Designation: D7381 – 07

StandardPractice for Establishing Allowable Stresses for Round Timbers for Piles from Tests of Full-Size Material[1]

This standard is issued under the fixed designation D7381; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice contains procedures for establishing allowable compression parallel to grain and bending stresses for round timbers used for piling, based on results from full-size tests.

NOTE 1—Allowable stresses for compression perpendicular to grain and shear properties are established in accordance with the provisions of Practice D2899.

1.2 Stresses established under this practice are applicable to piles conforming to the size, quality, straightness, spiral grain, knot, shake and split provisions of Specification D25.

1.3 A commentary on the practice is available from ASTM International.

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D25 Specification for Round Timber Piles
D198 Test Methods of Static Tests of Lumber in Structural Sizes
D245 Practice for Establishing Structural Grades and Related Allowable Properties for Visually Graded Lumber
D1036 Test Methods of Static Tests of Wood Poles
D1990 Practice for Establishing Allowable Properties for Visually-Graded Dimension Lumber from In-Grade Tests of Full-Size Specimens
D2555 Practice for Establishing Clear Wood Strength Values
D2899 Practice for Establishing Allowable Stresses for Round Timber Piles
D2915 Practice for Sampling and Data-Analysis for Structural Wood and Wood-Based Products
D4761 Test Methods for Mechanical Properties of Lumber and Wood-Base Structural Material
D6555 Guide for Evaluating System Effects in Repetitive-Member Wood Assemblies

3. Terminology

3.1 *Definitions:*

3.1.1 *allowable stress*—the numeric value of pile strength appropriate for use in design.

3.1.2 *end-bearing*—compression parallel to grain stress used in design when the pile load is not carried to the soil through skin friction.

3.1.3 *load sharing*—the distribution of load that occurs in two or more piles which are capped with a load-distributing element that assures the piles deform as a group. The load distributed to the piles in such a group is in proportion to the stiffness of each pile. This distribution of loads to the piles in the group reduces the effect of between pile variability and increases system reliability over that of piles which perform as single members.

3.1.4 *skin friction*—the interaction between the pile surface and the surrounding soil which serves to distribute load either away from or into a pile. A positive skin friction refers to pile loads distributed to the soil. Negative skin friction refers to loads being distributed into the pile as a result of soil subsidence or consolidation.

3.2 *Symbols:*

c = circumference of a round timber pile

C_{cp} = conditioning adjustment

C_{ds} = adjustment for duration of load and miscellaneous factor of safety

C_{ls} = load sharing adjustment

C_{oc}, C_{ob}, C_{oe}, C_{oeb}, = adjustments to F_c, F_b, E and $EMOE$ for pile oversizing relative to Specification D25 specified minimum circumferences

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

C_t = adjustment of allowable compression parallel to grain stress at pile tip to critical section location *L*

D = pile diameter

E_i = modulus of elasticity for individual member individual compression parallel to grain specimen

E_a = average modulus of elasticity of butt and tip compression parallel to grain specimens from the same pile

E' = sample mean modulus of elasticity in compression

E = allowable modulus of elasticity in compression

$EMOE_i$ = effective modulus of elasticity in bending for an individual pile

EMOE' = sample mean effective modulus of elasticity in bending

EMOE = allowable effective modulus of elasticity in bending

F_b = allowable stress in bending

F_c = allowable stress in compression parallel to grain

f_{cTL} = compression parallel to grain 5 % tolerance limit with 75 % confidence determined from test results for the tip specimen

f_{bTL} = bending 5 % tolerance limit with 75 % confidence determined from test results

L = distance from pile tip to critical section, ft

L_e = distance from top of butt compression parallel to grain test specimen to top of tip compression parallel to grain test specimen, ft

MORBP = modulus of rupture at breakpoint

k = number of random variables used in random products simulation

n = number of piles in a species or species group selected for testing

p = exponent of L_e used to calculate pile length effect on compression strength

r = radius of gyration = *D*/4

UCS = ultimate compressive strength

z = number of piles in a cluster

4. Significance and Use

4.1 This practice is primarily intended for use by associations, third-party grading agencies, technical societies and other groups that develop national design standards and use recommendations for round timber piles.

4.2 This practice provides procedures for establishing compression parallel to grain and bending stresses for round timber piles including: sampling of material for testing; methods of test and property calculation procedures; distribution analysis of test data; procedures for determining adjustments for critical section location; pile oversize, load sharing and treatment; and procedures for deriving allowable stresses.

4.3 In using allowable stresses established under this practice, factors specific to each end use which may affect the performance of the pile system shall be considered by the designer. Such factors include the location of the critical section, the bearing capacity of the soil, the ability of the pile to withstand driving forces, the properties of the cap or load distributive element tying piles together and the loading and conditions of service.

5. Sampling Full-Size Round Timbers

5.1 The population to be sampled shall be round timbers of a particular species or species group meeting the provisions of Specification D25. Only those species groups that do not exceed the variability, as measured by the criteria of Section 5 of Practice D2555, of the major lumber species groups sampled in the In-Grade lumber testing program in the United States and Canada shall be considered as a single species for sampling and analysis purposes. For species groups exceeding these variability limits, the species composition should be changed such that the limits will be met by the remaining species in the group if sampling of the group as a single species is desired.

NOTE 2—See X9.1 of Practice D1990 for discussion of in-grade sampling of species groups. Major species groups sampled in the In-Grade lumber testing program are given in Note 3 of Practice D1990.

5.2 A representative sample (*n*) of all sizes (diameters) and lengths of timber piles as in Tables X1.2 or X1.3 and Tables X1.4 or X1.5 of Specification D25 shall be selected for the species or species group being evaluated. Sampling by size, length and class shall be in proportion to total production and shall be distributed across plants representative of the producing region.

NOTE 3—Specification D25 pile specifications provide for only one grade and quality level.

5.3 Individual piles selected as test material shall be green and randomly chosen from inventory in the yard at each plant.

5.4 Sample size shall be based on the principles of Practice D2915 and shall be sufficient to provide reliable estimates of the distributions of bending and compression parallel to grain strengths of timbers of the species or species group being evaluated. Each pile selected for test shall be evaluated for both bending and compression strength with compression specimens being cut from the butt and tip ends after the bending test is completed.

6. Test Methods and Calculation Procedures

6.1 All test members shall be maintained in a green condition prior to test.

6.2 Each member shall be tested in bending in accordance with the procedures of Test Methods D1036. Modulus of rupture at breakpoint (*MORBP*) and effective modulus of elasticity in bending (*EMOE*) shall be calculated in accordance with the formulas given in 19.4 of Test Methods D1036. If an alternative formula is used to calculate *EMOE*, its derivation and assumptions shall be documented.

NOTE 4—The cross-section of round timbers varies from butt to tip as a result of taper. A linear taper between butt and tip is assumed in the derivation of the *EMOE* equation. As tree tapers may not be linear but parabolic, the moment of inertia of the resisting cross-section is underestimated and the resulting bending *EMOE* value for the pile is typically substantially higher than the average *E* based on compression parallel to grain tests.

6.3 After completion of the bending test, compression test specimens shall be cut from the butt and tip ends of the member. These specimens shall be prepared and tested in accordance with Sections 12–19 of Test Methods D198. The same slenderness ratio, specimen length divided by the small end radius of gyration (*r*), shall be used for the butt and tip specimens but shall not exceed 17. Specific gravity disks shall be cut from the bottom and top of each pile, immediately above the small end of the compression test specimens.

6.4 To prevent excessive end crushing, the compression specimens shall be banded or the ends air-dried prior to testing. Load-deformation data shall be obtained for both specimens. In place of the testing speeds specified in section 17.3 of Test Methods D198, a rate of straining (in./in. per min) such that maximum load is obtained between 1 and 5 min shall be used and both butt and tip specimens shall be tested at the same rate.

NOTE 5—A range of 1 to 5 min in failure times is within the range of 10 s to 10 min specified for in-grade testing of lumber in section 34.4 of Test Methods D4761.

6.5 Ultimate compression strength (*UCS*) and modulus of elasticity (E_i) shall be calculated for both the butt and tip specimens using the area of the small end of each specimen. Values of E_i shall be based on the linear portion of the load-deformation curves with suitable adjustment made for any nonlinearity occurring at the beginning of the test. The average of the E_i values for the butt and tip specimens shall be calculated as the E_a of the pile.

7. Reporting Requirements for Sampling and Testing

7.1 The following information shall be reported:

7.1.1 The production volumes for the various sizes, lengths and classes of piles building poles used to develop the sampling plan for each species or species group evaluated.

7.1.2 The methods used to select the manufacturing facilities for sampling and the individual test piles from each facility.

7.1.3 A complete description of each test specimen including length, butt and tip circumference, rings per inch, percent summerwood, slope of spiral grain and the maximum individual knot size and the maximum sum of knot diameters in any one-foot of pile length.

7.1.4 The diameters of the small and large ends of the butt and tip compression parallel to grain test specimens selected from each pile and the maximum individual knot size and the maximum sum of knot diameters in any one-foot of length in each of these specimens.

7.1.5 Slenderness ratios, rate of load application, time to maximum load, section properties, specific gravity, formulas used to calculate strength and stiffness properties and other information as required by the provisions of Test Methods D198 and D1036.

7.1.6 A complete description of the analytical methods used to develop the statistics and factors described in Sections 8-11.

8. Analysis of Test Data

8.1 The average of the individual pile $EMOE_i$ and E_a values shall be calculated as the sample mean values (*EMOE'* and *E'*) for the species or species group evaluated.

8.2 The distributions of *UCS* values for the tip compression specimens and the *MORBP* values for the *n* piles in the sample shall be examined to determined what type of distribution (normal, lognormal or nonparametric) best describes each data set, particularly the lower strength values in the sample.

8.3 If a parametric distribution is to be used, the mean, standard deviation and 5 % tolerance limit with 75 % confidence (f_{cTL} or f_{bTL}) determined for the property and sample using the methods of sections 3.4.3.2, 4.5, and Table 1 of Practice D2915.

8.4 If a nonparametric distribution is to be used, the sample test values shall be arranged in ascending order and the *m*th order statistic selected as the sample 5 % tolerance limit with 75 % confidence (f_{cTL} or f_{bTL}) in accordance with 4.5.4, 4.5.5, and Table 2 of Practice D2915.

9. Critical Section Located Above the Pile Tip

9.1 Paired butt and tip compression parallel to grain *UCS* values shall be used to establish an equation for adjusting tip compression allowable design values (F_c) when the critical section is located above the tip as a result of skin friction.

9.2 For each test pile, the difference between butt and tip *UCS* values shall be normalized using the following calculation:

$$R_i = [(UCS_{butt} - UCS_{tip})/UCS_{tip}]/L_e^{\,p} \qquad (1)$$

where:

R_i = normalized individual pile length effect on compression strength $p = 1.6$.

9.3 If the significance of the slope coefficient of the regression of R_i on L_e is not less than a probability of 25 %, the average of the R_i values for the sample (R_{avg}) shall be used to establish the following equation for determining C_l:

$$C_l = (R_{avg} \times 100)/L^p \qquad (2)$$

where:

C_l = percentage increase in pile compression strength at distance *L* from the pile tip $p = 1.6$

9.4 If the significance of the slope coefficient is less than 25 %, the value of the exponent *p* shall be changed so as to meet this criterion. Individual R_i values based on a butt compression specimen containing a split that occurred during the bending test shall not be included in the regression analysis nor in the calculation of R_{avg} for the sample.

10. Effect of Pile Sizes Exceeding Specification D25 Size Class Minimums

10.1 Piles are marketed in accordance with circumference (diameter) and length specified in Specification D25. The actual diameters of piles qualifying for a particular circumference class generally exceed the minimum required, ranging from that minimum up to the minimum size defining the next larger class. The effect of this pile oversizing shall be determined through random product analysis using Monte Carlo simulation from normal or log normal distributions of *UCS* tip and *MORBP* test values and uniform distributions of section property values for representative pile circumference classes in Specification D25.

10.2 The ratio of the 5 % nonparmetric point estimate of the distribution of *k* products of individual random strength and section property values to the 5 % point estimate of the distribution of the *k* random strength values times the section