Summary
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 2½ years. The primary change in the 2005 NDS is the introduction of LRFD methods to the Specification. 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. 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 are available for the new standard.

1. 2005 NDS Changes and Additions
The 2005 Edition of the National Design Specification for Wood Construction was approved as an American National Standard on January 6, 2005, 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 2½ 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 paper 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 $E_{\text{min}}$ property)
• 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
• 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.

2. Introducing LRFD to the NDS - 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, to remain user-friendly. As a result, NDS 2005 is very similar to the 2001 NDS for ASD design, with few exceptions, one of them being that the 2005 NDS has green covers (Figure 1).

Users familiar with the NDS ASD provisions will also find transition to LRFD straight-forward. 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, such as LRFD load combinations consistent with ASCE 7-02, and adjustment factors for LRFD.

2.1 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 ($F_b, F_t, F_v, F_c, F_{c,\perp}, E, E_{\text{min}}$) are multiplied by adjustment factors to determine adjusted design values ($F_b', F_t', F_v', F_c', F_{c,\perp}', E', E_{\text{min}}'$).
2.2 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 (shown here) as follows:

For ASD: \[ F_{b}' = F_b \times C_D \times C_M \times C_t \times C_f \times C_{fr} \times C_i \times C_r \]
For LRFD: \[ F_{b}' = F_b \times K_F \times \phi \times \lambda \times C_M \times C_t \times C_f \times C_{fr} \times C_i \times C_r \]

where: $F_b$ is the reference bending design value based on normal load duration.

For connection design, the adjusted lateral design value, $Z'$, of a dowel connection is determined using Table 10.3.1 Applicability of Adjustment Factors for Connections as follows:

For ASD: \[ Z' = Z \times C_D \times C_M \times C_t \times C_g \times C_{\Delta} \times C_{eg} \times C_{di} \times C_{in} \]
For LRFD: \[ Z' = Z \times K_F \times \phi \times \lambda \times C_M \times C_t \times C_g \times C_{\Delta} \times C_{eg} \times C_{di} \times C_{in} \]

where: $Z$ is 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 design values 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. 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.

Table 1 2005 NDS Typical ASD and LRFD Adjustment Factor Table

<table>
<thead>
<tr>
<th>Table 4.3.1</th>
<th>Applicability of Adjustment Factors for Sawn Lumber</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ASD only</strong></td>
<td><strong>ASD and LRFD</strong></td>
</tr>
<tr>
<td>$F_{b}' = F_b$</td>
<td>$x$</td>
</tr>
<tr>
<td>$F_{t}' = F_t$</td>
<td>$x$</td>
</tr>
<tr>
<td>$F_{c}' = F_c$</td>
<td>$x$</td>
</tr>
<tr>
<td>$F_{c\Delta}' = F_{c\Delta}$</td>
<td>$x$</td>
</tr>
<tr>
<td>$F_{c\Delta}' = F_{c\Delta}$</td>
<td>$x$</td>
</tr>
<tr>
<td>$E' = E$</td>
<td>$x$</td>
</tr>
<tr>
<td>$E_{tan} = E_{tan}$</td>
<td>$x$</td>
</tr>
</tbody>
</table>

2.3 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:
\[ C_L = \frac{1 + \left( \frac{F_{bE}}{F_b^*} \right)}{1.9} - \sqrt{\frac{1 + \left( \frac{F_{bE}}{F_b^*} \right)^2}{1.9}} - \frac{F_{bE}}{0.95} \quad (3.3-6) \]

where:

- \( F_b^* \) = tabulated bending design value multiplied by all applicable adjustment factors except \( C_{fa}, C_V \) and \( C_L \) (see 2.3)
- \( F_{bE} = 1.20 \frac{E_{min}'}{R_b^2} \)

The value \( F_{bE} = 1.20 \frac{E_{min}'}{R_b^2} \) is algebraically equivalent to and replaces \( F_{bE} = K_b E' / R_b^2 \) 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 embedded in 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:

\[ C_p = \frac{1 + \left( \frac{F_{cE}}{F_c^*} \right)}{2c} - \sqrt{\frac{1 + \left( \frac{F_{cE}}{F_c^*} \right)^2}{2c}} - \frac{F_{cE}}{c} \quad (3.7-1) \]

where:

- \( F_c^* \) = reference compression design value parallel to grain multiplied by all applicable adjustment factors except \( C_p \) (see 2.3)
- \( F_{cE} = 0.822 \frac{E_{min}'}{(l_e/d)^2} \)

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

### 2.4 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% lower exclusion value on pure bending modulus of elasticity, divided by a 1.66 factor of safety), is tabulated in the *NDS Supplement* but can also be calculated as follows:

\[ E_{min} = 1.03 E (1 - 1.645(COV_E)) / 1.66 \quad (D-4) \]

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 glulam,
- 1.66 = factor of safety, and
- COV\(_E\) = coefficient of variation in modulus of elasticity (see *NDS Appendix F*)

### 2.5 Reformat of Radial Tension Design Values

Glulam radial tension values have been added to Table 5.3.1 *Applicability of Adjustment Factors for Glued Laminated Timber* to clarify use for both ASD and LRFD.
Reference values for radial tension, \( F_{rt} \), are provided in the glulam chapter to match the format of other reference design values in the NDS. In prior editions, equations for determining allowable design values for radial tension were specified.

### 2.6 New Appendix N

For LRFD only, Appendix N specifies format conversion factors \( (K_F) \) and phi factors \( (\phi) \) consistent with those in ASTM D5457 – Standard Specification for Computing the Reference Resistance of Wood-Based Materials and Structural Connections for Load and Resistance Factor Design.

Applicable time effect factors are associated with load combinations of ASCE 7-02 – Minimum Design Loads for Buildings and Other Structures and are provided in Table N3 (shown here as Table 2):

**Table 2**

2005 NDS Table N3 Time Effect Factor, \( \lambda \) (LRFD Only)

<table>
<thead>
<tr>
<th>Load Combination</th>
<th>( \lambda )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.4(D+F)</td>
<td>0.6</td>
</tr>
<tr>
<td>1.2(D+F) + 1.6(( L ) or S or R)</td>
<td>0.6</td>
</tr>
</tbody>
</table>
| 1.2(D+F) + 1.6(\( L \)+H) + 0.5(L or S or R) | 0.7 when \( L \) is from storage  \( \)
|                   | 0.8 when \( L \) is from occupancy  \( \)
| \( 1.2H \) + 1.6(L or S) + (L or 0.8W) | 0.8 |
| \( 1.2D \) + 1.6W + L + 0.5(L or S or R) | 1.0 |
| \( 1.2D \) + 1.0E + L + 0.2S | 1.0 |
| \( 0.9D \) + 1.6W + 1.6H | 1.0 |
| \( 0.9D \) + 1.0E + 1.6H | 1.0 |

1. Time effect factors, \( \lambda \), greater than 1.0 shall not apply to connections or to structural members pressure-treated with waterborne preservatives (see Reference 30) or fire retardant chemicals.
2. Load combinations and load factors consistent with ASCE 7-02 are listed for ease of reference. Nominal loads shall be in accordance with N1.12.

Application of the time effect factor \( (\lambda) \) was also clarified for cases involving load due to lateral earth pressure, ground water pressure or pressure of bulk materials, \( H \). For cases where \( H \) is not in combination with \( L \), a \( \lambda = 0.6 \) is applicable.

### 2.7 Removal of Form Factor

The form factor, \( C_f \), has been removed from the 2005 NDS. Plastic deformation of small clear test specimens provided theoretical justification; however, plastic deformation observed in small clear test specimens may not be applicable to full size members.

Additionally, applicability of form factors to standard wood products addressed in the NDS was limited. Pole and pile design values do not permit further adjustment by the form factor and the form factor for the specific case of a square member loaded about its diagonal was considered to be an uncommon design case.

### 2.8 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.

2.9 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 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.

2.10 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…. Each ratio shall be used to calculate a column stability factor, \( C_p \), per section 15.3.2.4 and the smaller \( C_p \) shall be used in determining the allowable compression design value parallel to grain, \( F_c' \), for the column. \( F_c' \) 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.
3. **2005 NDS Supplement Changes and Additions**

An integral part of the National Design Specification® (NDS®) for Wood Construction is the NDS Supplement – Design Values for Wood Construction. The 2005 NDS Supplement has been updated to include the latest design values for visually graded lumber and timber, mechanically graded lumber, and glued laminated timber. An overview of those changes is presented below.

### 3.1 Modulus of Elasticity for Beam and Column Stability

A notable change to all design values tables in the NDS Supplement is the addition of modulus of elasticity for beam and column stability, $E_{\min}$, design values. The 2005 NDS utilizes $E_{\min}$, which represents a 5% lower exclusion shear-free $E$ value so that design value adjustments are not part of the basic design equation for beam and column stability. Applicable adjustments to $E_{\min}$ are used to establish the appropriate adjusted modulus of elasticity for beam and column stability, $E'_{\min}$, for either ASD or LRFD. NDS Supplement tables now show the additional $E_{\min}$ column for visually graded dimension lumber, visually graded timbers and structural glued laminated timber, respectively. Similar values are included in tables for other materials as well.

### 3.2 Visually Graded Dimension Lumber

Four new species have been added to the 2005 NDS Supplement for visually graded dimension lumber: Alaska Cedar, Alaska Hemlock, Alaska Yellow Cedar, and Baldcypress. Alaska Cedar grows in Alaska and the western States. Alaska Yellow Cedar lumber is manufactured from timber grown only in Alaska.

### 3.3 Mechanically Graded Dimension Lumber

New design values have been added for mechanically graded dimension lumber. Specifically, footnote 2 of Table 4C in the NDS Supplement provides specific gravity, shear parallel to grain, and compression perpendicular to grain design values for machine stress rated (MSR) and mechanically evaluated lumber (MEL).

As with visually graded lumber and timbers, modulus of elasticity for beam and column stability, $E_{\min}$, design values have been added to Table 4C for MSR and MEL lumber.

### 3.4 Visually Graded Timbers

Two new species have been added to the 2005 NDS Supplement for visually graded timbers: Alaska Cedar and Baldcypress.

### 3.5 Non-North American Species

Several new species have been added to Table 4F - Reference Design Values for Non-North American Visually Graded Dimension Lumber. Table 3 summarizes the new Non-North American Species.
Table 3
New Non-North American Species Added to Table 4F in the 2005 NDS Supplement – Design Values For Wood Construction

<table>
<thead>
<tr>
<th>Species</th>
<th>Grading Rules Agency</th>
</tr>
</thead>
<tbody>
<tr>
<td>MONTANE PINE - South Africa</td>
<td>WCLIB</td>
</tr>
<tr>
<td>NORWAY SPRUCE - Romania &amp; the Ukraine</td>
<td>WCLIB</td>
</tr>
<tr>
<td>SILVER FIR (Abies alba) - Germany, NE France, and Switzerland</td>
<td>WCLIB</td>
</tr>
<tr>
<td>SOUTHERN PINE - Misiones Argentina</td>
<td>SPIB</td>
</tr>
<tr>
<td>SOUTHERN PINE - Misiones Argentina, Free of Heart Center and Medium Grain Density</td>
<td>SPIB</td>
</tr>
</tbody>
</table>

3.6 Structural Glued Laminated Timber

Several changes have been made to structural glued laminated timber design values in the 2005 NDS Supplement. As with dimension lumber and timber tables, modulus of elasticity for beam and column stability, $E_{min}$, design values have been added for glued laminated timber.

Species groups for split ring and shear plate connectors were removed from Tables 5A-5D. In some cases, these groups did not correspond to species groups assigned according to NDS Table 12A. A review of the data used to establish connector species groups indicated that values in Table 12A are appropriate. Specific gravity, $G$, of the wood located on the face receiving the connector should be used with NDS Table 12A for assignment of species group. This change is consistent with current recommendations of the American Institute of Timber Construction (AITC) and APA-The Engineered Wood Association.

There were specific changes to Tables 5A, 5A-Expanded, and 5B. An overview is provided below and is organized by NDS Supplement table number.

3.6.1 Table 5A Design Values for Structural Glued Laminated Softwood Timber (Members stressed primarily in bending) and Table 5A Expanded – Design Values for Structural Glued Laminated Timber (Members stressed primarily in bending)

In Table 5A of the 2005 NDS Supplement, design values for tension parallel to grain, $F_t$, compression parallel to grain, $F_c$, and specific gravity, $G$, are revised for the 16F stress class. The 2001 NDS Supplement showed different values for this stress class in Table 5A versus 5A-Expanded. Analysis indicated that the values in Table 5A-Expanded were correct, so Table 5A was updated accordingly.

Shear parallel to grain (horizontal shear) design values have increased for prismatic members, and adjustment factors in accordance with Footnote 4 have been revised. Horizontal shear values in the 2001 NDS Supplement were based on full-scale tests of laminated beams, which were reduced by 10% based on judgments made at that time. Shear values for non-prismatic members were those derived according to ASTM D3737 from tests of small shear-block specimens. Since that time, the structural glued laminated timber industry has revised its recommendations and has elected to publish test-based shear values for prismatic members, removing the 10% reduction. This change is adopted in the 2005 NDS Supplement consistent with recommendations of AITC and APA. Footnote 4 adjustment factors were revised to keep shear values for non-prismatic members essentially unchanged.

Historically, radial tension design values for structural glued laminated timber were established as 1/3 of shear parallel to grain design values. In the 1991 NDS, radial tension values were 67 psi for
Southern Pine and 55 psi for Douglas Fir-Larch, respectively. For Douglas Fir-Larch, radial reinforcement designed to carry all induced stresses was required to utilize this number, otherwise the radial tension value was limited to 15 psi; this point was clarified in the 2005 NDS. Comparing 2005 to 1991 NDS Supplements in Table 4, increased shear values for non-prismatic members of Douglas Fir-Larch and Southern Pine have resulted in small increases for radial tension design values in these species. The slightly increased radial stress are recommended by AITC and APA and are considered appropriate and preferable to multiple adjustment factors as were used in the 2001 NDS.

Table 4
Shear Parallel to Grain Design Value (\(F_v\)) Comparison for Southern Pine and Douglas Fir Glued Laminated Timber from 1991 to Present, PSI.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Douglas Fir</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prismatic Members</td>
<td>165</td>
<td>190</td>
<td>240</td>
<td>265</td>
</tr>
<tr>
<td>Notched/Connections/Cyclic</td>
<td>165</td>
<td>190</td>
<td>192 (= 240 x 0.8)</td>
<td>191 (= 265 x 0.72)</td>
</tr>
<tr>
<td>Radial Tension (Reinforced)</td>
<td>55 (= 165 / 3)</td>
<td>63 (=190 / 3)</td>
<td>56 (= 240 x 0.7 / 3)</td>
<td>63 (= 191 / 3)</td>
</tr>
<tr>
<td><strong>Southern Pine</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prismatic Members</td>
<td>200</td>
<td>240</td>
<td>270</td>
<td>300</td>
</tr>
<tr>
<td>Notched/Connections/Cyclic</td>
<td>200</td>
<td>240</td>
<td>216 (= 270 x 0.8)</td>
<td>216 (= 300 x 0.72)</td>
</tr>
<tr>
<td>Radial Tension</td>
<td>67 (= 200 / 3)</td>
<td>80 (=240 / 3)</td>
<td>63 (= 270 x 0.7 / 3)</td>
<td>72 (= 216 / 3)</td>
</tr>
</tbody>
</table>

3.6.2 Table 5B Design Values for Structural Glued Laminated Softwood Timber (Members Stressed Primarily in Axial Tension or Compression)

Table 5B of the NDS Supplement incorporates the following changes:
- Re-formatting of bending design values for bending about the X-X axis, \(F_{bx}\). If special tension laminations are included, tabulated values may be adjusted according to applicable footnotes.
- New combinations for Southern Pine were added with extra information regarding slope of grain differences.
- Shear value columns were consolidated for bending about the Y-Y axis, \(F_{vy}\), and shear values were updated consistent with Table 5A discussion above.

4. Additional Design Tools

The revised NDS will be packaged with additional publications as follows:
- ANSI/AF&PA SDPWS-05 NDS Supplement – Special Design Provisions for Wind and Seismic with Commentary

A related design tool has been developed to assist designers with the use of the 2005 NDS. A workbook titled LRFD Solved Example Problems for Wood Structures has been updated and renamed Structural Wood Design Using ASD and LRFD to include parallel ASD solutions to the 40 LRFD example problems shown in the former.
5. 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 are available for the new standard.

The 2005 NDS Supplement has been updated to include the latest design values for visually graded lumber and timber, mechanically graded lumber, and structural glued laminated timber. An overview of those changes has been presented. The most notable change to all design values tables in the NDS Supplement is the addition of modulus of elasticity for beam and column stability, Emin, design values. The change to shear design values for prismatic glued laminated timber members is another significant modification.

6. References


