Wood Design FOCUS

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Theme: 2018 Wood Design Standards Update

Editorial

Several industry standards have been updated in 2018 and referenced in the *2018 International Building Code (IBC)* and *2018 International Residential Code (IRC)*. This issue of *Wood Design Focus* will provide an overview of changes to several of those standards.

The first paper deals with the *National Design Specification*® (*NDS*®) *for Wood Construction,* designated *ANSI/AWC NDS-2018*. Key changes include revision of *NDS* connection design provisions which were primarily in response to significant increases in Components and Cladding (C&C) roof wind pressures in *ASCE 7-16 Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. Wind uplift related changes include new fastener withdrawal and new fastener head pull-through design provisions.

Another change to the NDS includes allowance for incising factors for specific incising patterns and lumber sizes when obtained from the company providing the incising. The incising adjustment factor, which is used to modify design stresses, is incorporated in the *NDS*. Analytical models have been developed for calculating incising strength factor adjustments for specific incising patterns and lumber/timber sizes. The second article outlines the use of such models as an alternative way to calculate incising strength factor adjustments for any incising pattern or lumber/timber size.

ANSI/APA PRG 320 *Standard for Performance-Rated Cross-Laminated Timber* is the primary product standard covering manufacturing, qualification, quality control and structural properties of CLT for use in building applications in the U.S. and Canada. The third paper highlights the evolution of PRG 320 with a discussion of changes incorporated in 2017 and 2018 editions of the standard. Recent updates to PRG 320-18, in coordination with the International Code Council's Ad-Hoc Committee on Tall Wood Buildings, support proposals for the use of mass timber in buildings up to 18 stories in the *2021 International Building Code*.

Finally, the fourth article covers changes to the 2018 Edition of the *Wood Frame Construction Manual (WFCM) for One- and Two-Family Dwellings,* designated *ANSI/AWC WFCM-2018*. Primary changes to the *2018 WFCM* include updated wind loads based on *ASCE/SEI 7-16* and updated fastener criteria to coordinate with new *2018 NDS* fastener provisions.

We hope you find this issue of *Wood Design Focus* informative. As always, comments and questions are welcome.

John "Buddy" Showalter, P.E.
Editorial Board Chair

p.s. We are pleased to welcome Scott Coffman, P.E., to the Editorial Board. Scott brings over 35 years in structural wood design experience to the Board having worked at TrusJoist MacMillan and Builders FirstSource. He is currently a Forensic and Structural Engineer with Construction Science & Engineering in Westminster, SC.

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Changes to the *2018 National Design Specification (NDS) for Wood Construction* and *2018 NDS Supplement: Design Values for Wood Construction*

John "Buddy" Showalter, P.E., Bradford K. Douglas, P.E., and Philip Line, P.E.

Introduction

The 2018 Edition of the *National Design Specification®* (*NDS®*) *for Wood Construction* was recently published. The updated standard designated *ANSI/AWC NDS-2018* was approved as an ANSI American National Standard on November 30, 2017 (Figure 1). The *2018 NDS* was developed by the American Wood Council's (AWC) Wood Design Standards Committee and is referenced in the *2018 International Building Code (IBC)*.

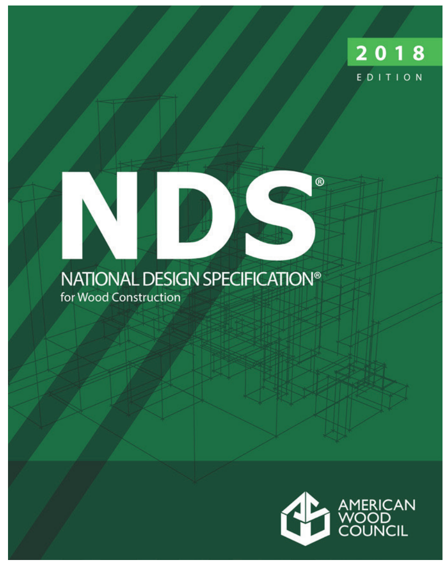

Figure 1. The *2018 NDS* is referenced in the *2018 IBC.*

Primary changes to the *2018 NDS* and the *2018 NDS Supplement: Design Values for Wood Construction* are listed here and major topics are subsequently covered in more detail:

- Allowance for incising factors for specific incising patterns and lumber sizes when obtained from the company providing the incising
- Inclusion of a volume factor for structural composite lumber tension parallel to grain values
- Inclusion of effective shear stiffness for cross-laminated timber
- Added equation for withdrawal design values for smooth shank stainless steel nails
- New provisions for Roof Sheathing Ring Shank nails in accordance with *ASTM F 1667*
- New design provisions for fastener head pull-through of fasteners with round heads
- Revision to method for calculating of lateral design values for threaded nails to be based on use of shank diameter instead of root diameter in accordance with changes in *ASTM F 1575*
- Revised timber rivet design value tables to limit maximum distance perpendicular to grain between outermost rows of fasteners
- Revised terminology for Fire Design of Wood Members to clarify the difference between "char depth" and "effective char depth," used in structural calculations. Provisions for connections is also revised to more precisely describe the requirements for protection of the connection from fire exposure
- Changes to the NDS Supplement include removal of Redwood grades requiring "close grain," Norway Spruce from Norway added to foreign species dimension lumber, and addition of shear-free moduli of elasticity for structural glued laminated softwood timber (glulam)

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Structural Composite Lumber

NDS Chapter 8 on Structural Composite Lumber (SCL) was revised to include a volume factor, C_V, for tension parallel to grain design values, F_t. The change occurs in NDS Table 8.3.1 Applicability of Adjustment Factors for Structural Composite Lumber and Section 8.3.6 Volume Factor. A change was also made to clarify that dry service conditions are associated with conditions in which the moisture content of sawn lumber is less than 16%, as in most covered structures. These changes correlate with *ASTM D 5456 Standard Specification for Evaluation of Structural Composite Lumber Products*.

Cross-Laminated Timber (CLT)

Revisions were made to CLT deflection provisions to include the term GA_{eff} (effective shear stiffness of the CLT section). This is a correlating change with *ANSI/APA PRG 320-2017 Standard for Performance-Rated Cross-Laminated Timber* – to facilitate the calculation of apparent bending stiffness $(EI)_{app}$ consistent with properties as provided in *PRG 320*. The revised equation excerpted from the *2018 NDS* is shown below:

$$(EI)_{app} = \frac{EI_{eff}}{1 + \frac{K_s EI_{eff}}{GA_{eff} L^2}} \qquad (10.4\text{-}1)$$

where:

EI_{eff} = Effective bending stiffness of the CLT section, lbs-in.^{2}/ft of panel width

K_s = Shear deformation adjustment factor

GA_{eff} = Effective shear stiffness of the CLT section, lbs/ft of panel width

L = Span of the CLT section, in.

Changes to Fastener Design

Revision of *NDS* connection design provisions were primarily in response to significant increases in Components and Cladding (C&C) roof wind pressures in *ASCE 7-16 Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. Wind uplift related changes include new fastener withdrawal and new fastener head pull-through design provisions.

Added Equation for Stainless Steel Nail Withdrawal Strength

An equation for the withdrawal strength of smooth shank stainless steel nails was added. Stainless steel nails have lower withdrawal strength when compared to carbon steel wire nails of the same diameter, due to the reduced surface friction of stainless steel. The differences in withdrawal strength vary with the specific gravity of wood (Figure 2). When stainless steel nails are specified as an alternative to reference smooth shank carbon steel wire (bright or galvanized) nails in wood construction including shear walls and diaphragms, these differences in nail withdrawal strengths must be considered. For example, where smooth shank stainless steel nails are used for roof sheathing attachment, more nails, or nails of greater length or diameter, may be required to provide equivalent withdrawal strength performance for wind uplift.

Roof Sheathing Ring Shank Nails

Roof Sheathing Ring Shank (RSRS) nails were recently added to *ASTM F 1667 Standard Specification for Driven Fasteners: Nails, Spikes, and Staples*. Design provisions for RSRS nails have been added to the *2018 NDS*. RSRS nails, which have higher withdrawal design values than smooth shank nails, provide additional options for efficient attachment of wood structural panel roof sheathing. In many cases, specification of RSRS nails will produce a reduced roof sheathing attachment schedule than permissible by use of smooth shank nails and enable use of a single minimum fastener schedule for roof perimeter edge zones and interior zones. Recognition of higher withdrawal strength in the *NDS* is based on presences of standardized ring deformations including minimum 1-1/2" length of deformations on the nail. In a related change, tabular values for generic threaded-hardened nails, which had no standardized deformation pattern, were deleted to remove an approximate 10% increase in withdrawal values for such nails relative to smooth shank nails of equivalent diameter.
The revised NDS provisions allow these generic deformed shank nails in accordance with *ASTM F*

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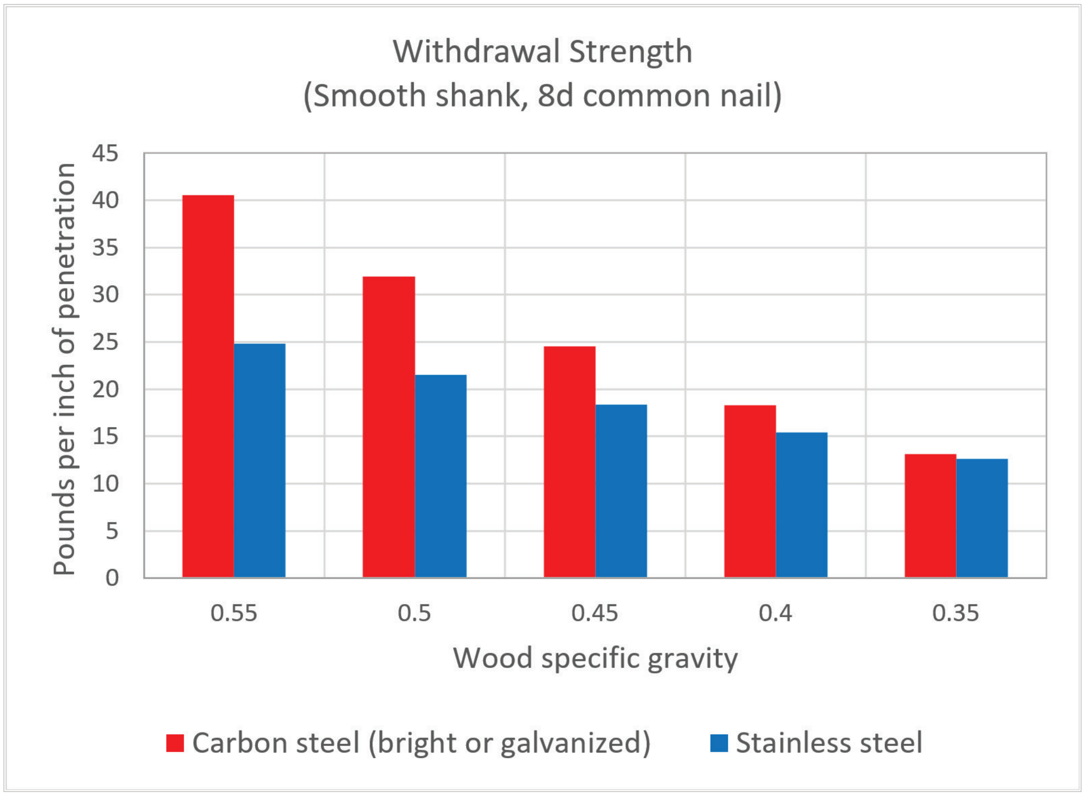

Figure 2. Smooth shank nail withdrawal strength (allowable stress design) from wood in accordance with 2018 NDS.

1667 to use withdrawal design value equations for smooth shank nails.

Fastener Head Pull-through Provisions

Fastener head pull-through data, used to set industry recommendations for wood structural panels, combined with historical data from tests of lumber and plywood was analyzed to develop new fastener head pull-through provisions. Within the range of head diameters, thicknesses and specific gravities in the NDS, the analysis found that head pull-through is related to the perimeter of the fastener head. New equations based on fastener head diameter, specific gravity, and net side member thickness are as follows:

$W_H = 690\,\pi\,D_H\,G^2\,t_{ns}$ for $t_{ns} \leq 2.5\,D_H$

$W_H = 1725\,\pi\,D_H^2\,G^2$ for $t_{ns} > 2.5\,D_H$

where:

$\pi\,D_H$ = perimeter for fasteners with round heads

D_H = fastener head diameter, in.

G = specific gravity of side member

t_{ns} = net side member thickness

An excerpt of tabulated head pull-through values from *2018 NDS* Table 12.2F is shown on the following page.

For design of roof sheathing fastening to resist wind uplift, the addition of head pull-through allows the controlling roof sheathing fastener spacing to be calculated from the lesser of the head pull-through design value or the fastener withdrawal design value from wood in accordance with the *NDS*. Previously, such design required use of a combination of design documents including minimum prescribed spacing criteria for wood panels.

Although not specifically addressed by the added head pull-through equations in the *NDS* which assume fasteners with round heads, analysis of underlying data is considered to support use of the fastener head perimeter model for fasteners with other than round heads such as proprietary nails with clipped or oval heads.

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Table 12.2F Head Pull-Through, W_H[1]

Tabulated pull-through design values, W_H, are in pounds.

Side Member Specific Gravity[2], G	Head Diameter, D_H (in.)	Net Side Member Thickness, t_{ns} (in.)								
		5/16	3/8	7/16	15/32	1/2	19/32	5/8	23/32	3/4
0.50	0.234	40	48	55	59	63	74	74	74	74
	0.250	42	51	59	64	68	80	85	85	85
	0.266	45	54	63	68	72	86	90	96	96
	0.281	48	57	67	71	76	90	95	107	107
	0.297	50	60	70	75	80	96	101	116	120
	0.312	53	63	74	79	85	100	106	122	127
	0.344	58	70	82	87	93	111	117	134	140

An excerpt of tabulated head pull-through values from 2018 NDS

Diameter for Threaded Nails

A change in *ASTM F 1575 Standard Test Method for Determining Bending Yield Moment of Nails* clarifies that nail bending yield strength, F_{yb}, is based on the nominal diameter, D, not on the root diameter, D_r. This change allowed simplification of the calculation of nail moment resistance in the *NDS* yield equations for nails specified in *F 1667* because D is provided for all nail types, but D_r is not always provided for deformed shank nails. As a result, revised *NDS* provisions allow the use of D for deformed shank nails per *F 1667* when calculating lateral design values in accordance with the yield limit equations.

Fire Design of Wood Members

NDS Chapter 16 on Fire Design of Wood Members was revised to provide separate calculations of char depth based on nominal char rates for wood, a_{char}, and effective char depth for use in structural calculations, a_{eff}. Increased use of wood as a fire protective covering has made it important to provide provisions for calculation of the expected a_{char} separate from a_{eff}. Previous versions of the *NDS* have only provided a_{eff} which is increased 20% over a_{char} to account for loss of strength and stiffness due to elevated temperatures in uncharred wood near the char front.

Design of connections for fire were also clarified as follows:

> Wood connections, including connectors, fasteners, and portions of wood members included in the connection design, shall be protected from fire exposure for the required fire resistance time. Protection shall be provided by wood, fire-rated gypsum board, other approved materials, or a combination thereof.

These provisions, while not intended to be technically different from current *NDS* provisions, clarify that protection of all components of the connection (connectors, fasteners, and wood) must be protected from fire exposure for the required time.

NDS Supplement

NDS Supplement design values are unchanged from prior *NDS Supplements* with only a few exceptions. New and revised grades of machine stress-rated lumber and machine evaluated lumber are added. Redwood grades requiring “close grain,” were removed due to general lack of availability for commercial use. Other revisions include addition of Norway Spruce from Norway to foreign species

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dimension lumber, and addition of shear-free moduli of elasticity for structural glued laminated softwood timber (glulam). As a compendium of product types, species, grades and sizes, a note has been added to the *NDS Supplement* to alert designers and product specifiers to check for availability of sizes and grades of products prior to specifying.

More Details

A section by section list of changes to the *NDS* is available in the appendix to this paper.

Availability

The *2018 NDS* with Commentary, *2018 NDS Supplement*, and *2015 Special Design Provisions for Wind and Seismic* are available in print and electronic format (PDF) in the *2018 Wood Design Package*. Check the AWC website (www.awc.org) for more information.

Conclusion

The *2018 NDS* represents the state-of-the-art for design of wood members and connections. Added head-pull through design values and withdrawal provisions for RSRS nails provide design options to address increased design wind uplift pressures resulting from *ASCE 7-16* and added withdrawal equation for stainless steel smooth shank nails are among the major changes in this edition. The *2018 NDS* is referenced in the *2018 IBC*.

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APPENDIX

Summary of Changes – *2018 National Design Specification (NDS) for Wood Construction* and *2018 NDS Supplement: Design Values for Wood Construction*

Section	Description of Change
Chapter 1 General Requirements for Structural Design	Add/revise notation to address effective bending stiffness and effective shear stiffness in the calculation of $(EI)_{app}$ for cross-laminated timber (CLT) (per Chapter 10), addition of fastener head pull-through (per Chapter 12), and changes in Chapter 16 (Fire Design of Wood Members) regarding Section 16.2.1 Char Rate.
Chapter 2 Design Values for Structural Members	1. Revise Section 2.1.2 Responsibility of Designer to Adjust for Conditions of Use, to clarify that the designer is responsible for determining the appropriate design value adjustments to use for end use conditions that are addressed in the NDS. 2. Revise Footnote 2 in Table 2.3.2 Frequently Used Load Duration Factors, C_D, to clarify that the impact load duration factor does not apply to wood structural panels. This change reflects current wood structural panel industry recommendations.
Chapter 3 Design Provisions and Equations	Revise F_b* in Section 3.3.3.8 Beam Stability Factor, to clarify that the volume factor, C_V, shall be included in the calculation of F_b* when C_V is greater than 1.0 – which can be the case for SCL per Section 8.3.6.

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Chapter 4 Sawn Lumber	1. In Section 4.3.7 Flat Use Factor, C_{fu}, add a new Section 4.3.7.2 to clarify that the application of the flat use factor, C_{fu}, in Adjustment Table 4.3.1 is required for beams and stringers. 2. Revise Section 4.3.8 Incising Factor, C_i, to permit incising factors, C_i, for specific incising patterns and lumber sizes, when obtained from the company providing the incising. This is added as an alternative to using the C_i values per Table 4.3.8. 3. Revise Section 4.4.2 Wood Trusses, to clarify that the buckling stiffness factor, C_T, for wood trusses, applies not only when the truss is sheathed with "plywood" but also when sheathed with Oriented Strand Board (OSB) panels. Plywood panels and OSB panels are both "wood structural panel (WSP) sheathing."
Chapter 5 Structural Glued Laminated Timber	In Table 5.3.1 Applicability of Adjustment Factors for Structural Glued Laminated Timber, add a footnote to clarify that wet service and temperature adjustment factors, C_M and C_t, for shear parallel to grain, shall be used to adjust reference radial tension, F_{rt}.
Chapter 7 Prefabricated Wood I-joists	Revise Section 7.1.4 Service Conditions, to clarify that dry service conditions are associated with conditions where the moisture content of sawn lumber is less than 16%.

Chapter 8 Structural Composite Lumber	1. Revise Section 8.1.4 Service Conditions, to clarify that dry service conditions are associated with conditions where the moisture content of sawn lumber is less than 16% for consistency with ASTM D5456, *Standard Specification for Evaluation of Structural Composite Lumber Products*. 2. In Table 8.3.1 Applicability of Adjustment Factors for Structural Composite Lumber, and Section 8.3.6 Volume Factor, C_V, a volume adjustment factor, C_V, applicable to tension, F_t, is added. This is a correlating change with ASTM D5456, which requires development of a volume factor for tension. Footnotes for C_L and C_V are removed from the column headings in Table 8.3.1 and repositioned next to these adjustment factors within the table for greater clarity.
Chapter 10 Cross-Laminated Timber	1. Revise the Format Conversion Factor, K_F, for rolling shear in CLT in Table 10.3.1 Applicability of Adjustment Factors for CLT, from 2.88 to 2.00. This is a correlating change with ASTM D5457, *Standard Specification for Computing Reference Resistance of Wood-Based Materials and Structural Connections for Loads and Resistance Factor Design*. The format conversion factor of 2.00 is consistent with format conversion assumptions implemented for modulus of elasticity and compression perpendicular to grain design properties which are not adjusted for either load duration or time effect factors. 2. Revise Equation 10.4-1 to include the term GA_{eff} (effective shear stiffness of the CLT section). This is a correlating change with ANSI/APA PRG 320 *Standard for Performance-Rated Cross-Laminated Timber* – to facilitate the calculation of $(EI)_{app}$ per Equation 10.4-1 consistent with properties as provided in PRG 320.
Chapter 11 Mechanical Connections	1. Revise Table 11.3.1 Applicability of Adjustment Factors for Connections, to add Head Pull-Through. 2. Revise Table 11.3.3 Wet Service Factors, C_M, for Connections, as follows: a. Add wet service factors for Round Head Fasteners subjected to Pull-Through Loads. b. Delete reference to Threaded Hardened Nails. c. Add a new footnote for Nails & Spikes subjected to Withdrawal Loads - to indicate the appropriate C_M factor for Roof Sheathing Ring Shank nails and Post-Frame Ring Shank nails.

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Chapter 12 Dowel-Type Fasteners	1. Revise Section 12.1.6 General: Nails and Spikes: a. Add language for Roof Sheathing Ring Shank (RSRS) Nails, including reference to new Appendix Table L6. b. Clarify that nails and spikes used in engineered construction shall meet the Supplementary Requirements of ASTM F1667 S1 Nail Bending Yield Strength. c. Add "head diameters," required for new head pull-through design provisions. d. Remove "Threaded Hardened Nails" in Section 12.1.6.2 and replace with new provision for "other deformed shank nails" per new Section 12.2.3.2d. 2. Revise Section 12.2.3 Reference Withdrawal Design Values: Nails and Spikes, as follows: a. Add new Section 12.2.3.1 to address smooth shank nails or spikes as follows: i. Utilize terminology "smooth shank" instead of "plain shank" for consistency with ASTM F1667 terminology. ii. Clarify that withdrawal design provisions for steel wire nails are applicable for carbon steel nails and spikes including bright or galvanized nails. iii. Add provisions in 12.2.3.1b, new Table 12.2D and new equation 12.2-4 for withdrawal design provisions of smooth shank stainless steel nails. b. Add new Section 12.2.3.2 to address deformed shank nails as follows: i. Add language in 12.3.2a to address withdrawal design provisions for Roof Sheathing Ring Shank (RSRS) nails. Table 12.2E includes withdrawal design values for RSRS nails. ii. Add language to permit reference withdrawal design values for uncoated Roof Sheathing Ring Shank or Post-Frame Ring Shank nails to be multiplied by 1.25. iii. Add 12.2.3.2d to address other deformed shank nails (e.g. threaded hardened nails) to permit use of withdrawal design provisions for smooth shank nails or spikes in 12.2.3.1. 3. Add new Section 12.2.5 and Table 12.2F to address fastener head pull-through for fasteners with round heads based on pull-through tests results. 4. Revise Section 12.3.7.1 Reference Lateral Design Values: Dowel Diameter, to clarify the fastener diameter to be used in Tables 12.3.1A and 12.3.1B (Yield Limit Equations) for different fastener types. This change specifies use of diameter D for both smooth shank and deformed shank nails in accordance with ASTM F1667 for calculation of lateral design values. It accounts for standard method of determining F_{yb} for nails which is based on diameter D. 5. Revise Tables 12Q and 12R (Reference Lateral Design Values for Single-Shear Connections using WSP side members), to add Roof Sheathing Ring Shank Nails. 6. Revise Table 12S and 12T (Reference Lateral Design Values for Single-Shear Connections) for Post-Frame Ring Shank nails. Updated lateral design values are based on a lower F_{yb} for low-medium carbon steel considered to be more widely used than high-carbon steel, and an increase in the diameter from D_r (root diameter) to D.

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Chapter 14 Timber Rivets	Revise Tables 14.2.1A through 14.2.1F, and Table 14.2.2A to limit the tabulated maximum number of timber rivet rows per side and maximum number of timber rivet rows, respectively – to be consistent with the provisions in Section 14.3.1 (Spacing between Rivets) which limits the maximum distance perpendicular to grain between outermost rows of rivets to 12”.
Chapter 16 Fire Design of Wood Members	Revise terminology in Chapter 16 (Fire Design of Wood Members) to clarify the difference between “char depth,” (a_{char}) and “effective char depth,” (a_{eff}) used in structural calculations. Section 16.3 (Wood Connections) is also revised to more precisely describe the requirements for protection of the connection from fire exposure.
Appendix L Typical Dimensions for Dowel-Type Fasteners and Washers	Addition of Head Diameter in Table L3 (Standard Wood Screws) to facilitate calculation of head pull-through. Addition of new Table L6 (Roof Sheathing Ring Shank Nails).
References	References are updated to most recent applicable editions.
NDS Supplement	1. Introduction revised to advise users that it is good practice to “check for sources of availability of sizes, species and grades of products specified in this Supplement.” 2. Northern Softwood Lumber Bureau (NSLB) references replaced with Northeastern Lumber Manufacturers Association (NELMA). 3. Norway Spruce species added to the Spruce-Pine-Fir (South) species combination for lumber. 4. Redwood grades requiring “Close Grain” removed. 5. Modified Table 4C footnote 2 applicable to mechanically graded dimension lumber to show specific modulus of elasticity ranges (e.g. “1.0 to 1.9” for DFL instead of “1.0 and higher”). 6. Modified Table 4D adjustment factors for visually graded timbers for consistency with flat use factor definition per NDS changes. 7. Norway Spruce from Norway added to Table 4F for Non-North American Visually Graded Dimension Lumber. 8. Revised Tables 5A, 5A Expanded, and 5B for structural glued laminated timber to address new format for design values for modulus of elasticity.

Review of Revisions to Incising Factors (C_i) in the *2018 National Design Specification for Wood Construction*

Dr. Jerrold E. Winandy, Dr. Jeffrey J. Morrell, Dr. Kevin C. K. Cheung, P.E.

Abstract

The effect of the incising process on wood properties has been found to be dependent on incision depth and length, the degree of damage to wood around and below individual incisions and the pattern and number of incisions (density) per surface area. Engineers derive engineering design values for the strength and stiffness of treated and incised lumber and timber using the *National Design Specification® (NDS®) for Wood Construction*. The incising adjustment factor (C_i), which is used to modify design stresses, is also incorporated in the *NDS*. Analytical models based on the use of *Reduced Section Modulus* (RSM) have been developed for calculating incising strength factor adjustments for specific incising patterns and lumber/timber sizes. This paper outlines the use of such models as an alternative way to calculate incising strength factor adjustments for any incising pattern or lumber/timber size.

Introduction

Many species of refractory lumber or timber require pre-treatment incising to facilitate proper pressure preservative treatment. Incising involves making shallow, slit-like holes parallel-to-grain into the surfaces of materials to obtain deeper and more uniform penetration of preservatives. The process improves treatment of wood members having heartwood surfaces and of species that tend to resist radial or tangential penetration of preservative solutions, such as Douglas fir, Engelmann spruce, true firs and hemlock.

The effect of the incising process on lumber strength and stiffness has been found to be dependent on depth and length of individual incisions and number of incisions (density) per surface area (Kass 1975, Lam & Morris 1991, Perrin 1978, Winandy & Morrell 1998, Morrell et al 1998). Table 1 illustrates data for incised and treated 2x4 lumber tested in bending. The incising adjustment factors, C_i, for E, F_b, F_t, F_v and F_c given in Table 4.3.8 of the *2015 NDS* are limited to dimension lumber (nominal 2" to 4" in thickness) using patterns where the incisions are not deeper than 0.4 inches and where the number of incisions does not exceed 1,100 per square foot. Where these limits are exceeded, the designer is responsible for determining, by calculation or tests, the incising adjustment factors that should be used with the structural wood material being specified. However, the *2015 NDS* does not allow for the use of *Reduced Section Modulus* (RSM) models for lumber having incising patterns of less than 1,100 incisions/ft^2.

The concept of modeling the effects of incising on lumber and timber using an adjustment based on the RSM method was first proposed by Luxford and Zimmerman (1923). It is generally accepted that incising factors for specific incising patterns

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				Incision density and depth			
				660 incisions/ft^2		800 incisions/ft^2	
Species group[b]	Grade	Treatment[c]	SG	0.2 in.	0.28 in.	0.2 in.	0.28 in.
HF	1650f/1.5E	CCA	0.43	0.90 (0.91)	0.69 (0.88)	0.87 (0.92)	0.86 (0.94)
	2400f/2.0E	CCA	0.48	0.84 (0.90)	0.65 (0.79)	0.92 (0.92)	0.87 (0.91)
	1650f/1.5E	ACZA	0.44	0.89 (1.03)	0.68 (0.91)	0.89 (1.00)	0.92 (1.02)
	2400f/2.0E	ACZA	0.48	0.89 (0.96)	0.68 (0.93)	0.90 (0.99)	0.83 (1.01)
DF	1800f/1.8E	ACZA	0.46	0.79 (0.87)	0.55 (0.74)	0.82 (0.92)	0.77 (0.84)
	2400f/2.2E	ACZA	0.52	0.86 (0.88)	0.62 (0.78)	0.84 (0.97)	0.78 (0.86)
SPF–S	1650f/1.5E	CCA	0.43	—	0.82 (0.96)	0.87 (0.95)	—
	2250f/1.9E	CCA	0.47	—	0.74 (0.91)	0.90 (0.92)	—
	1650f/1.5E	ACQB	0.43	—	0.68 (0.81)	0.82 (0.98)	—
	2250f/1.9E	ACQB	0.47	—	0.69 (0.82)	0.77 (0.87)	—
	Average of normalized data			0.86 (0.93)	0.68 (0.85)	0.86 (0.94)	0.84 (0.93)

[a]Normalized values were obtained by dividing averages of incised groups by averages unincised groups. Values are normalized modulus of rupture (MOR); values in parentheses are normalized modulus of elasticity (MOE) (1 inch = 25.4 mm).
[b]HF is Hem–Fir; DF, Douglas Fir; and SPF–S, Spruce–Pine–Fir (South).
[c]CCA is chromated copper arsenate; ACZA, ammoniacal copper zinc arsenate; and ACQB, ammoniacal copper quinone borate.

Table 1. Normalized modulus of rupture and modulus of elasticity (in parenthesis) ratios for nominal 2x4 lumber incised in dry condition compared to matched untreated, unincised control groups (from Winandy and Morrell 1998)[a]

and dimension lumber or timber sizes can be determined by test or by calculation using reduced section properties (Winandy & Hernandez 1998, Hernandez & Winandy 2005) (Figure 1). However, it is critical that users of RSM models recognize that any use of such models must also account for damage to wood around edges and below the bottom of incisions (Hernandez & Winandy 2005) (Figure 2).

A review of early testing (Perrin 1978) of timbers and railway ties indicated that incising induced only a slight decrease in strength properties, and, in some cases, no strength reductions. Incising effects are minimal for timber size 5″ nominal and thicker and C_i can be assumed to vary from 0.95 to 1.0 depending on timber species and size, incision depth and density, and incision damage to wood around edges and below the bottom of incisions. Thus, property adjustments provided in Table 4.3.8 of the *NDS* are usually not applied to larger members such as solid sawn timbers.

2015 NDS Language on Incising Adjustments

Engineers use reference engineering design values for the strength and stiffness of lumber and timber provided in the *NDS Supplement: Design Values for Wood Construction*. Incising lumber or timber to facilitate proper preservative treatment has been shown to cause strength loss. Thus, the *NDS* includes specific instructions to engineers

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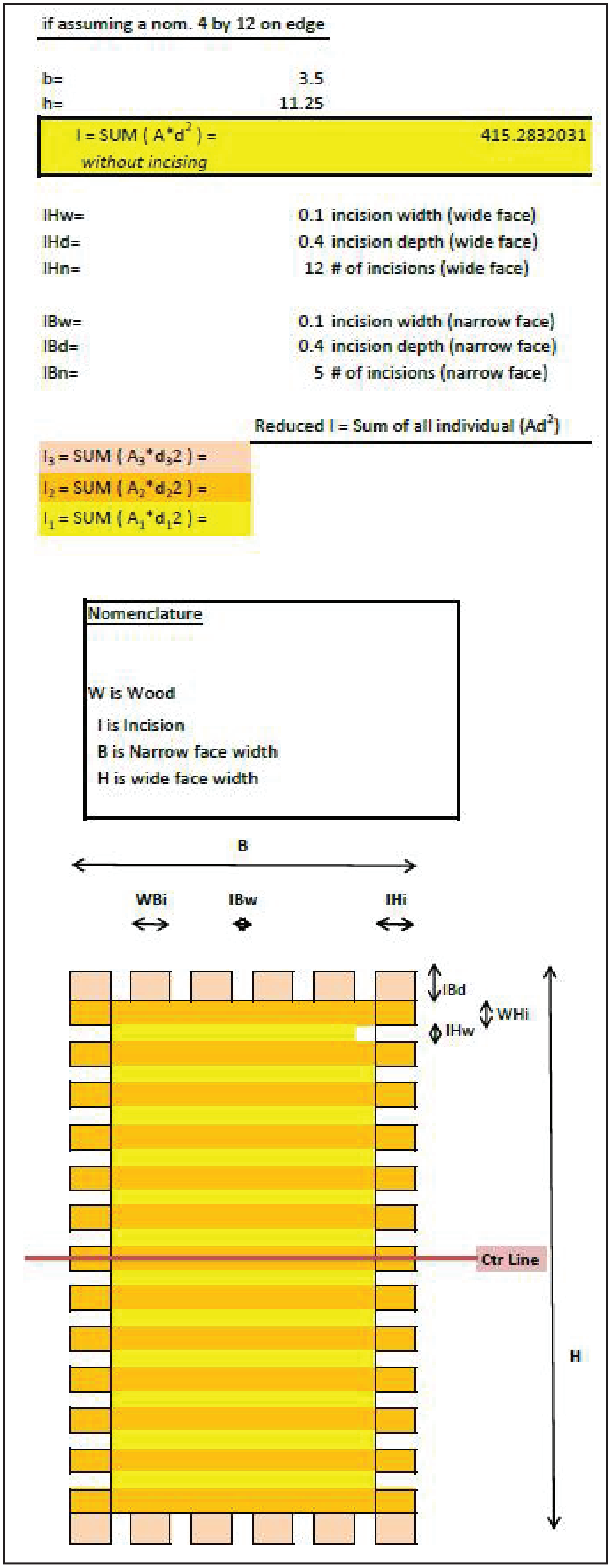

Figure 1. Conceptual example of theory for calculating incising effects when using the reduced section modulus approach

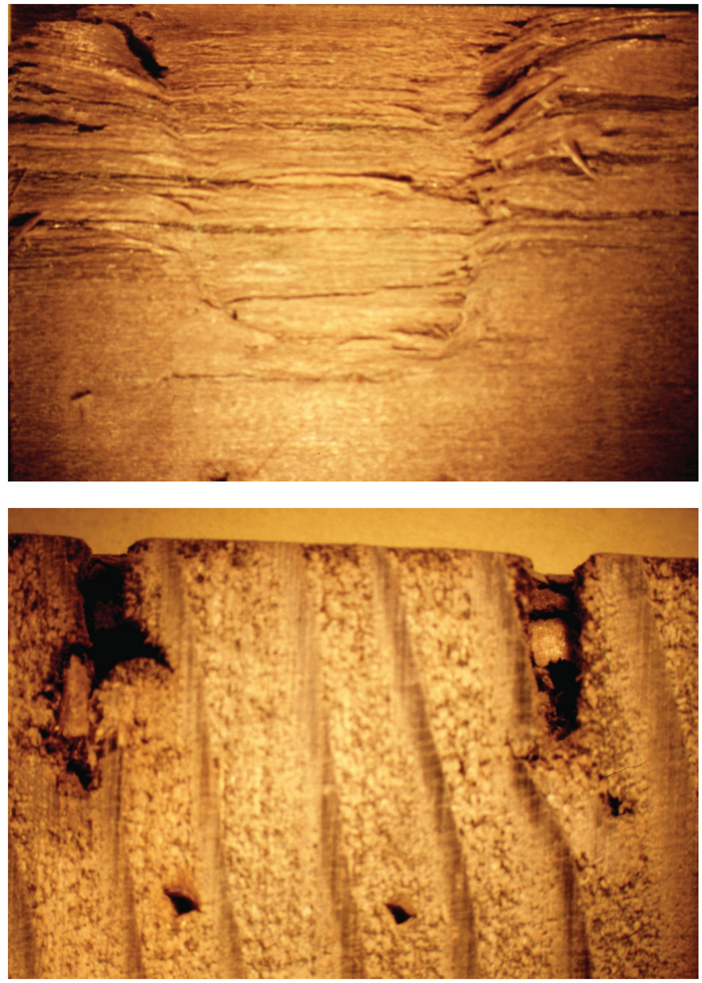

Figure 2. Examples of potential sub-incision damage (upper) and peripheral incision damage (lower) to wood beneath and/or around the individual incisions. Such damage is critical and must be accounted for in any reduced section modulus calculation. Note the center-to-center distance between the two pin marks below the incision is 1/4-inch.

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on how and how much to reduce the reference design values. In the *2015 NDS*, that information is presented in Section 4.3.8. It states:

4.3.8 Incising Factor, C_i

Reference design values shall be multiplied by the following incising factor, C_i, when dimension lumber is incised parallel to grain to a maximum depth of 0.4", a maximum length of 3/8", and density of incisions up to 1,100/ft^2. Incising factors shall be determined by test or by calculation using reduced section properties for incising patterns exceeding these limits.

2015 NDS Table 4.3.8 Incising Factors

Design Value	C_i
E, E_{min}	*0.95*
F_b, F_t, F_c, F_v	*0.80*
$F_{c\perp}$	*1.00*

Note how this *2015 NDS* language of the final sentence of *NDS* 4.3.8 excludes using RSM models for incising patterns of ≤1,100/ft^2. Discussions within the engineering and wood treating communities focused on developing engineering models for calculating incising strength factor adjustments for specific incising patterns and lumber sizes at incising densities of ≤1,100/ft^2, and allowing the use of such models by introducing revisions to the *NDS*. This process provides an alternative way to calculate incising strength factor adjustments for any incising pattern or lumber/timber size. Development and acceptance of such models enhance both engineering reliability and wise and sustainable utilization. Of specific interest to the membership of the American Wood Protection Association, such changes in *NDS* allow consideration of preserved treated and incised wood products in a broader number of engineered uses with stricter structural requirements.

Rationale for the *2018 NDS* Section for Incising Factors

Section 4.3.8 of the *2015 NDS* did not allow a designer or engineer to substitute a specific pattern or size of lumber and re-calculate the standard incising factor when using lumber greater than 2" nominal and less than 5" nominal in thickness.

With the increase in bridge and building load requirements, the 20 percent incising factor strength reduction has forced the specification of larger sizes for treated structural wood components in some designs. Because of this, timber designs are becoming more expensive, making wood less competitive with steel and concrete in certain cases.

A recognized model is readily available to calculate the strength reduction for virtually any species-grade-size combination for specific incising patterns (Hernandez and Winandy 2005). This model can be used by a licensed design engineer to perform calculations based on reduced section properties for specific incised lumber products to determine applicable incising strength reduction factors.

In recognition of the potential for using a model-based reduced section modulus to optimize efficient engineering design of incised lumber, a task group was formed within the American Wood Council committee. This task group was charged to review potential revisions to the 2015 edition of the *NDS* for section 4.3.8 Incising Factors. New wording has now been incorporated into the *2018 NDS* to clarify the potential for use of an approach based on reduced section modulus models.

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2018 NDS Incising Factors

> ***4.3.8 Incising Factor, C_i***
> *Reference design values for dimension lumber shall be multiplied by the incising factor, C_i, in Table 4.3.8 when dimension lumber is incised parallel to grain up to a maximum depth of 0.4", a maximum length of 3/8", and a density of incisions up to 1,100/ft^2. As an alternative, incising factors for specific incising patterns and lumber sizes shall be obtained from the company providing the incising.*

2018 NDS Table 4.3.8 Incising Factors

Design Value	C_i
E, E_{min}	0.95
F_b, F_t, F_c, F_v	0.80
$F_{c\perp}$	1.00

Additional information on the potential application of such proposed models to dimension lumber or to larger timber sizes is then given in the *NDS Commentary* (which is considered as suggestive, non-mandatory information). The following additional information on incising has been incorporated into the *2018 NDS Commentary*:

> ***C4.3.8 Incising Factor, C_i***
> *Incising involves making shallow, slit-like holes parallel-to-grain in the surfaces of refractory wood species to be preservative treated. For such species, incising is required by treatment standards to obtain deeper and more uniform penetration of preservatives. Incising results in improved treatment for members having heartwood surfaces or for species which tend to be resistant to side penetration of preservative solutions, such as Douglas fir, Spruce, and Hemlock.*
>
> *The effect of the incising process has been found to reduce the strength properties of wood. More recent work on nominal 2x4 lumber of multiple species having either 660 or 880 incisions/ft^2 has shown that incising effects are dependent on the number of incisions (density) per square foot of surface area, the depth, width and length of individual incisions, and the damage beneath the boundaries of the incisions. The incising adjustment factors for E, F_b, F_t, F_v, and F_c given in Table 4.3.8 of the Specification are limited to dimension lumber using patterns in which the incisions are not deeper than 0.4 inches and no more than 1,100 per square foot in number.*
>
> *To verify the current practices of incising across the Western U.S., a survey was recently conducted by Western Wood Preservers Institute and Oregon State University (Morrell and Winandy, 2017). It confirmed that the current incising machines used in Pacific Northwest treating plants produced average incising densities of 377 incisions/ft^2 with a standard deviation of 145 incisions/ft^2. The 16 plants responding to the survey used incision densities between 148-638 incisions/ft^2. Incision depth ranged from 0.04-0.24 inches and averaged 0.14 inch with a standard deviation of 0.06 inch.*
>
> *The incising effect on larger member sizes is generally less than nominal 2x4 size lumber due to the larger cross-section and the common practice on timbers of using lower incision densities (<800/ft^2).*
>
> *Alternatively, incising factors for specific incising patterns, in conjunction with dimension lumber or timber sizes may be obtained from the company providing the incising and reported in their design documents. These incising factors may either be determined by test or by calculation using reduced section properties and shall account for damage to wood around edges and below the bottom of incisions.*

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For larger sizes, such as timbers, reviews of early testing of timbers and railway ties indicated that a slight decrease in strength properties for timbers was expected, but in some cases no strength reductions were reported.

For timber sizes with thicknesses larger than 5 inches, the effects of incising are small to minimal and C_i can be assumed to vary from 0.95 to 1.0 depending on timber species and size, incision depth and density, and incision damage to wood around edges and below the bottom of incisions. Thus, reductions provided in Table 4.3.8 are usually not applied to larger members such as solid sawn timbers.

Development of the Model

Currently, additional studies are being conducted to determine actual strength reductions for nominal 4x12 and 4x16 copper naphthenate-treated Coastal Douglas fir that was incised. The mechanical testing on these samples is currently on-going and will be used in subsequent development of incising effect models following the same process the U.S. Forest Product Laboratory used in their studies from 1995 to 2005 that resulted in the establishment of the *NDS* incising factors.

Some projected results of these current studies based on a RSM modeling approach for nominal 4x12 and 4x16 lumber indicate that the calculated strength reductions could be less than 5 percent for both sizes, well below the current *NDS* value of a 20 percent reduction. The enhanced use of such models will allow licensed professional engineers to more accurately perform calculations for strength adjustments for incised, treated lumber or timber materials.

Summary

Based on this information, the *2015 NDS* incising adjustment of a 20 percent strength reduction may be appropriate for nominal 2-inch thick lumber based on existing literature (Kass 1975, Lam & Morris 1991, Perrin 1978, Winandy & Morrell 1998, Morrell et al 1998). However, that same adjustment appears to be overly conservative for nominal 4” thick material. Therefore, incorporation of the RSM modeling approach in the *2018 NDS* as an alternative to the tabulated incising factors is appropriate.

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Updated CLT Standard

Tom Williamson, P.E., Dr. B.J. Yeh, P.E.

Introduction

ANSI/APA PRG 320 *Standard for Performance-Rated Cross-Laminated Timber* (PRG 320) is the primary product standard covering manufacturing, qualification, quality control and structural properties of cross-laminated timber (CLT) for use in building applications in the U.S. and Canada. This paper highlights the evolution of PRG 320 with a discussion of the changes incorporated in 2017 and 2018 editions of the standard.

Background

CLT was first standardized for use in building projects in North America with the creation of the ANSI/APA PRG 320 *Standard for Performance-Rated Cross-Laminated Timber* in 2011 and subsequently revised in 2012. For the use of CLT in building structures in the US, the PRG 320 standard is referenced in the 2018 ANSI/AWC *National Design Specification® (NDS®) for Wood Construction* and the International Code Council's (ICC) 2018 *International Building Code (IBC)* and 2018 *International Residential Code (IRC)*. For use in Canada, the PRG 320 standard is referenced in the CSA O86-14 *Engineering Design in Wood*, Update No. 1 and the 2015 *National Building Code of Canada (NBCC)*.

The *2015 IBC* and *IRC* were the first version of the model building codes to recognize CLT as a code accepted product through recognition of CLT conforming to PRG 320. The *2015 NDS* includes design provisions for CLT, commodity fasteners (e.g., nails and bolts) used with CLT, and a method to calculate the structural fire resistance rating of CLT using a relationship of char depth to standard fire exposure time. In Canada, CSA O86-14 Update No. 1 recognizes CLT conforming to PRG 320 and includes provisions for engineering design.

An update committee for the PRG 320 standard was convened in 2016 to create the 2017 and 2018 revisions of the standard. The committee consisted of 41 voting members and 22 non-voting observers including CLT manufacturers, researchers, practicing engineers and engineered-wood-products manufacturers. The authors of this paper are part of the executive subcommittee of the PRG 320 update with Tom Williamson serving at the Committee Chair and B.J. Yeh serving as the Secretariat.

PRG 320-2017 Updates

ANSI/APA PRG 320-2017 was approved by ANSI and published by APA in November 2017. Significant changes between the 2012 and the 2017 editions which impact design properties include the following:

- The nomenclature based upon "flatwise" vs. "edgewise" properties (see Figures 1 and 2). Flatwise properties, also known as out-of-plane properties have been included in prior versions of the PRG 320 standard.
- Tables A1 through A4 were updated to reflect changes to the design properties for CLT layups.
- A reduction of the required strength of the visually graded southern-pine laminations to account for lower southern-pine design values which were published in the *2015 NDS Supplement, Design Values for Wood Construction*. This results in a reduction in the design properties of CLT grade (V4) constructed of visually graded southern pine.

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- A change in the span-to-depth ratio for the qualification of flatwise shear strength design values (V_s).
- The inclusion of flatwise shear strength values (V_s) in the published design properties for standard grades and laminations.
- Sections 8.4 (Qualification for Structural Performance) and 8.5 (Mechanical Property Qualification) were expanded.
- Noted in Section 8.4, the flatwise bending (Figure 1) in the minor strength direction was changed from a span-to-depth ratio of approximately 30:1 to 18:1 (the major strength direction remains unchanged at 30:1).
- Many referenced test standards used for qualification of CLT were also updated.
- The flatwise shear stiffness (GA) tests are a new requirement.
- Optional qualification tests for edgewise bending (Figure 2) and shear properties were also added but are required only when the CLT manufacturer elects to publish proprietary edgewise properties. Manufacturers wanting to provide the new optional edgewise design values will need to demonstrate compliance with PRG 320 such as in an updated product report after the appropriate verification by the approved agency.

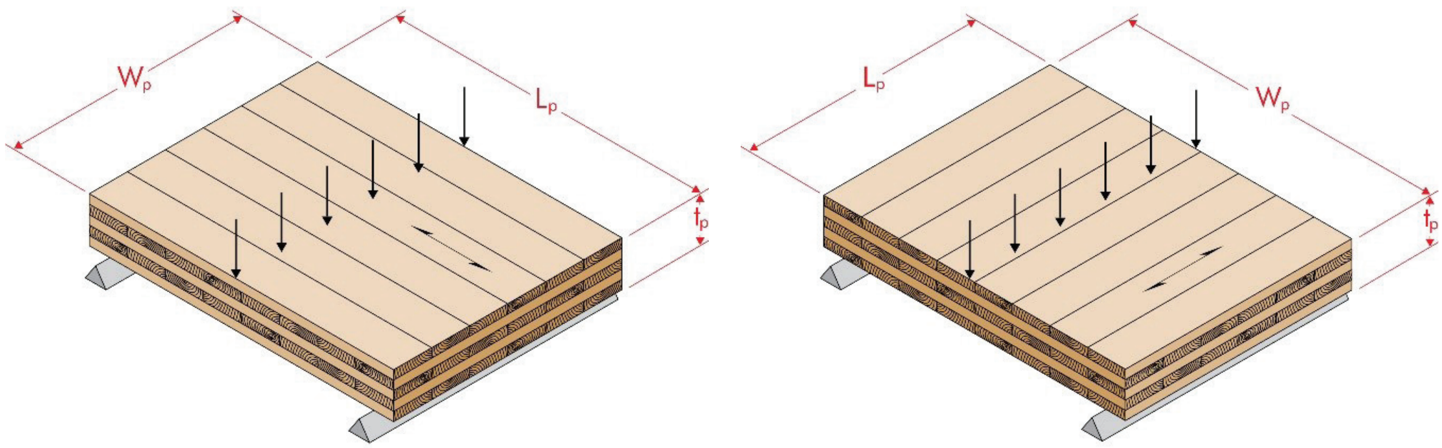

Figure 1: Flatwise bending in major (left) and minor (right) CLT strength directions.

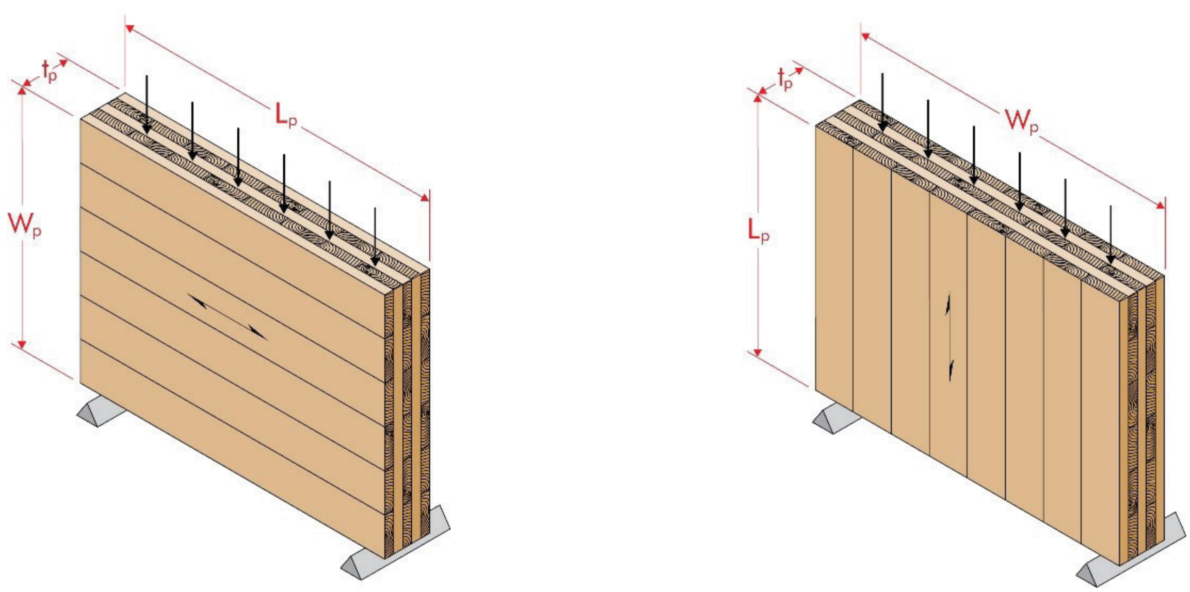

Figure 2: Edgewise bending in major (left) and minor (right) CLT strength directions.

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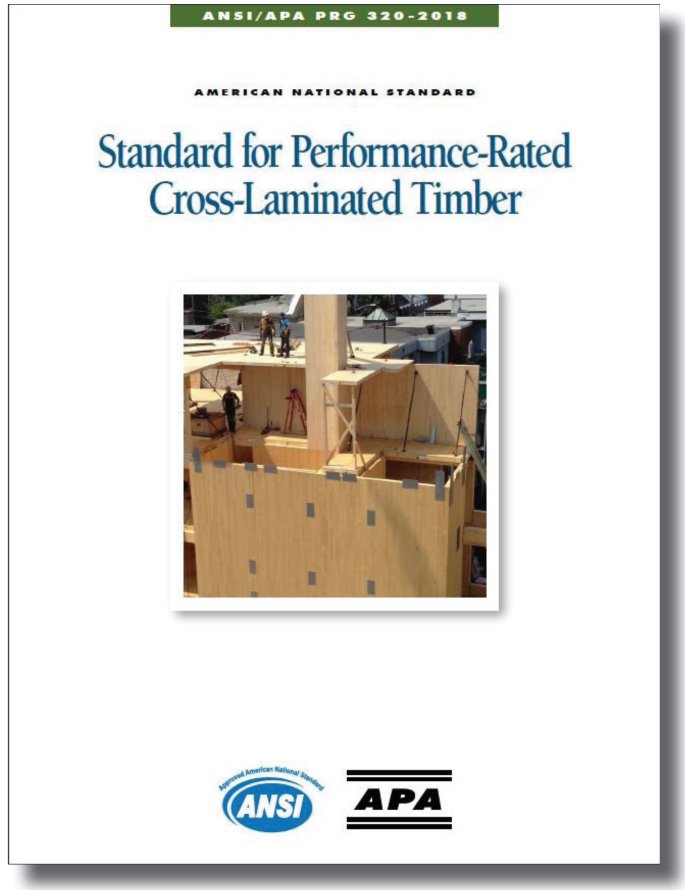
PRG 320-2018 Updates

ANSI/APA PRG 320-2018 was published by APA on February 6, 2018. In this version of PRG 320, adhesive qualification requirements are updated and enhanced to include full-scale compartment fire acceptance criteria, based on a new fire test method developed by the Committee and published in a mandatory annex in the standard. In addition, a small-scale flame test is required, based on Section A.2 of CSA O177-06 (R2015), *Qualification Code for Manufacturers of Structural Glued Laminated Timber*, as adopted in ANSI 405-2018, *Standard for Adhesives for Use in Structural Glued Laminated Timber*, also published by APA. These considerations were in coordination with needs identified by the ICC Ad-Hoc Committee on Tall Wood Buildings, which has developed proposals for the use of mass timber in buildings up to 18 stories in the *2021 International Building Code*.

The ANSI/APA PRG 320 Committee is currently considering the following updates:

- Providing detailed requirements for the use of structural composite lumber as laminations in CLT.
- Harmonization of the gluebond durability requirements between the U.S. and Canada.



CONCLUSION

ANSI/APA PRG 320 is the primary product standard covering manufacturing, qualification, quality control and structural properties of CLT for use in building applications in the U.S. and Canada. For the use of CLT in building structures in the US, the PRG 320 standard is referenced in the 2018 *NDS* and the 2018 *IBC* and *IRC*. For use in Canada, the PRG 320 standard is referenced in the CSA O86-14 Update No. 1 and the *2015 NBCC*. Recent updates to PRG 320-18, in coordination with the ICC Ad-Hoc Committee on Tall Wood Buildings, support proposals for the use of mass timber in buildings up to 18 stories in the *2021 International Building Code*.

ACKNOWLEDGEMENT

The authors would like to acknowledge the hard work of the members of the PRG 320 update committee for their dedication and assistance in achieving the valuable step in the advancement of the use of CLT in North America.

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Changes to the *2018 Wood Frame Construction Manual*

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Introduction

The 2018 Edition of the *Wood Frame Construction Manual (WFCM) for One- and Two-Family Dwellings,* designated *ANSI/AWC WFCM-2018,* is approved as an ANSI American National Standard (Figure 1). The *2018 WFCM* was developed by the American Wood Council's (AWC) Wood Design Standards Committee (WDSC) and is referenced in the *2018 International Residential Code (IRC)* and *2018 International Building Code (IBC)*.

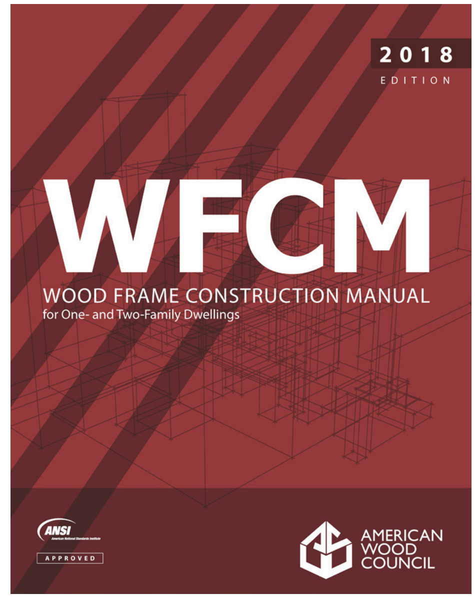

Figure 1. The *2018 WFCM* is referenced in the *2018 IRC* and *2018 IBC*.

Tabulated engineered and prescriptive design provisions in WFCM Chapters 2 and 3, respectively are based on the following loads from *ASCE/SEI 7-16 Minimum Design Loads and Associated Criteria for Buildings and Other Structures*:

- 0-70 psf ground snow loads
- 90-195 mph 3-second gust basic wind speeds for risk category II buildings
- Seismic Design Categories A-D

The *WFCM* includes design and construction provisions for connections, wall systems, floor systems, and roof systems. A range of structural elements are covered, including sawn lumber, structural glued laminated timber, wood structural panel sheathing, I-joists, and trusses.

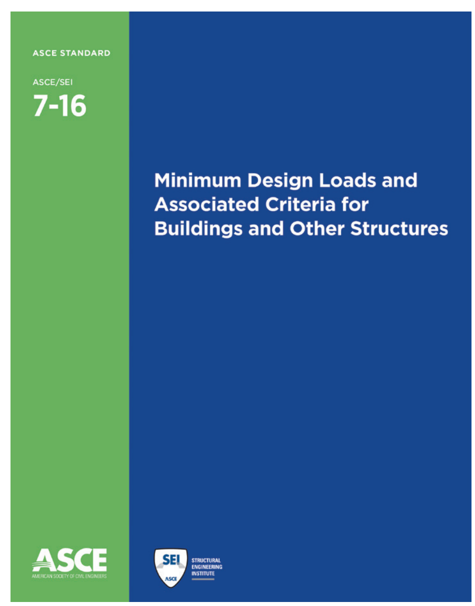

Figure 2. The majority of changes to the *2018 WFCM* reflect increased C&C wind pressures in *ASCE/SEI 7-16*.

Primary changes to the *2018 WFCM* are listed here and major topics are subsequently covered in more detail:

- Updated wind loads from *ASCE/SEI 7-10* to *ASCE/SEI 7-16*
- Inclusion of lower wind speed categories (e.g. 90, 95, 100, and 105 mph) to coordinate with ASCE/SEI 7-16
- Updated fastener criteria to coordinate with *2018 National Design Specification® (NDS®) for Wood Construction* including provisions for roof sheathing ring shank (RSRS) nails and fastener head pull through design values
- Revised provisions for roof rake overhangs at gable ends
- Revised shear wall assembly allowable unit shear capacities, maximum shear wall segment aspect ratios, and sheathing type

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adjustments incorporate updated aspect ratio adjustments to be consistent with the *2015 Special Design Provisions for Wind and Seismic (SDPWS)*

ASCE/SEI 7-16 Revised Wind Loads

The majority of changes to the *2018 WFCM* were developed to address increased component and cladding (C&C) wind pressures in *ASCE/SEI 7-16*. Lower wind speed categories (e.g. 90, 95, 100, and 105 mph) were also added consistent with *ASCE/SEI 7-16*. For a summary of ASCE 7-16 wind provisions, see the 2017 NCSEA Webinar titled "*ASCE 7-16* Wind Provisions – How they affect the Practicing Engineer" by Don Scott, Chair of both the *ASCE 7-16* Wind Load Subcommittee and NCSEA Wind Engineering Committee.

Wind pressure changes for roof design can be summarized as follows:

- New C&C roof pressure coefficients increase localized pressures on roofs
- New C&C roof pressure zones have been added
- Interior C&C roof pressures have the largest increase on a percentage basis

Table 1a provides a comparison of *ASCE/SEI 7-16* to *ASCE/SEI 7-10* C&C roof coefficients and Table 1b provides the same comparison for the larger roof overhang coefficients. Figure 3 provides an overview of the various roof zones as defined in *ASCE/SEI 7-16* for a gable roof with roof slopes between 7 and 45 degrees. Tables 1a and 1b also show the roof coefficients as implemented for *2018 WFCM* chapters 2 and 3. *WFCM* Chapter 2 uses the maximum magnitude suction loads for roof slopes between 7 and 45 degrees in Roof Zones 1, 2, and 3. *WFCM* Chapter 3 further simplifies the roof loading requirements by combining Roof Zones 2 and 3 into an end zone and reducing the magnitude of Zone 3 loads by limiting rake overhangs. As a result of these simplifications, the effective uplift pressures on critical roof edge and overhang zones is limited to an 11% increase in WFCM Chapter 3 requirements as shown in Tables 1a and 1b (e.g. -4.1 coefficient under *ASCE 7-16* versus -3.7 coefficient under *ASCE 7-10*). This results in a smaller increase in uplift load requirements between editions of the WFCM than the actual percent increase in design pressures between *ASCE/SEI 7-10* and *ASCE/SEI 7-16*.

Table 1a. Comparison of C&C Roof Coefficients [a] (suction)

	ASCE 7-16						ASCE 7-10					
	Roof GC_p - GC_{pi}						Roof GC_p - GC_{pi}					
	3r	3e	2n	2r	2e	1	3r	3e	2r	2n	2e	1
7 < Θ ≤ 20	-3.8	-3.2	-3.2	-3.2	-2.2	-2.2	-2.8	-2.8	-1.9	-1.9	-1.9	-1.1
20 < Θ ≤ 27	-3.8	-2.7	-2.7	-2.7	-1.7	-1.7	-2.8	-2.8	-1.9	-1.9	-1.9	-1.1
27 < Θ ≤ 45	-2.2	-3.4	-2.2	-2.0	-2.0	-2.0	-1.4	-1.4	-1.4	-1.4	-1.4	-1.2
Maximum (suction)	**-3.8**	**-3.4**	**-3.2**	**-3.2**	**-2.2**	**-2.2**	**-2.8**	**-2.8**	**-1.9**	**-1.9**	**-1.9**	**-1.2**
WFCM Ch. 2 Simplified	**-3.8**		**-3.2**			**-2.2**	**-2.8**		**-1.9**			**-1.2**
WFCM Ch. 3 Simplified	**-4.1 [b]**					**-2.2**	**-3.7**					**-1.2**

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Table 1b. Comparison of C&C Roof Overhang Coefficients (suction)

	ASCE 7-16						ASCE 7-10					
	Roof Overhang GC_p						Roof Overhang GC_p					
	3r	3e	2r	2n	2e	1	3r	3e	2r	2n	2e	1
7 < Θ ≤ 20	-4.7	-4.1	-3.5	-3.5	-2.5	-2.5	-3.7	-3.7	-2.2	-2.2	-2.2	-
20 < Θ ≤ 27	-4.7	-3.6	-3.0	-3.0	-2.0	-2.0	-3.7	-3.7	-2.2	-2.2	-2.2	-
27 < Θ ≤ 45	-2.8	-4.0	-2.8	-2.6	-2.6	-2.6	-2.0	-2.0	-2.0	-2.0	-2.0	-
Maximum (suction)	**-4.7**	**-4.1**	**-3.5**	**-3.5**	**-2.6**	**-2.6**	**-3.7**	**-3.7**	**-2.2**	**-2.2**	**-2.2**	**-**
WFCM Ch. 2 Simplified	**-4.7**		**-3.5**			**-** [c]	**-3.7**		**-2.2**			**-**
WFCM Ch. 3 Simplified	**-4.1** [b]					**-** [c]	**-3.7**					**-**

a. C&C roof coefficients include external and internal pressures assuming an enclosed structure.

b. In *2018 WFCM* Chapter 3, the maximum length of rake overhangs (without outlookers) has been limited to 9”, so the effective GC_p value in overhang zone 3r is less than non-overhang zone 3r or overhang zone 3e.

c. In *2018 WFCM* Chapter 3, the maximum length of eave and rake overhangs has been limited to 2’, so a Zone 1 Overhang would never exist since the edge dimension “a” is always greater than 2’.

Changes to Fastener Design

Wind uplift related changes include new fastener withdrawal and new fastener head pull-through design provisions.

<u>Roof Sheathing Ring Shank Nails</u>

Roof Sheathing Ring Shank (RSRS) nails were recently added to *ASTM F 1667 Standard Specification for Driven Fasteners: Nails, Spikes, and Staples*. Design provisions for RSRS nails have been added to the *2018 NDS* and *2018 WFCM*. RSRS nails, which have larger withdrawal design values than smooth shank nails of equal length and diameter, provide additional options for efficient attachment of wood structural panel roof sheathing. In many cases, specification of RSRS nails will produce a reduced roof sheathing attachment schedule than permissible by use of smooth shank nails and enable use of a single minimum fastener schedule for roof perimeter edge zones and interior zones. Recognition of higher withdrawal

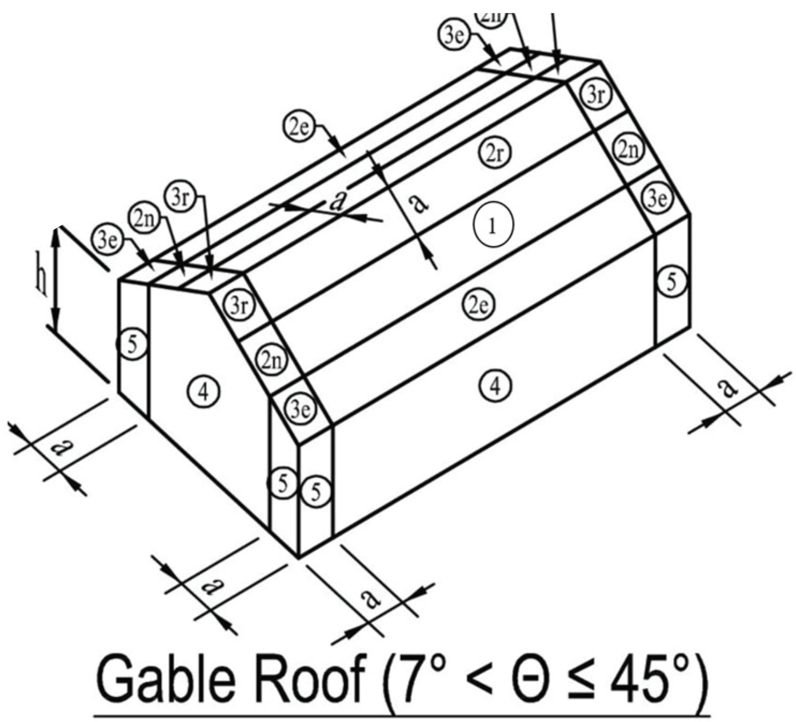

Figure 3. Overview of various gable roof zones as defined in ASCE/SEI 7-16

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strength is based on presence of 1-1/2" length of standardized ring deformations on the nail.

<u>Fastener Head Pull-through Provisions</u>
Fastener head pull-through design in accordance with NDS 2018 is incorporated in to sheathing attachment requirements for resistance to wind uplift/suction forces. For design of roof sheathing fastening to resist wind uplift, the lesser of the head pull-through design value or the fastener withdrawal design value from wood is used to establish the "fastener uplift capacity" as shown in Figure 4 which is excerpted from *2018 WFCM* Table 3.10.

Sheathing Thickness (in.)	Fastener Uplift Capacity[2, 3] (lbs) 3/8		7/16		15/32		19/32		23/32	
Framing Member G	**0.42**	**0.49**	**0.42**	**0.49**	**0.42**	**0.49**	**0.42**	**0.49**	**0.42**	**0.49**
8d common[4]	70	91	68	100	67	98	63	92	58	86
10d box[4]	84	101	82	118	81	120	77	114	73	108
RSRS-03[5]	91	91	99	106	99	114	99	135	99	135

2 Minimum capacity of withdrawal and fastener head pull-through is tabulated.
3 Tabulated values include a load duration factor adjustment, C_D=1.6.
4 Tabulated values for 8d common nails and 10d box nails are applicable to carbon steel nails (bright or galvanized).
5 Tabulated values for RSRS-03 nails are applicable to carbon steel (bright or galvanized) or stainless steel nails.

Figure 4. Excerpt from *2018 WFCM* Table 3.10 showing fastener uplift capacity controlled either by nail withdrawal capacity or head pull-through.

<u>Example</u>

Compare fastener uplift capacity of 8d Common and RSRS-03 nails as shown in Figure 4. Fastener uplift capacity is the lesser of withdrawal and head pull through.

Assume 180 mph Exposure B wind loads, 19/32" WSP sheathing, framing specific gravity (G) = 0.49 or higher, and rafter spacing = 24". Using 2018 WFCM Table 3.10, the required nailing pattern (i.e. panel edge/panel field) at roof perimeter zones and interior zones is shown in Table 2.

Table 2. Comparison of RSRS-03 to 8d Common Nailing Patterns for High Wind.[a]

Nail Type[b]	**Roof Perimeter Zone Nail Spacing** (o.c. WSP edge/interior, inches)	**Roof Interior Zone Nail Spacing** (o.c. WSP edge/interior, inches)
RSRS-03 (L=2.5", TL=1.5", D=0.131", H=0.281")	6/6	6/12
8d Common (L=2.5", D=0.131", H=0.281")	4/4	6/6

a. Assume 180 mph Exposure B wind loads, 19/32" WSP sheathing, framing specific gravity (G) = 0.49 or higher, and rafter spacing = 24".

b. TL=thread length, D=diameter, H=head diameter, L=length.

In this case, the RSRS nail provides nailing pattern options that reduce required nailing when compared to 8d common smooth shank nails.

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Roof Rake Overhangs

Rake overhang provisions were revised to clarify terminology and limit rake overhang lookout blocks to 9 inches (previously limited to 12 inches) based on increased wind pressures (see Figure 5a). Rake overhang outlooker provisions were expanded to tabulate requirements for overhang spans of 12”, 16” and 19.2” in addition to 24” previously tabulated (see Figure 5b). The smaller span cases were added to address increased wind pressures and remove conservatism associated with tabulated requirements based only on assumed 24” overhang span.

Shear Wall Assemblies

Shear wall aspect ratio adjustments were revised to be consistent with the *2015 Special Design Provisions for Wind and Seismic (SDPWS)*. Shear walls using gypsum wallboard are subject to the following limits (underlines show clarifying text added to *2018 WFCM*):

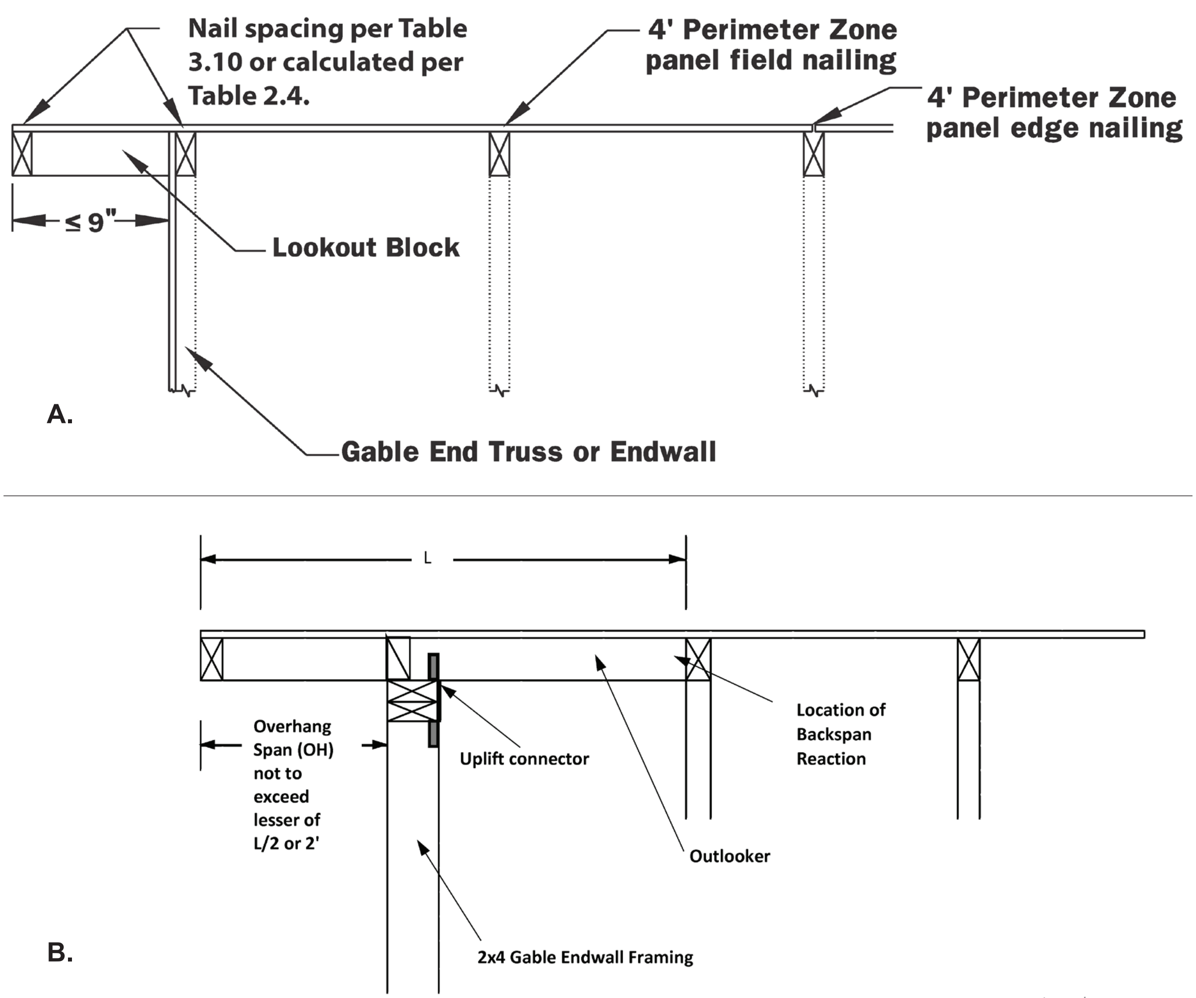
Gypsum wallboard walls having aspect ratios exceeding 1.5:1 shall be blocked. Where shear walls are gypsum wallboard only, the maximum aspect ratio shall not exceed 2:1 in accordance with *AWC/ANSI Special Design Provisions for Wind and Seismic (SDPWS)* Table 4.3.4.

Shear walls with blocked wood structural panel sheathing now show a maximum shear wall segment aspect ratio for wind of 2:1 (previously 3.5:1). However, the *2018 WFCM* still allows aspect ratio increases up to 3.5:1 for walls with blocked WSP sheathing or structural fiberboard sheathing provided the unit shear capacity and sheathing type adjustment factor are adjusted in accordance with *2015 SDPWS* Section 4.3.3.4.1 Exception 1 for wood structural panel shear walls or Exception 2 for structural fiberboard shear walls.

Figure 5. Rake Overhang Outlooker and Lookout Block Details (excerpted from *2018 WFCM*).

A. Lookout Block Detail

B. Outlooker Detail



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Applicability to Non-Residential Structures

IBC 2309 allows for use of the *WFCM* for non-residential structures within its scoping limitations:

(IBC) 2309.1 Wood Frame Construction Manual. Structural design in accordance with the AWC WFCM shall be permitted for buildings assigned to Risk Category I or II subject to the limitations of Section 1.1.3 of the AWC WFCM and the load assumptions contained therein. Structural elements beyond these limitations shall be designed in accordance with accepted engineering practice.

While *WFCM* provisions are intended primarily for detached one-and two-family dwellings due to the floor live load assumption associated with those occupancies, many of the *WFCM* provisions for specific geographic wind, seismic, and snow loads may be applicable for other buildings. For example, wind provisions for sizing of roof sheathing, wall sheathing, fastening schedules, uplift straps, shear anchorage, shear wall lengths, and wall studs for out of plane wind loads are included in the *WFCM* and are applicable for other use groups within the load limitations of the *WFCM* tables. Similarly, roof rafter size and spacing for heavy snow, and shear wall lengths and anchorage for seismic are applicable within the load limitations of the *WFCM* tables. Examples of non-residential applications include single-story wood structures or top stories in mixed use structures in Risk Categories I or II.

Applications outside the scope of the *WFCM* tabulated requirements, such as floor joist design for floor live loads greater than 40 psf and design of supporting gravity elements for the additional floor live load is beyond the applicability of the *WFCM* and must be designed in accordance with accepted engineering practice. This parallels the approach taken in *IRC* Section R301.1.3, which permits unconventional elements of one and two-family dwellings to be designed per the *IBC*.

More Details

A section by section list of changes to the *WFCM* is available in the Appendix to this paper.

Availability

The *2018 WFCM* is currently available in electronic format (PDF) only. Once the *WFCM Commentary* is updated, printed copies will be available for purchase. Check the AWC website (www.awc.org) for status updates on the *2018 WFCM*.

Conclusion

The *2018 WFCM* represents the state-of-the-art for design of wood members and connections. The *2018 WFCM* updates pre-engineered design provisions based on loads from ASCE 7-16 and design requirements from the 2018 NDS and 2015 SDPWS. Both the *2018 IRC* and *2018 IBC* reference the 2018 *WFCM* for design of wood structures.

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Appendix

Summary of Changes - *2018 Wood Frame Construction Manual (WFCM) for One- and Two-Family Dwellings*

Section	Description of Change
Chapter 1 General Information	1) Updated design load reference from *ASCE 7-10* to *ASCE 7-16 Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. 2) Revised Figure 1.1 Basic Wind Speeds for One- and Two-Family Dwellings Based on 3-second Gust Basic Wind Speeds for Risk Category II Buildings to coordinate with updated reference to *ASCE 7-16*. 3) Added requirements for identification and description of wood structural panels to recognize “Performance Category” consistent with the *International Building Code*. *WFCM* reference to wood structural panel (WSP) thickness appears in several forms. Reference to WSP thickness were revised throughout the standard to consistently describe wood structural panels and more accurately describe thickness as a nominal value to coordinate with the change to Section 1.2.1.8. For example: 15/32” Wood Structural Panel becomes Nominal 15/32” Wood Structural Panel; 7/16” becomes Nominal 7/16”; Minimum Panel Thickness (in.) becomes Minimum Nominal Panel Thickness (in.).
Chapter 2 Engineered Design	1) Revisions to coordinate with *ASCE 7-16* wind pressures and lower wind speed categories (e.g. 90, 95, 100, and 105 mph) include the following: Section 2.1.3.1 Adjustments for Wind Exposure and Mean Roof Height Table 2.1.3.1 Adjustment for Wind Exposure and Mean Roof Height Table 2.1 Lateral Framing Connection Loads from Wind Table 2.2A Uplift Connection Loads from Wind Table 2.2B Ridge Connection Loads from Wind Table 2.2C Rake Overhang Outlooker Uplift Connection Loads Table 2.4 Roof and Wall Sheathing Suction Loads Table 2.5A Lateral Diaphragm Loads from Wind – Perpendicular to Ridge Table 2.5B Lateral Diaphragm Loads from Wind – Parallel to Ridge Table 2.5C Lateral Diaphragm Loads from Wind – Parallel to Ridge (For Attic Floor or Ceiling Diaphragm When Bracing Gable Endwall) Table 2.9A Exterior Wall Stud Bending Stresses from Wind Loads Table 2.10 Exterior Wall Stud Wind Loads (Normal to the Wall Surface). This wind pressure table replaces previously tabulated “induced moments” to facilitate checking deflection per building code deflection criteria. Table 2.14A Rafter Spans for 20 psf Live Load. Revisions remove footnote for wind design based on addition of new Table 2.16 and new Table 3.26M. Table 2.15A Roof Framing Capacity Requirements for 20 psf Roof Live Load. Revisions remove footnote for wind design based on addition of new Table 2.16. Table 2.16 Roof Framing Wind Loads (Normal to the Roof Surface). This new table provides wind pressures for rafter design for wind. Coordinating change to charging text is in 2.5.1.1 Rafters. Existing Table 2.16 and Table 2.17 are re-numbered Table 2.17 and Table 2.18, respectively. 2) Revised Section 2.1.5.6 Fasteners incorporates fastener criteria from the *2018 National Design Specification (NDS) for Wood Construction* including provisions for roof sheathing ring shank (RSRS) nails and fastener head pull through design values. 3) Revised Section 2.5.1.1.3 Rake Overhangs clarifies terminology and limits rake overhang lookout blocks to 9 inches based on increased wind pressures as follows: Revised Figure 2.1h to reflect the 9 inch limit. Revised Figure 2.1g Rake Overhang limits – Outlookers clarifies call-outs for the rake overhang detail. 4) Revised Figure 2.3 title and figure labels clarify applicability of the detail to floor and roof construction.

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Chapter 3 Prescriptive Design	1) Revisions to coordinate with *ASCE 7-16* wind pressures and lower wind speed categories (e.g. 90, 95, 100, and 105 mph) include the following list of tables: Table 3.2 Sill or Bottom Plate to Foundation Requirements for Wind Table 3.2A Sill Plate to Foundation Connections Resisting Shear Loads from Wind Table 3.2C Sill or Bottom Plate to Foundation Connections (Anchor Bolts) Resisting Uplift from Wind Table 3.4 Rafter/Truss Framing to Wall Connection Requirements for Wind Loads Table 3.4A Rafter and/or Ceiling Joist to Top Plate Lateral and Shear Connection Requirements Table 3.4B Shear Walls Resisting Uplift and Shear Table 3.4C Rake Overhang Outlooker Uplift Connection Requirements. Revisions include new prescribed connection and framing requirements to enable sheathing to span with strong axis across support provided by blocking and fly rafter. Table 3.5 Top and Bottom Plate to Stud Lateral Connection Requirements for Wind Loads Table 3.5A Top and Bottom Plate to Stud Lateral Connections for Wind Loads Revisions also remove Footnote 2 since it is a carryover from Footnote 1 in Table 3.5 (Unit Framing Loads) where the footnote is more applicable. There is also never a case in Table 2.5A where footnote 2 would reduce the number of nails required. Table 3.6 Ridge Connection Requirements for Wind Table 3.7 Header Connection Requirements for Wind Table 3.8 Window Sill Plate Connection Requirements for Wind Table 3.10 Roof Sheathing Attachment Requirements for Wind Loads. Table 3.10 is a replacement of the former table and includes both requirements for uplift load per nail and fastener uplift capacity. Fastener uplift capacity is in accordance with NDS and based on nail type, sheathing thickness, and framing specific gravity (G). Table 3.10A Roof Sheathing Attachment Requirements for Wind Loads (Prescriptive Alternative to Table 3.10). Table 3.10A is similar to former Table 3.10 and provides prescriptive nailing at panel edges and in the panel field for assumed 7/16 nominal panel thickness and framing G=0.50. Table 3.11 Wall Sheathing and Cladding Attachment Requirements for Wind Loads Table 3.12A Roof Sheathing Requirements for Wind Loads. Revisions for WSP sheathing address recommended inclusion of panel span rating, associated with sheathing grades, to potentially avoid misapplications based on specifying nominal thickness only. Table 3.13A Wall Sheathing Requirements for Wind Loads. Revisions for WSP sheathing with strength axis parallel to supports are in accordance with revised panel capacities in *SDPWS 2015* and address recommended inclusion of panel span rating to potentially avoid misapplications based on specifying nominal thickness only. Potentially smaller required span ratings and nominal thickness for Structural I Sheathing with greater cross-bending properties is addressed by footnote 5. Table 3.13B Wall Cladding Requirements for Wind Loads Table 3.15 Minimum Attic Floor/Ceiling Lengths When Bracing Gable Endwall for Wind Loads Table 3.16A1-A4 Roof Diaphragm Limits for Wind Table 3.16B Floor Diaphragm Limits for Wind Table 3.17A Segmented Shear Wall Sheathing Requirements for Wind Table 3.20 A1-A6 Maximum Exterior Loadbearing and Non-Loadbearing Stud Lengths Resisting Interior Zone Wind Loads Table 3.20 B1-B6 Maximum Exterior Loadbearing and Non-Loadbearing Stud Lengths Resisting Interior Zone Wind Loads Table 3.23A Laterally Unsupported (Dropped) Header Spans for Exterior Loadbearing Walls Resisting Wind Loads Table 3.23B Laterally Unsupported (Dropped) Header Spans for Exterior Non- Loadbearing Walls and Window Sill Plate Spans Resisting Wind Loads Table 3.26M Rafter Spans for Wind Loads. New span tables for roof rafters based on wind pressures. Table 3.26M replaces footnote 3 of Table 3.26A which is removed. 2) Revised Section 3.1.3.4c and Section 3.5.1.1.3 Rake Overhangs – clarify terminology used for rake overhangs and limit rake overhang lookout blocks to 9 inches. 3) Revised Table 3.17D to incorporate updated shear wall aspect ratio adjustments consistent with *SDPWS 2015*.

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Appendix	1) Revisions to coordinate with *ASCE 7-16* lower wind speed categories (i.e. 90, 95, 100, and 105 mph) include the following: Table A-3.4 Uplift Strap Connection Requirements (Roof-to-Wall, Wall-to-Wall, and Wall-to-Foundation) Table A-3.6 Ridge Tension Strap Connection Requirements for Wind 2) Revised Table A-3.4 and A-3.6 incorporates a check of strap capacity and removes cases where strap load exceeds the tension capacity of the strap based on calculations in accordance with *AISI S100 North American Specification for the Design of Cold-Formed Steel Structural Members*.