2005 National Design Specification® (NDS®) for Wood Construction

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The primary change in the *2005 NDS* is the introduction of load and resistance factor design (LRFD). Learn more about the format changes that were necessary to accommodate the addition of LRFD.

The 2005 Edition of the *National Design Specification for Wood Construction* has been approved as an American National Standard, with a designation *ANSI/AF&PA NDS-2005.* The 2005 NDS was developed as a dual format specification incorporating design provisions for both allowable stress design (ASD) and load and resistance factor design (LRFD). AF&PA's Wood Design Standards Committee (WDSC) guided it through the consensus process over the course of 2-1/2 years. The primary change in the *2005 NDS* is the introduction of LRFD methods to the Specification.

Several format changes to the *NDS* to accommodate addition of LRFD are summarized in this article and include:

- Revised terminology,
- Expanded applicability of adjustment factor tables,
- Re-format of radial tension design values,
- Revised format of beam and column stability provisions (addition of E_{min} property), and
- Addition of *NDS* Appendix N – Load and Resistance Factor Design.

A number of other changes introduced in the 2005 Edition include:

- Removal of form factor,
- Revision of repetitive member factor for I-joists,
- Revision of full-design value terminology, and
- Clarification of built-up column provisions.

The *NDS Supplement, Design Values for Wood Construction* has also been updated to provide the latest design values for sawn lumber and glued laminated timber. What follows are the updates most likely to affect those undertaking wood member design in the wood truss industry.

at a glance

- Wood allowable stress design, used extensively by the truss industry, does note change significantly in the *2005 NDS.*
- One of the key features of the *2005 NDS* is the work done to make the *NDS* more consistent in terminology and clarify sections that have been known to be confusing in the past.
- The *2005 NDS* has very minimal impact on allowable stress design and has the added benefit of having a transparent approach to learning and using load and resistance factor design.

Introducing LRFD to NDS – An Overview

Over the years, the WDSC identified benefits of developing a dual format specification which would include: addressing user needs for consistent design information regardless of design format (ASD or LRFD); better utilizing standards committee resources; and providing current design information for the academic community. The *2005 NDS* maintains the current *2001 NDS* format, familiar to most wood designers. As a result, *NDS 2005* is very similar to the *2001 NDS* for ASD design, with few exceptions.

Users familiar with the *NDS* ASD provisions will also find transition to LRFD straightforward. Behavioral equations, such as those for member and connection design, are the same for both ASD and LRFD. Adjustment factor tables now include applicable factors for determining an adjusted ASD design value or an adjusted LRFD design value. A new *Appendix N - Mandatory Appendix for Load and Resistance Factor Design (LRFD)* outlines requirements that are unique to LRFD and adjustment factors for LRFD.

Terminology:

Basic requirements for checking strength are revised to use terminology applicable to both ASD and LRFD. For example, the basic requirement for strength in bending is revised as follows:

> "3.3.1 The actual bending stress or moment shall not exceed the adjusted ~~allowable~~ bending design value."

In equation format, this takes the standard form $f_b \leq F_b'$. The term "allowable," typically associated with ASD, is replaced by "adjusted" to be more generally applicable to either ASD or LRFD and to better describe the approach of applying adjustment factors to reference design values. Reference design values (F_b, F_t, F_v, F_c, $F_{c\perp}$, E, E_{min}) are multiplied by adjustment factors to determine adjusted design values (F_b', F_t', F_v', F_c', $F_{c\perp}'$, E', E_{min}').

Applicability of Adjustment Factor Tables:

For member design, the adjusted bending design value, F_b', of a sawn lumber bending member is determined using Table 4.3.1 (see page 52) as follows:

For ASD:

$$F_b' = F_b \, C_D \, C_M \, C_t \, C_L \, C_F \, C_{fu} \, C_i \, C_r$$

For LRFD:

$$F_b' = F_b \, K_F \, \phi_b \, \lambda \, C_M \, C_t \, C_L \, C_F \, C_{fu} \, C_i \, C_r$$

where:

F_b = the reference bending design value based on normal load duration.

For connection design, the adjusted lateral design value, Z', of a dowel connection (i.e., nail, bolt, etc.) is determined using Table 10.3.1 *Applicability of Adjustment Factors for Connections* as follows:

For ASD:

$$Z' = Z \, C_D \, C_M \, C_t \, C_g \, C_\Delta \, C_{eg} \, C_{di} \, C_{tn}$$

For LRFD:

$$Z' = Z \, K_F \, \phi \, \lambda \, C_M \, C_t \, C_g \, C_\Delta \, C_{eg} \, C_{di} \, C_{tn}$$

where:

Z = the reference design value based on normal load duration. Z may be taken from connection tables directly or calculated using yield mode equations.

For ASD member and connection design, this approach is identical to that used in prior editions of the *NDS*. For LRFD member and connection design, adjustment factors applicable to reference design values, make conversion between ASD and LRFD-based design values transparent.

In the *2005 NDS,* "reference design value" designates the allowable stress design value based on normal load duration and replaces terms such as *tabulated, nominal, base,* and *published,* which were also based on normal load duration. The variety of terms was considered potentially confusing. For example, tabulated and published values outside of the Specification may already include adjustment factors.

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Table 4.3.1 Applicability of Adjustment Factors for Sawn Lumber

		ASD only	ASD and LRFD										LRFD only		
		Load Duration Factor	Wet Service Factor	Temperature Factor	Beam Stability Factor	Size Factor	Flat Use Factor	Incising Factor	Repetitive Member Factor	Column Stability Factor	Buckling Stiffness Factor	Bearing Area Factor	Format Conversion Factor	Resistance Factor	Time Effect Factor
$F_b' = F_b$	x	C_D	C_M	C_t	C_L	C_F	C_{fu}	C_i	C_r	-	-	-	K_F	ϕ_b	λ
$F_t' = F_t$	x	C_D	C_M	C_t	-	C_F	-	C_i	-	-	-	-	K_F	ϕ_t	λ
$F_v' = F_v$	x	C_D	C_M	C_t				C_i					K_F	ϕ_v	λ
$F_{c\perp}' = F_{c\perp}$	x	-	C_M	C_t	-	-	-	C_i	-	-	-	C_b	K_F	ϕ_c	λ
$F_c' = F_c$	x	C_D	C_M	C_t		C_F		C_i		C_P			K_F	ϕ_c	λ
$E' = E$	x	-	C_M	C_t	-	-	-	C_i	-	-	C_T	-	-	-	-
$E_{min}' = E_{min}$	x		C_M	C_t				C_i			C_T		K_F	ϕ_s	

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Nominal may be interpreted as nominal strength (especially with the addition of LRFD) rather than in current *NDS* use where it means unadjusted. To avoid confusion, the descriptor "reference" is used and serves as a reminder that design value adjustment factors are applicable for design values in accordance with referenced conditions specified in the *NDS*—such as normal load duration.

Revised Format of NDS Beam and Column Stability Provisions:

The *2005 NDS* includes a revised format for column and beam behavioral equations to address both ASD and LRFD:

NDS 2005 3.3.3.8:

3.3.3.8 The beam stability factor shall be calculated as follows:

$$C_L = \frac{1+\left(F_{bE}/F_b^*\right)}{1.9} - \sqrt{\left[\frac{1+(F_{bE}/F_b^*)}{1.9}\right]^2 - \frac{F_{bE}/F_b^*}{0.95}} \qquad (3.3\text{-}6)$$

where:

F_b^* = reference bending design value multiplied by all applicable adjustment factors except C_{fu}, C_V, and C_L (see 2.3) and

$F_{bE} = 1.20E_{min}' / R_b^2$.

The value $F_{bE} = 1.20E_{min}' / R_b^2$ is algebraically equivalent to and replaces $F_{bE} = K_{bE}\,E' / R_b^2$ used in the *2001 NDS*. Because the design equation for K_{bE} includes a reduction for safety, two different formats of the *2001 NDS* equation would be needed to address both ASD and LRFD.

Instead, the *2005 NDS* utilizes E_{min}, which is adjusted for safety, so the safety factor is not part of the basic design equation. Applicable adjustments to E_{min}, based on applicability of adjustment factor tables are used to establish the appropriate adjusted modulus of elasticity for beam and column stability, E_{min}' for either ASD or LRFD.

NDS 2005 3.7.1.5:

3.7.1.5 The column stability factor shall be calculated as follows:

$$C_P = \frac{1+\left(F_{cE}/F_c^*\right)}{2c} - \sqrt{\left[\frac{1+(F_{cE}/F_c^*)}{2c}\right]^2 - \frac{F_{cE}/F_c^*}{c}} \qquad (3.7\text{-}1)$$

where:

F_c^* = reference compression design value parallel to grain multiplied by all applicable adjustment factors except C_P (see 2.3) and

$F_{cE} = 0.822E_{min}' / (l_e/d)^2$.

The value $F_{cE} = 0.822E_{min}' / (l_e/d)^2$ is algebraically equivalent to and replaces $F_{cE} = K_{cE}\,E' / (l_e/d)^2$ used in the *2001 NDS*. The background justification for this change is identical to that for the beam equation in 3.3.3.8.

Modulus of Elasticity for Beam and Column Stability, E_{min}':

For sawn lumber and glulam, reference modulus of elasticity for beam and column stability, E_{min} (which represents an approximate 5 percent lower exclusion value on pure bending modulus of elasticity, divided by a 1.66 factor of safety),

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is tabulated in the NDS Supplement. However, it can also be calculated as follows:

$$E_{min} = 1.03E\ (1\text{-}1.645(COV_E))\ /\ 1.66$$

where:

E = reference modulus of elasticity,

1.03 = adjustment factor to convert E to a pure bending basis except that the factor is 1.05 for glued laminated timber,

1.66 = factor of safety, and

COV_E = coefficient of variation in modulus of elasticity (see *NDS* Appendix F).

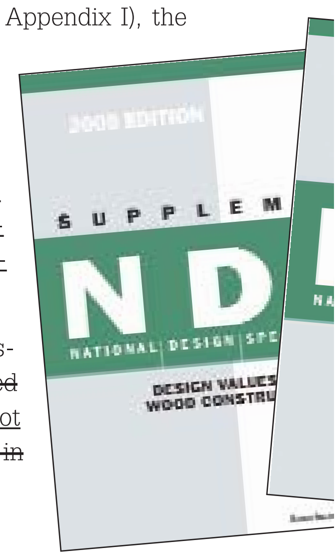
Repetitive Member Factor for I-joists:
Revision to the *NDS 2005* repetitive member factor, C_r, for I-joists corresponds to revisions in ASTM D5055-02 setting the factor equal to 1.0:

> **7.3.6 Repetitive Member Factor, C_r**
> For prefabricated wood I-joists with structural composite lumber flanges or sawn lumber flanges, adjusted moment design resistances shall be multiplied by the repetitive member factor, C_r = 1.0

In lieu of complete removal of the C_r factor for I-joists in the *2005 NDS,* the repetitive member factor was set to 1.0 for clarity since past practice has permitted other C_r factors. For example, in the 2001 NDS, C_r= 1.04, for I-joists with structural composite lumber flanges and C_r = 1.07, for I-joists with sawn lumber flanges.

Revised "Full-Design Value" Terminology and Added Reference to Provisions for Checking Wood Stresses:
Phrases such as "minimum spacing for full design value" and "minimum end distance for full design value" are replaced with alternate descriptions since other provisions for evaluating wood strength must also be checked to ensure that the "full-design value" can be developed. Multiple references to section 10.1.2 are added as a reminder to check wood strength at connections. Example revisions follow:

> **10.2.2 Multiple Fastener Connections**
> When a connection contains two or more fasteners of the same type and similar size, each of which exhibits the same yield mode (see Appendix I), the total adjusted design value for the connection shall be the sum of the adjusted design values for each individual fastener. Local stresses in connections using multiple fasteners shall be checked in accordance with principles of engineering mechanics (see 10.1.2).
>
> 11.1.2.4 Edge distance, end distance, and fastener spacing ~~required to develop full design values~~ shall not be less than the requirements in ~~be in accordance with~~ Table 11.5.1A-D.



These revisions do not change methods for calculating strength of connections, but remove language that is potentially confusing. For example, there are additional requirements for checking wood strength at connections based on principles of engineering mechanics and procedures outlined in Appendix E for evaluating member strength around fastener groups.

Clarify 15.3.2.2 Built-Up Column Design:

Built-up column provisions were revised to correct an obvious but unintended limitation on short built-up columns.

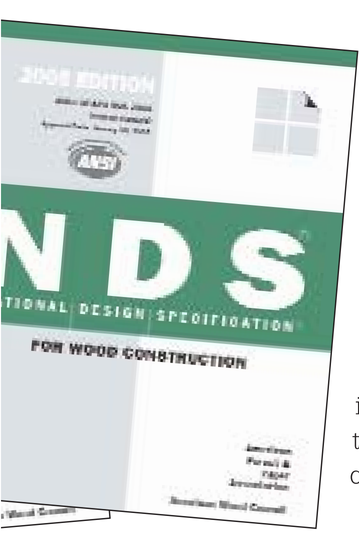
> 15.3.2.2.... F_c' for built-up columns need not be less than F_c' for the individual laminations designed as individual solid columns per section 3.7.

This change permits individual laminations in a built-up column to be designed using provisions of section 3.7 for solid columns. With this change, built-up columns are not unnecessarily limited to design capacities less than the sum of individual member capacities.

Additional Design Tools

The revised NDS will be packaged with additional publications as follows:

- *ANSI/AF&PA NDS-2005 with Commentary,*
- *NDS Supplement – Design Values for Wood Construction, 2005 Edition,*
- *ANSI/AF&PA SDPWS-05 Supplement – Special Design Provisions for Wind and Seismic (SDPWS)* with Commentary, and
- *ASD/LRFD Manual for Engineered Wood Construction, 2005 Edition.*



The 2005 Wood Design Package will be available later this year through WTCA Publications. Visit www.woodtruss.com/pubs to place your order online.

Conclusion

The primary change in the *2005 NDS* is the introduction of LRFD methods to the Specification. Several format changes to the *NDS* to accommodate the addition of LRFD have been summarized. Users will find very minimal impact on the ASD process as a result, with the added benefit of having a transparent approach to learn and use LRFD. An integrated commentary and other design tools will be available for the new standard. **SBC**

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