Round Timber Poles and Piles

John "Buddy" Showalter, P.E.

Introduction

This paper provides an overview of timber pole and pile design procedures and more detail on specific changes to the *2012 National Design Specification® (NDS®) for Wood Construction* for those products. Chapter 6 of the *2012 NDS* has been updated to address changes to ASTM standards for developing and adjusting round timber pile and round construction pole design values. Changes are summarized as follows:

- New design values for Table 6A Untreated Round Timber Piles and Table 6B Untreated Round Construction Poles were relocated from *NDS* Chapter 6 to the *NDS Design Value Supplement* (Figure 1).
- Specific gravity values were added to *NDS Supplement* Tables 6A and 6B.
- NDS Section 6.3.5 "Untreated Factor" adjustment was changed to "Condition Treatment Factor" in recognition that new reference design values are now based on air dried condition.
- NDS Section 6.3.9 "Critical Section" is changed to be consistent with changes to reference design values in *ASTM D2899 Standard Practice for Establishing Allowable Stresses for Round Timber Piles*.
- NDS Section 6.3.11 "Single Pile Factor" adjustment was changed to "Load Sharing Factor" in recognition that new reference design values are now based on a single pile condition.

History

Round timber piles have been widely used in the United States in the construction of railroads, highways, harbors and dams, as well as for building foundations, since the middle of the 18th century. In addition to availability and cost, the natural taper of round timber piles makes them relatively easy to drive, compacts the soil around the pile during driving, and provides a larger diameter butt end capable of withstanding driving forces and supporting loads from other structural members.The earliest standardization effort involving timber piles was the establishment of uniform size and grade characteristics in *ASTM D25, Standard Specification for Round Timber Piles*. First developed in 1915, the current edition of this standard includes specifications for minimum butt and tip sizes for various pile lengths, establishes limits on crook and knot sizes, and sets minimum rate of growth and percent summerwood quality requirements.

The establishment of standard physical characteristics for timber piles in ASTM D25 was subsequently followed by the development of standard requirements for preservative treatment. Such specifications were available from the American Wood Protection Association (AWPA) since well before World War II. This Association's Standard C3, Piles-Preservative Treatment by Pressure Processes, establishes conditioning, pressure, temperature, retention, and penetration limitations and requirements for various preservative treatments by species and pile use. Because of the effect treatment processes can have on strength properties, standardization of the processes used are an important element in the specification and use of timber piles.

Engineering design with timber piles in the early years was largely based on experience, observation of the performance of piles under similar loading conditions, and the results of static loading tests. Piles were considered to fall into two groups: those in which the pile tip bears on a solid layer and were designed as columns, and those in which the pile receives most of its support from soil friction on the sides and were designed from driving records or empirical formulas. Standard design procedures were not available.

To meet the growing need for uniform design rec-

Table 6A Reference Design Values for Treated Round Timber Piles Graded per ASTM D25

(Tabulated design values are for normal load duration and wet service conditions. See NDS 6.3 for a comprehensive description of design value adjustment factors.)

	Design values in pounds per square inch (psi)						
	Bending	Shear parallel to grain	Compression perpendicular to grain	Compression parallel to grain	Modulus of elasticity		Specific Gravity[4]
Species	F_b	F_v	$F_{c\perp}$	F_c	E	E_{min}	G
Pacific Coast Douglas Fir[1]	2,050	160	490	1,300	1,700,000	690,000	0.50
Red Pine[2]	1,350	125	270	850	1,300,000	520,000	0.42
Southern Pine (Grouped)[3]	1,950	160	440	1,250	1,500,000	600,000	0.55

1. Pacific Coast Douglas Fir reference design values apply to this species as defined in ASTM Standard D 1760. For connection design use Douglas Fir-Larch reference design values.

2. Red Pine reference design values apply to Red Pine grown in the United States. For connection design use Northern Pine reference design values.

3. Southern Pine reference design values apply to Loblolly, Longleaf, Shortleaf, and Slash Pines.

4. Specific gravity, G, based on weight and volume when oven-dry.

Table 6B Reference Design Values for Construction Poles Graded per ASTM D3200

(Tabulated design values are for normal load duration and wet service conditions. See NDS 6.3 for a comprehensive description of design value adjustment factors.)

	Design values in pounds per square inch (psi)						
	Bending	Shear parallel to grain	Compression perpendicular to grain	Compression parallel to grain	Modulus of elasticity		Specific Gravity[4]
Species	F_b	F_v	$F_{c\perp}$	F_c	E	E_{min}	G
Pacific Coast Douglas Fir[1]	2,050	160	490	1,300	1,700,000	690,000	0.50
Lodgepole Pine	1,275	125	265	825	1,100,000	430,000	0.42
Ponderosa Pine	1,200	175	295	775	1,000,000	400,000	0.43
Red Pine[2]	1,350	125	270	850	1,300,000	520,000	0.42
Southern Pine (Grouped)[3]	1,950	160	440	1,250	1,500,000	600,000	0.55
Western Hemlock	1,550	165	275	1,050	1,300,000	560,000	0.47
Western Larch	1,900	170	405	1,250	1,500,000	660,000	0.49
Western Red Cedar	1,250	140	260	875	1,000,000	360,000	0.34

1. Pacific Coast Douglas Fir reference design values apply to this species as defined in ASTM Standard D 1760. For connection design use Douglas Fir-Larch reference design values.

2. Red Pine reference design values apply to Red Pine grown in the United States. For connection design use Northern Pine reference design values.

3. Southern Pine reference design values apply to Loblolly, Longleaf, Shortleaf, and Slash Pines.

4. Specific gravity, G, based on weight and volume when oven-dry.

Figure 1. Reference design values for timber poles and piles.

ommendations, the American Association of State Highway Officials (AASHTO) began to specify allowable pile compression design values of 1200 psi for Douglas fir and slightly lower values for other species in the 1940's. However, maximum pile loads in the order of 36,000 to 50,000 pounds per pile also were specified which generally was the limiting criterion.

In the 1950's, AASHTO, the American Railway Engineering Association, and other user groups began to establish pile design values using the procedures of *ASTM D245, Standard Methods for Establishing Structural Grades of Lumber*. Building codes also began to establish allowable pile stresses using basic stresses and other information given in ASTM D245.

Uniform national standards for development of strength values for timber piles became available in 1970 with the publication of *ASTM D2899, Standard Method for Establishing Design Stresses for Round Timber Piles*. This consensus standard provided for the establishment of stresses for piles of any species meeting the size and quality requirements of ASTM D25. Under D2899, clear wood property information from ASTM D2555 were adjusted for grade, relation of pile tip strength to clear wood strength, variability of pile strength to that of small clear specimens, load duration, and treatment conditioning effects.

In 1997, reference design values were added for construction poles based on D2899 per reference in ASTM D3200.

In 2003, the provisions of D2899 were revised to derive single pile design values rather than pile cluster design values derived in previous versions of D2899. As a result, the *2012 NDS* was revised to adjust and use single member pile and pole design values. In addition, the new design values for Table 6A Untreated Round Timber Piles and Table 6B Untreated Round Construction Poles were moved from *NDS* Chapter 6 to the *NDS Supplement*.

Table 6.3.1 Applicability of Adjustment Factors for Round Timber Poles and Piles

		ASD only	ASD and LRFD							LRFD only		
		Load Duration Factor	Temperature Factor	Condition Treatment Factor	Size Factor	Column Stability Factor	Critical Section Factor	Bearing Area Factor	Load Sharing Factor	Format Conversion Factor K_F	Resistance Factor ϕ	Time Effect Factor
$F_c' = F_c$	x	C_D	C_t	C_{ct}	-	C_P	C_{cs}	-	C_{ls}	2.40	0.90	λ
$F_b' = F_b$	x	C_D	C_t	C_{ct}	C_F	-	-	-	C_{ls}	2.54	0.85	λ
$F_v' = F_v$	x	C_D	C_t	C_{ct}	-	-	-	-	-	2.88	0.75	λ
$F_{c\perp}' = F_{c\perp}$	x	-	C_t	C_{ct}	-	-	-	C_b	-	1.67	0.90	-
$E' = E$	x	-	C_t	-	-	-	-	-	-	-	-	-
$E_{min}' = E_{min}$	x	-	C_t	-	-	-	-	-	-	1.76	0.85	-

Figure 2. Applicability of Adjustment Factors for Round Timber Poles and Piles.

NDS Design Scope

The provisions of *NDS* Chapter 6 relate solely to properties of round timber poles and piles. It is the designer's responsibility to determine soil loads, such as frictional forces from subsiding soils and fills, adequacy of surrounding soil or water to provide sufficient lateral bracing, the method of pole or pile placement that will preclude damage to the wood member, bearing capacity of the strata at the pile tip, and effects of any other surrounding environmental factors on the supporting or loading of poles or piles.

Specifications

In addition to setting standard pile sizes, ASTM D25 establishes minimum quality requirements, straightness criteria, and knot limitations. All pile tips are required to have an average rate of growth of 6 or more rings per inch and percent summerwood of 33 percent or more in the outer 50 percent of the radius; except less than 6 rings per inch growth rate is acceptable if the summerwood percentage is 50 percent or more in the outer 50 percent of the tip radius. Thus, 75 percent of the cross-sectional area of pile tips conforming to ASTM D25 essentially meets lumber requirements for dense material.

Knots in piles are limited by ASTM D25 to a diameter of not more than one-sixth of the circumference of the pile at the point where they occur. The sum of knot diameters in any one-foot length of pile is limited to one-third or less of the circumference.

ASTM D3200 establishes standard sizes and minimum grades for construction poles based on ASTM D25 for piles.

Preservative treatment requirements and limitations differ depending upon where the piles are to be used. Designation of the applicable treatment standard and use condition defines the treatment desired by the specifier.

Standard Sizes

Standard sizes for round timber piles range from 7 to 18 inches in diameter measured 3 feet from the butt. Pile lengths range from 20 to 85 feet for southern pine and to 120 feet for Douglas fir and other species. Pile taper is controlled by establishing a minimum tip circumference associated with a minimum circumference 3 feet from the butt for each length class; or by establishing a minimum circumference 3 feet from the butt associated with a minimum tip circumference for each length class. This provides a known tip area for use in engineering design as well as a conservative estimate of the area at any point along the length of the pile.

Standard sizes for round timber construction poles range from 5 to 12 inches in diameter measured at the tip. Pole lengths range from 10 to 40 feet.

Preservative Treatment

Green timber piles are generally conditioned prior to pressure treatment. For southern pine, the conditioning usually involves steaming under pressure to obtain a temperature of 245°F and then applying a vacuum. The process results in water being forced out of the outer part of the pile, but does not dry it to a seasoned condition.

Table 6.3.5 Condition Treatment Factor, C_{ct}

Air Dried	Kiln Dried	Boulton Drying	Steaming (Normal)	Steaming (Marine)
1.0	0.90	0.95	0.80	0.74

Figure 3. Condition Treatment Factor for Timber Poles and Piles.

Conditioning of Douglas fir is usually done by the Boulton or boiling-under-a-vacuum-process. This method of conditioning, which partially seasons the sapwood portion of the pile, involves heating the material in the preservative oil under a vacuum at temperatures up to 220°F. The Boulton process also is used with hardwood species.

Both the steaming and Boulton conditioning processes affect pile strength properties. The effects of conditioning (steaming, Boultonizing, and drying) are not included in pile design values given in Table 6A of the *NDS Supplement* and must be addressed with the reduction factors in NDS 6.3.5 (see Figure 3 and further discussion below on condition treatment factors).

Decay does not occur in softwood species and in most hardwoods that are completely saturated and an air supply is not available. Permanently submerged piles meet these conditions.

Other Species or Grades

Where piles of species other than those listed in *NDS Supplement* Table 6A are used, it is the designer's responsibility to assure that the methods of ASTM D2899 for establishing design values are properly applied, including appropriate adjustments for conditioning process.

Adjustment of Reference Design Values

Adjustment factors for round timber poles and piles are specified in Table 6.3.1 of the NDS (see Figure 2 and further discussion below).

Load Duration Factor (ASD only)

As shown in NDS Table 6.3.1, the load duration factor, C_D, is not applicable to compression design values perpendicular to grain, $F_{c\perp}$ for round timber poles and piles. Pressure impregnation of water borne preservatives or fire retardant chemicals to retentions of 2.0 pcf or more may significantly reduce energy absorbing ability as measured by work-to-maximum-load in bending. For this reason, the impact load duration adjustment is not to be applied to members pressure treated with preservative oxides for salt water exposure or those pressure treated with fire retardant chemicals.

Condition Treatment Factor, C_{ct}

Reference design values for poles and piles are based on air dried conditioning. Kiln-drying, steam conditioning, or boultonizing prior to treatment will have the effect of reducing the reference design value. Figure 3 outlines condition treatment factors, C_{ct}.

Beam Stability Factor, C_L

A round member can be considered to have a *d/b* ratio of 1 and therefore, in accordance with NDS 3.3.3.1, the beam stability factor, C_L, equals 1.0.

Size Factor, C_F

Bending design values, F_b, for round timber poles and piles that are larger than 13.5 inches in diameter at the critical section in bending are adjusted for size, C_F, using the same equation used to make size adjustments with sawn lumber Beams & Stringers and Posts & Timbers (see NDS 4.3.6.3 and C4.3.6.2). When applied to round timbers, equation 4.3-1 is entered with a *d* equal to the depth of a square beam having the same cross-sectional area as that of the round member. The equivalency of the load-carrying-capacity of a circular member and a conventionally loaded square member of the cross-sectional area has long been recognized.

Column Stability Factor, C_P

Column stability provisions from NDS 3.7.1 can be used to calculate the column stability factor, C_P, for round timber poles and piles by substituting for the depth, *d*, in the equations, where *r* is the applicable radius of gyration of the column cross section.

Critical Section Factor, C_{cs}

The critical section factor, C_{cs}, accounts for the effect of tree height on compression design values parallel to grain. The specific adjustment, based on D2899, provides for an increase in the design value as the critical section moves from the pile tip toward the pile butt and is limited to a maximum increase of 10%.

Load Sharing Factor (Pile Group Factor), C_{ls}

Reference design values in *NDS Supplement* Table 6A are based on a single pile. Where piles are used in clusters such that the pile group deforms as a single element, the single pile reference compression design value parallel to grain, F_c, and the single pile reference bending design value, F_b, are permitted to be multiplied by C_{ls} in NDS Table 6.3.11 (Figure 4).

The load sharing factor (pile group factor) is applicable to F_b and F_c and is not applicable to soil-related properties such as pile tip bearing or skin friction.

Table 6.3.11 Load Sharing Factor, C_{ls}, per ASTM D 2899

Reference Design Value	Number of Piles in Group	C_{ls}
F_c	2	1.06
	3	1.09
	4 or more	1.11
F_b	2	1.05
	3	1.07
	4 or more	1.08

Figure 4. Load Sharing Factor for Timber Poles

Conclusion

New design values for timber poles and piles have been incorporated in the *2012 NDS*. For consistency with other products such as lumber and glulam, timber pole and pile design values have been tabulated in the *NDS Supplement*. Several design adjustment factors were revised based on changes to the design values as well.

References

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John"Buddy" Showalter, P.E., is Vice President of Technology Transfer, American Wood Council, BShowalter@awc.org.