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American Forest & Paper Association
American Society of Civil Engineers

Standard for Load and Resistance Factor Design (LRFD) for Engineered Wood Construction

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Standard for Load and Resistance Factor Design (LRFD) for Engineered Wood Construction



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ABSTRACT:

This first *Standard for Load and Resistance Factor Design (LRFD) for Engineered Wood Construction* was prepared as a joint activity between the American Society of Civil Engineers and the American Forest & Paper Association (AF & PA) to provide design provisions based on reliability theory. This standard was the result of deliberations of a team of structural engineers and wood material scientists with wide experience and high professional standing. The team included professionals from private practice, industry, government, and universities. By reflecting this current state of knowledge, the *LRFD Standard* offers uniform practice in the design of engineered wood structures. It specifically covers such topics as: 1) Design requirements; 2) tension members; 3) compression members and bearing; 4) flexural members; 5) members with combined bending and axial loads; 6) mechanical connections; 7) structural-use panels; 8) shear walls and diaphragms; and 9) serviceability. In addition, the Appendices address issues such as: 1) Resistance of spaced columns; 2) glued laminated timber; 3) ponding; 4) qualification of fasteners and connectors; 5) resistance of shear plates; and 6) design of panel-based assemblies. Finally, a Glossary and a Commentary that provides additional background information are included.

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PREFACE

The design of wood structures has previously been governed by the general design provisions and recommended practice of the National Design Specification® for Wood Construction (NDS®). This specification was first adopted in 1944 and has been updated periodically to reflect new knowledge under the auspices of the American Forest & Paper Association (AF&PA) and its predecessor organizations, the National Lumber Manufacturers Association and the National Forest Products Association. In recognition of a new generation of standards based on reliability theory, this first Load and Resistance Factor Design (LRFD) Standard for Engineered Wood Construction was prepared as a joint activity between AF&PA and ASCE to provide alternate design provisions reflecting the current state of knowledge. The LRFD Standard was developed to provide uniform practice in the design of engineered wood structures.

Design criteria provide recommended practice for most applications but may not cover infrequently encountered designs for which additional judgment in applying data or recommendations must be exercised. It is intended that the LRFD Standard be used in conjunction with competent engineering design, accurate fabrication, and adequate supervision of construction. Particular attention is directed to the designer's responsibility to make adjustments for particular end use conditions.

The Appendices to this Standard are considered an integral part of the LRFD Standard. A Commentary has been prepared to provide additional background information. Users desiring further details leading to LRFD Standard provisions are requested to consult the Commentary and cited references.

Development of the LRFD Standard was a result of deliberations of a team of structural engineers and wood material scientists with wide experience and high professional standing. The team included professionals from private practice, industry, government, and universities. Review and trial use by practicing consulting engineers preceded publication.

The information contained herein is not intended as a representation or warranty, on the part of AF&PA or ASCE or any other person involved in its development, that this Standard is suitable for any general or particular use.

While every effort has been made to insure the accuracy of the data and information contained herein, neither AF&PA nor ASCE assumes responsibility for errors or omissions, nor for plans, designs, or construction prepared from this LRFD Standard.

Those using this LRFD Standard assume all liability arising from its use. The design of engineered structures is within the scope of expertise of licensed engineers, architects, or other licensed professionals for applications to a particular structure.

This Standard is not intended to preclude the use of any other materials, assemblies, or designs that can satisfactorily demonstrate adequate performance.

STANDARDS

In April 1980, the Board of Direction approved ASCE Rules for Standards Committees to govern the writing and maintenance of standards developed by the Society. All such standards are developed by a consensus standards process managed by the Management Goup F (MGF), Codes and Standards. The consensus process includes balloting by the balanced standards committee made up of Society members and non-members, balloting by the membership of ASCE as a whole and balloting by the public. All standards are updated or reaffirmed by the same process at intervals not exceeding five years.

The following standards have been issued:

ANSI/ASCE 1-82 N-725 Guidelines for Design and Analysis of Nuclear Safety Related Earth Structures

ANSI/ASCE 2-91 Measurement of Oxygen Transfer in Clean Water

ANSI/ASCE 3-91 Standard for the Structural Design of Composite Slabs and ANSI/ASCE 9-91 Standard Practice for the Construction and Inspection of Composite Slabs

ASCE 4-86 Seismic Analysis of Safety-Related Nuclear Structures

Building Code Requirements for Masonry Structures (ACI530-95/ASCE5-95/TMS402-95) and Specifications for Masonry Structures (ACI530.1-95/ASCE6-95/TMS602-95)

Specifications for Masonry Structures (ACI530-95/ASCE6-95/TMS602-95)

ANSI/ASCE 7-93 Minimum Design Loads for Building and Other Structures

ANSI/ASCE 8-90 Standard Specification for the Design of Cold-Formed Stainless Steel Structural Members

ANSI/ASCE 9-91 listed with ASCE 3-91

ANSI/ASCE 10-90 Design of Latticed Steel Transmission Structures

ANSI/ASCE 11-90 Guideline for Structural Condition Assessment of Existing Buildings

ANSI/ASCE 12-91 Guideline for the Design of Urban Subsurface Drainage

ASCE 13-93 Standard Guidelines for Installation of Urban Subsurface Drainage

ASCE 14-93 Standard Guidelines for Operation and Maintenance of Urban Subsurface Drainage

ASCE 15-93 Standard Practice for Direct Design of Buried Precast Concrete Pipe Using Standard Installations (SIDD)

ASCE 16-95 Standard for Load and Resistance Factor Design (LRFD) of Engineered Wood Construction

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In addition to the participants listed below, the leadership of a Wood Industry Technical Committee, chaired by Dr. Kevin C.K. Cheung, Western Wood Products Association, and the Wood Industry Management Committee, chaired by Jeffrey M. Van Cott, and the vision of the funding organizations is acknowledged.

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FOREWORD

The material presented in this publication has been prepared in accordance with recognized engineering principles. This Standard and Commentary should not be used without first securing competent advice with respect to their suitability for any given application. The publication of the material contained herein is not intended as a representation or warranty on the part of the American Society of Civil Engineers, or of any other person named herein, that this information is suitable for any general or particular use or promises freedom from infringement of any patent or patents. Anyone making use of this information assumes all liability from such use.

Notation

A	Gross area
A_n	Net area, net bearing area
A_{min}, B_{min}	Minimum spacing permitted for shear plates and split rings, parallel and perpendicular to grain, respectively
A_{opt}, B_{opt}	Required spacing of shear plates and split rings to achieve reference connection resistance, parallel and perpendicular to grain, respectively
B_{bx}, B_{by}	Moment magnification factor for loads that result in no appreciable sidesway (strong and weak axes, respectively)
B_{sx}, B_{sy}	Moment magnification factor for loads that result in sidesway (strong and weak axes, respectively)
C_E	Composite action factor
C_F	Size factor
C_G	Grade/construction factor for structural panels
C_H	Shear stress factor
C_I	Stress interaction factor
C_L	Beam stability factor
C_M	Wet service factor
C_P	Column stability factor
C_T	Buckling stiffness factor for dimension lumber
C_V	Volume effect factor for structural glued laminated timber
C_b	Bearing area factor
C_b	Bending coefficient dependent on moment gradient
C_c	Curvature factor for structural glued laminated timber
C_{cs}	Critical section factor for round timber piles
C_d	Penetration depth factor for connections
C_{di}	Diaphragm factor
C_{eg}	End-grain factor for connections
C_f	Form factor
C_{fu}	Flat-use factor
C_g	Group action factor for connections
C_m, C_{mx}, C_{my}	Moment shape factor for biaxial bending (general, strong, and weak axes, respectively)
C_{pt}	Preservative treatment factor
C_r	Load-sharing factor
C_{rt}	Fire-retardant treatment factor
C_{sp}	Single pile factor
C_{st}	Metal side plate factor for 4 in. shear plate connections
C_t	Temperature factor
C_{tn}	Toe-nail factor for nailed connections
C_u	Untreated factor for round timber piles
C_w	Width factor for structural panels
C_Δ	Geometry factor for connections
D	Diameter
D	Dead load
D, D'	Reference and adjusted diaphragm shear resistance per unit length
D_u	Diaphragm shear force per unit length due to factored loads
D_1, D_2	Minimum and maximum diameters in round tapered members
E	Earthquake load
E, E'	Reference and adjusted mean modulus of elasticity

E_{05}, E_{05}'	Reference and adjusted fifth percentile modulus of elasticity
EA	Axial stiffness
EI	Flexural stiffness
F_b, F_b'	Reference and adjusted bending strength
F_{bx}*	Bending strength for strong (x-x) axis bending multiplied by all applicable adjustment factors except C_{fu}, C_V, and C_L
F_c, F_c'	Reference and adjusted compression strength parallel to grain
F_c*	Compression strength parallel to grain multiplied by all applicable adjustment factors except C_P
$F_{c\perp}$, $F_{c\perp}'$	Reference and adjusted compression strength perpendicular to grain
F_e	Dowel bearing strength
F_{em}, F_{es}	Dowel bearing strength of main and side members, respectively
$F_{e\parallel}$, $F_{e\perp}$, $F_{e\theta}$	Dowel bearing strength parallel, perpendicular, and at an angle to the grain, respectively
F_g, F_g'	Reference and adjusted bearing strength parallel to grain
F_r', F_{rc}', F_{rt}'	Adjusted radial strength (general, compression, and tension, respectively)
F_s, F_s'	Reference and adjusted rolling shear strength for structural panels
F_t, F_t'	Reference and adjusted tensile strength parallel to grain
F_{tv}'	Adjusted torsional shear strength
F_v, F_v'	Reference and adjusted shear strength parallel to grain (horizontal shear)
F_v, F_v'	Reference and adjusted through-thickness shear strength for structural panels
F_{yb}	Bending yield strength of fastener
G	Specific gravity
G, G′	Reference and adjusted shear modulus
G_v, G_v'	Reference and adjusted shear modulus for structural panels
I	Moment of inertia
J	Torsional constant for a section
K_M	Moisture content coefficient for sawn lumber truss compression chords
K_T	Truss compression chord coefficient for sawn lumber
K_e	Effective length factor for compression members
L	Design span of bending member or compression member
L	Live load caused by storage, occupancy, or impact
L_r	Roof live load
M, M′	Reference and adjusted moment resistance
M_1, M_2	Smaller and larger end moment in a beam or segment
M_{bx}, M_{by}	Factored moment from loads that result in no appreciable sidesway (strong and weak axes, respectively)
M_e	Elastic lateral buckling moment
M_{mx}, M_{my}	Factored moment, including magnification for second-order effects (strong and weak axes, respectively)
M_s'	Adjusted moment resistance computed with $C_L = 1.0$
M_{sx}, M_{sy}	Factored moment from loads that result in sidesway (strong and weak axes, respectively)
M_t, M_t'	Reference and adjusted torsion resistance
M_{tu}	Torsion due to factored loads
M_u, M_{ux}, M_{uy}	Moment due to factored loads (general, strong and weak axes, respectively)
M_x', M_y'	Adjusted moment resistance (strong and weak axes, respectively)
M_x*	Moment resistance for strong (x-x) axis bending multiplied by all applicable adjustment factors except C_{fu}, C_V, and C_L
P, P′	Reference and adjusted compression resistance parallel to grain
P_0'	Adjusted member axial parallel to grain resistance of a zero length column (i.e., the limit obtained as length approaches zero)
P_a	Assumed axial load acting on a side bracket
P_e	Euler buckling resistance
P_g, P_g'	Reference and adjusted bearing resistance

$P_\perp$, $P_\perp'$	Reference and adjusted compression resistance perpendicular to grain
P_θ, P_θ'	Reference and adjusted compression resistance in bearing at angle θ
P_s	Assumed horizontal side load placed at center of height of column
P_u	Compressive or bearing force due to factored loads
Q	Statical moment of an area about the neutral axis
R	Load caused by initial rain water and/or ice
R, R′	Reference and adjusted resistance
R_B	Slenderness ratio of bending member
R_{EA}	Ratio of minimum to maximum member axial stiffness in a connection
R_e	Ratio of main to side member embedment strength in a connection
R_t	Ratio of main to side member thickness in a connection
R_f, R_m	Radius of curvature at the inside face and at mid-depth, respectively
R_u	Force due to factored loads
S	Section modulus
S	Snow load
T, T′	Reference and adjusted tension resistance parallel to grain
T_u	Tensile force due to factored loads
V, V′	Reference and adjusted shear resistance
V_u	Shear force due to factored loads
W	Wind load
Z, Z′	Reference and adjusted connection lateral resistance
Z_u	Connection force due to factored loads
Z_W, Z_W'	Reference and adjusted connection withdrawal resistance
Z_α'	Adjusted resistance of a fastener loaded at an angle to the surface of the wood member
$Z_\parallel'$, $Z_\perp'$, Z_θ'	Adjusted resistance of a fastener loaded parallel, perpendicular, and at an angle to the grain, respectively
a	End distance for a connection
a_i	Effective number of fasteners for row i
a_{min}	Minimum end distance permitted for connections
a_{opt}	Required end distance to achieve reference connection resistance
b	Member width
b	Edge distance for connection
b_{min}	Minimum edge distance permitted for connections
b_{opt}	Required edge distance to achieve reference connection resistance
c	Coefficient in column stability factor equation
c_b	Coefficient in beam stability factor equation
d	Member depth
d_1, d_2	Minimum and maximum depth for a uniform width, linearly tapered member
d_e	Effective depth of member at a connection
d_n	Depth of member remaining at a notch
e	Eccentricity
h	Height
ℓ	Design span of bending member or compression member
ℓ	Distance between points of lateral support of a compression member
ℓ	Span length, clear span of arch between hinges
ℓ_b	Bearing length
ℓ_{br}	Distance from the bottom of the column or column segment to the top of the column bracket, in.
ℓ_c	Clear span
ℓ_e	Effective length
ℓ_m	Length of dowel-type fastener in main member
ℓ_P	Distance measured vertically from point of application of load on bracket to farther end of column

ℓ_u	Laterally unsupported span length of bending or compression member
n_f	Total number of fasteners in a connection
n_i	Number of equally spaced fasteners in row i
n_r	Number of serial rows of fasteners in a connection
p	Depth of fastener penetration into wood member
r	Radius of gyration
s	Spacing of fasteners in a connection (also called pitch spacing)
s_{min}	Minimum spacing for adjusted connection resistance
s_{opt}	Required spacing for reference connection resistance
t	Thickness
t_m, t_s	Thickness of main and side members, respectively, in a connection
w	Uniform load
α	Angle between applied force vector and the surface of the wood member
α	Angle of connector axis with respect to member longitudinal axis
α_b	Factor in design of flexural members
α_c	Factor in design of columns
γ	Load/slip constant for a single fastener
Δ	Deflection
λ	Time-effect factor
ϕ	Resistance factor
ϕ_b	Resistance factor for flexure
ϕ_c	Resistance factor for compression
ϕ_s	Resistance factor for stability
ϕ_t	Resistance factor for tension
ϕ_v	Resistance factor for shear/torsion
ϕ_z	Resistance factor for connections
θ	Angle of cut taper or cut notch from the grain direction
θ	Angle of force vector with respect to a direction parallel to grain
θ_b	Angle between bearing force and the direction of grain

CHAPTER 1

General Provisions

1.1 Scope

This standard provides design criteria for structures constructed of structurally graded lumber, structural glued laminated timber, panel products, poles, piles, and other structural wood components, and their connections. This standard is for the design of buildings and similar structures. Wherever in this standard reference is made to the appendices, the provisions of the appendices shall apply. The derivation of design strengths and resistances is outside the scope of this standard.

Design strengths and resistances established for use with this standard shall be determined in accordance with ASTM Specification D5457-93.

1.1.1 Units. Where units are required in the provisions of this standard, they are provided both in metric (SI) and in U.S. customary units. Many of the checking equations do not require explicit statement of units; in these equations the designer shall use units for all quantities that are consistent.

1.2 Applicable Documents

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