades of laminating stock</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Tight knots and stain may be present on exposed surfaces</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Sides shall be surfaced true to specified dimensions</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Planer misses along individual laminations shall be patched with replacement stock. Exposed surfaces shall be sanded smooth and free of adhesive</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Loose knots, knot holes, and voids greater than 19 mm in diameter on exposed surfaces shall be replaced by wood inserts or non-shrinking, waterproof filling material</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Wane, pitch pockets, loose knots, knot holes, and voids on exposed surfaces shall be replaced by wood inserts or non-shrinking, waterproof filling material</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Slightly broken knots, slivers, torn grain, and checks shall be filled</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Figure 1
Structural patch for occasional small edge-knot in Grade B-F lamination of glued-laminated beam
(See Clause 6.8.6.)

Approximate surface after repaired area is resurfaced

Figure 2
Block shear test specimens for bond quality
(See Clause 7.2.3.)

Note: Length and width of Type A and B specimens may vary slightly, but shear area should be 2000 mm² ± 100 mm².
Figure 3
Block shear stick test specimen for bond quality
(See Clause 7.2.3.)

Note: Depth and width of specimen may vary slightly, but the shear area of the two shear faces should be 4000 mm² ± 5%.
Figure 4
Vacuum-pressure cycle test specimen
(See Clause 7.3.3.)

Legend:

- $h$ = height ($\geq 150$ mm)
- $l$ = length (70–80 mm)
- $w$ = width ($\geq 80$ mm)

Note: If specimen is to be cut into smaller sections, no specimen shall have dimensions smaller than $h = 150$ mm, $l = 70$ mm, and $w = 80$ mm.
Figure 5
Bending test specimen for end joints
(See Clause 7.4.3.)

Legend:

- $a$ = distance from support to nearest load point (1/2 shear span)
- $b$ = distance from tip of end joint to nearest load point (50 mm min)
- $d$ = thickness of lamination
- $l$ = length of joint (tip to tip)

Note: Specimen width = width of lamination and $14d < 2a < 20d$.

Figure 6
Tension test specimen for end joints
(See Clause 7.4.3.)

Legend:

- Minimum distance between grips: 610 mm


**Figure 7**

**Failure modes**

(See Table 1.)

<table>
<thead>
<tr>
<th>Mode</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Failure mostly along the bondline surfaces of the joint profile with poor wood failure of any kind (wood failure &lt; 70%).</td>
<td><img src="image1.png" alt="Diagram" /></td>
</tr>
<tr>
<td>2.</td>
<td>Failure mostly along the bondline surfaces of the joint profile with good wood shear failure (wood failure &gt; 70%).</td>
<td><img src="image2.png" alt="Diagram" /></td>
</tr>
<tr>
<td>3.</td>
<td>Failure mostly along the joint profile but with some failure at the finger roots or scarf tips. Good overall wood shear failure along the joint profile surfaces.</td>
<td><img src="image3.png" alt="Diagram" /></td>
</tr>
<tr>
<td>4.</td>
<td>Mostly tensile wood failure at the fingerjoint roots or scarf tips and with high overall wood failure. Little failure of any kind along the joint profile.</td>
<td><img src="image4.png" alt="Diagram" /></td>
</tr>
<tr>
<td>5.</td>
<td>Failure beginning at the joint (possibly due to a stress riser) and progressing away from the joint. Essentially 100% wood failure.</td>
<td><img src="image5.png" alt="Diagram" /></td>
</tr>
<tr>
<td>6.</td>
<td>Failure away from the joint (not influenced by the joint) — all wood failure.</td>
<td><img src="image6.png" alt="Diagram" /></td>
</tr>
</tbody>
</table>

**Source:** This Figure is used with permission from FPInnovations.
Annex A (informative)
Metric/imperial conversions

Note: This Annex is not a mandatory part of this Standard.

A.1
Metric units in this Standard are converted to imperial units using the following conversion factors:

Table A.1
Metric/imperial conversions
(See Clause 4.2 and Table 3.)

<table>
<thead>
<tr>
<th>Metric unit</th>
<th>Imperial equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 millimetre (mm)</td>
<td>= 0.0393701 inch (in)</td>
</tr>
<tr>
<td>1 gram (g)</td>
<td>= 0.0352740 ounce (oz)</td>
</tr>
<tr>
<td>1 megapascal (MPa)</td>
<td>= 145.038 pounds/inch² (psi)</td>
</tr>
<tr>
<td>1 kilopascal (kPa)</td>
<td>= 0.145038 pounds/inch² (psi)</td>
</tr>
<tr>
<td>1 degree Celsius (°C)</td>
<td>See Note 5</td>
</tr>
</tbody>
</table>

Notes:
1) All references to lamination thicknesses of 38 mm and 19 mm may be taken as 1.5 in and 0.75 in, respectively.
2) The finished widths of glued-laminated timber in imperial units are: 3-1/8, 4-1/8, 5-1/8, 6-7/8, 8-1/2, 8-7/8, 10-3/8, 10-7/8, 12-3/8, 14-3/8, 16-3/8, 18-3/8, and 20-1/4 (all units in inches). See Clause 4.2 and Table 3.
3) The tolerance on finished widths is ± 1/16 in at the time of manufacture. See Clause 6.8.1 a).
4) All references to beams 608 mm in depth may be taken as 24 inches in depth.
5) To obtain degrees Fahrenheit (°F), use the following equation:
   °F = 32 + 1.8y
   where
   y = given temperature in degrees Celsius (°C)
### Table A.2
**Minimum radius of curvature (imperial units)**
(See Clause 6.4.3 and Table 10.)

<table>
<thead>
<tr>
<th>Lamination thickness, in</th>
<th>Minimum radius of curvature, ft-in</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tangent end</td>
<td>Curved end</td>
</tr>
<tr>
<td>1-1/2 standard</td>
<td>27-6</td>
<td>35-6</td>
</tr>
<tr>
<td>3/4 standard</td>
<td>9-4</td>
<td>12-6</td>
</tr>
<tr>
<td>1-3/8 non-standard</td>
<td>24-4</td>
<td>31-2</td>
</tr>
<tr>
<td>1-1/4 non-standard</td>
<td>20-8</td>
<td>28-0</td>
</tr>
<tr>
<td>1-1/8 non-standard</td>
<td>18-6</td>
<td>24-0</td>
</tr>
<tr>
<td>1 non-standard</td>
<td>15-0</td>
<td>20-4</td>
</tr>
<tr>
<td>5/8 non-standard</td>
<td>7-8</td>
<td>9-10</td>
</tr>
<tr>
<td>1/2 non-standard</td>
<td>6-0</td>
<td>7-2</td>
</tr>
<tr>
<td>3/8 non-standard</td>
<td>4-0</td>
<td>4-7</td>
</tr>
<tr>
<td>1/4 non-standard</td>
<td>2-7</td>
<td>2-7</td>
</tr>
</tbody>
</table>

**Note:** The tangent end requires a straight length of finished lamination beyond the tangent point of not less than 32 times the lamination thickness.
Annex B (Normative)

Development of specified strengths and modulus of elasticity for structural glued laminated timber

Note: This Annex is a mandatory part of this Standard.

B.1 Introduction

B.1.1
This Annex provides information for the development of specified strengths and modulus of elasticity for structural glued laminated timber (glulam).

B.1.2
The scope of this Annex is limited to glulam layup combinations and stress classes that are consistent with the existing design properties, including wood species and specific gravity, listed in the latest version of CSA O86.

B.1.3
This Annex is not intended for evaluation of proprietary glulam layup combinations, which may require additional consideration beyond the requirements specified in this Annex.

B.1.4
Structural glued laminated timber with laminations made of structural composite lumber (SCL) qualified in accordance with ASTM D5456 is beyond the scope of this Annex.

B.1.5
A mechanics-based model is required for the development of generic glulam layup combination of various widths and depths covered in this Annex. For the development of a single layup, the procedures specified in ASTM D7341 may be used.

B.2 Referenced publications
This Annex refers to the following publications, and where such reference is made, it is to the edition listed below.

ASTM International
D198-14e1
Standard Test Methods of Static Tests of Lumber in Structural Sizes

D2915-10
Standard Practice for Evaluating Allowable Properties for Grades of Structural Lumber

D3737-12
Standard Practice for Establishing Allowable Properties for Structural Glued Laminated Timber (Glulam)

D5456-14b
Specification for Evaluation of Structural Composite Lumber Products
B.3 Definitions
The following definitions apply to this Annex.

**Characteristic value** — a statistic from test results by which specified strengths and modulus of elasticity can be derived.

**Note:** For specified strengths of structural glued laminated timber, a lower 5th percentile estimate with 75% confidence is typically used as the characteristic value. For modulus of elasticity, the mean value is typically used as the characteristic value. The modulus of elasticity, \( E_{05} \), for calculating the column slenderness factor, \( K_c \), can be determined in accordance with CSA O86.

**Layup** — a specific arrangement of lamination grades for a single structural glued laminated timber width and depth.

**Layup combination** — a series of layups having similar lamination properties (grades, species, and end joint strengths), similar percentages of grade placement in the areas of critical stresses, and similar properties that are grouped together for design purposes.

**Note:** 24f-E Douglas fir-Larch is an example of structural glued laminated timber layup combination.

**Model** — a mathematical method for predicting a characteristic value of structural glued laminated timber based on the input properties of the individual laminations and/or end joints.

B.4 Basic material requirements

**B.4.1 Laminating lumber**

**B.4.1.1**

Lumber of any species recognized by the Canadian Lumber Standards Accreditation Board (CLSAB) shall be permitted for glulam manufacturing, provided that the glulam mechanical properties and specific gravity meet the requirements of a generic glulam layup combination and stress class listed in CSA O86.

**B.4.1.2**

Grades for laminating lumber shall meet the requirements specified in CSA O122. Only E-rated laminations in accordance with this Standard shall be permitted.
B.4.1.3
New laminating lumber grades may be developed, provided the grading rules are clearly defined and adopted by this Standard.

B.4.2 End and face joints
End joints and face joints for glulam shall meet the requirements specified in this Standard.

B.4.3 Mixed species

B.4.3.1
Mixed species may be used for a glulam layup combination, provided that the specific gravity of the lamination meets the requirements of a generic glulam layup combination and stress class listed in CSA O86.

B.4.4 Manufacturing requirements

B.4.4.1
Manufacturing requirements for the glulam layup combination shall meet the requirements of this Standard.

B.4.4.2
Manufacturing parameters, such as end joint strength, face bond quality, and lumber properties, for the glulam layup combination shall be monitored on an on-going basis and reaffirmed periodically.

B.5 Layup development requirements

B.5.1
Glulam layup combinations shall be developed through the use of a recognized mechanics-based model, as stipulated in Clause B.5.3 and confirmed by full-scale test results in accordance with Clause B.6.

B.5.2
A single glulam layup may be developed using empirical test results in accordance with the procedures specified in ASTM D7341.

B.5.3 Mechanics-based model

B.5.3.1
A mechanics-based model capable of predicting the performance of a glulam layup combination may be acceptable for layup development provided all requirements specified in this clause are met.

Note: The ULAG model (Folz, 1997; Mohadevan, 2007; Timusk, 1997) developed by the University of British Columbia is an example of such a model.

B.5.3.2
The model shall be approved by the competent bodies adopting the glulam layup combinations and their design properties.
B.5.3.3
The model shall be, as a minimum, capable of predicting the bending strength, bending modulus of
elasticity, and shear strength of glulam layup combinations. Other properties may be established in
accordance with established correlation with bending properties or rational analyses.

B.5.3.4
The methodology and limitations for the approved model shall be documented.

B.5.3.5
The characteristic values predicted by the approved model shall be confirmed by full-scale tests in
accordance with Clause B.6. The modulus of elasticity predicted by the model shall be ± 5% of the
average value determined from full-scale tests. The characteristic strength properties determined from
full-scale tests shall be equal to or higher than the characteristic value predicted by the model by no
more than 10%.

Note: The purpose of limiting the model prediction to be no more than 10% lower than the characteristic value
obtained from full-scale tests is to ensure the accuracy of the model. An overly conservative mode is considered
unacceptable for the purpose of this Annex.

B.5.3.6
The model shall prove to be accurate for at least three layup combinations at extreme and intermediate
bending capacities of glulam grades that are similar in characteristics to those specified in CSA O86.

B.5.3.7
The approved model shall have documented quality assurance procedures.

B.5.3.8
The model revisions shall be conducted only by personnel of the model developer and reapproved by
competent bodies in wood engineering.

B.5.4 Resource characterization and on-going monitoring

B.5.4.1
Properties of the lamination grades used in the development of layup combinations shall be
characterized at the time of full-scale tests and monitored on a periodic basis after the layup
combination is approved.

B.5.4.2
If the lumber properties are changed substantially, the layup combinations developed from the model
shall be reaffirmed by re-analysis and full-scale tests.

Note: Clause X1 of ASTM D3737 provides a general guideline for acceptance of new lumber property data.
B.6 New layup confirmation and data analysis requirements

B.6.1 Sampling

B.6.1.1
Lumber, end joints, and/or glulam beams used for the development of layup combinations shall be sampled from representative productions of at least two glulam plants, preferably one from Eastern Canada and the other from Western Canada, whenever possible.

B.6.1.2
The minimum number of samples required for the development of layup combinations shall be determined in accordance with a sound statistical method, or a recognized national or international standard, unless otherwise required in this clause.

Note: ASTM D2915 provides guidance for product sampling.

B.6.1.3
For the confirmation of each new layup combination, a minimum of 15 beams at 2 critical depths from each glulam plant specified in Clause B.6.1.1 shall be tested in full-scale bending. The critical depths shall be determined from the model predictions by considering the commercially popular glulam sizes and a range of glulam depths for the layup combination.

Note: A typical critical depth is 610 mm, which represents the base depth for the glulam bending size factor (K_{bg}) specified in CSA O86.

B.6.1.4
The minimum sample size for empirically developed single layup shall be 30 specimens for the specific glulam depth.

B.6.2 Test methods

Full-scale bending tests for the confirmation of model predictions or single layup shall be conducted in accordance with recognized national or international standards.

Note: ASTM D198 meets the intent of this Clause.

B.6.3 Data analysis

B.6.3.1
Test results shall be adjusted for moisture content, volume effect, and dead weight, when applicable, before data analysis.

B.6.3.2
Data analysis shall be conducted with a sound statistical method, or a recognized national or international standard, including the data confidence factor. The test results shall support the specified strengths and modulus of elasticity predicted by the approved model.

B.6.4 Reports

B.6.4.1
A comprehensive report shall be prepared for layup combinations evaluated in accordance with this Annex.
B.6.4.2
The report shall document the predicted properties by the mechanics-based model, the full-scale test results, and the recommended specified strengths and modulus of elasticity for the layup combination.

B.7 Acceptance requirements

B.7.1
The proposed layup combinations shall be independently reviewed by competent bodies adopting the glulam layup combinations and their design properties.

Note: The competent bodies may choose to engage external assistance to support their review.

B.7.2
The recommendation from the technical experts shall be submitted to the competent bodies adopting the glulam layup combinations and their design properties for review and approval.