PART VI: ROUND TIMBER PILES

6.1-GENERAL

Background

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 (218).

Timber piles are commonly used in sand, clay, silt and other soils in which they are relatively easy to drive and which will provide significant support through skin friction (218). However, because of the difficulty of quantifying friction forces and confinement pressures, timber piles today are designed primarily on the basis of their end bearing load-carrying capacity.

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 (22). 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 Preservers' Association since well before World War II (57). 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 (26). 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 (57). Standard design procedures were not available.

To meet the growing need for uniform design recommendations, the American Association of State Highway Officials 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 (218). 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, the American Association of State Highway Officials, 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 (218) (see Commentary for 4.2.3.2). Building codes also began to establish allowable pile stresses using basic stresses and other information given in ASTM D245 (196).

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 (16). This consensus standard provides 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 (20) are 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. Compression design values parallel to grain established under D2899 are of the same general magnitude as those previously specified earlier by user and code groups.

A table of design values for round timber piles made of Douglas fir, southern pine, red pine and red oak as recommended by the American Wood Preservers Institute was included in the 1971 edition of the Specification. A new timber piling section was introduced as Part X of the Specification in the 1973 edition which included a revised table of design values based on the methods of ASTM D2899. Covering the same species as were included in the 1971 edition, the 1973 design values were limited to piles conforming to the size and quality provisions of ASTM D25 and to the treating provisions of AWPA Standard C3.

In 1977, provisions for round timber piles in the Specification were redesignated as Part VI and expanded to reference AWPA Standard C18 (Marine Use) and to include information on modification of design values for size and other factors, including adjustment of values for piles acting singly rather than in clusters. Tabulated design values were not changed from the 1973 edition.

Timber pile provisions of the 1977 edition, including tabulated design values, have been carried forward to the 1991 edition essentially unchanged.

6.1.1-Application

6.1.1.2 The provisions of Part VI of the Specification relate solely to the properties of the piles themselves. It is the responsibility of the designer to determine soil loads, such as frictional forces from subsiding soils and fills, the adequacy of the surrounding soil or water to provide adequate lateral bracing, the method of pile placement that will preclude damage to the pile, the bearing capacity of the strata at the pile tip, and the effects of any other surrounding environmental factors on pile loads or pile support.

6.1.2-Pile Specifications

6.1.2.1 In addition to setting standard pile sizes, ASTM D25 (22) 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 tip cross sectional area of piles conforming to ASTM D25 essentially meet lumber requirements for dense material (18).

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.

6.1.2.2 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.

6.1.3-Standard Sizes

Standard sizes (22) 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.

6.1.4-Preservative Treatment

6.1.4.1 Green timber piles are generally conditioned prior to pressure treatment (25). 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 (62,88). 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 (62,88). The Boulton process also is used with hardwood species.

Both the steaming and Boulton conditioning processes affect pile strength properties (16,218). These effects are accounted for in pile design values given in Table 6A of the Specification. In the 1991 edition, conditioning by kiln drying is classified with the Boulton process for purposes of establishing design values (196,218).

6.1.4.2 Decay does not occur in softwood species and in most hardwoods that are completely saturated and an air supply is not available (88,170). Permanently submerged piles meet these conditions.

6.2-DESIGN VALUES

6.2.1-Tabulated Values

Design values for round timber piles given in Table 6A are based on ASTM D2899 (16). All values are derived from the properties of small clear specimens of the applicable species as given in ASTM D2555 (20) adjusted as appropriate for the specific property for variability, load duration, grade, lower strength of pile tip, and lower variability of piles compared to small clear specimens (197).

Tabulated compression design values parallel to grain, F_c, include a 10 percent reduction for pile grade, a 10 percent reduction to adjust average small clear values for the whole tree to the tips of the piles, a conservative 10 percent reduction in standard deviation of small clear values to account for the reduced variability of tree size piles, a reduction for conditioning, and the standard adjustment of short term test values for the property to a normal load duration. The combined factor applied to the nominal 5th percent exclusion value for small clear wood specimens of the species is 1/1.88 exclusive of the conditioning adjustment (197).

Similar adjustments are used for tabulated bending design values, F_b: 10 percent reduction for grade, 12 percent reduction to adjust average tree values to tip values, a conservative 12 percent reduction in standard deviation to account for the reduced variability of pile bending strength values, the conditioning adjustment, and the load duration adjustment for the property. The combined factor applied to the 5th percentile small clear strength value is 1/2.04 exclusive of the conditioning adjustment (197).

Tabulated shear design values parallel to the grain, F_v, are based on the 5th percentile clear wood strength value reduced for load duration and stress concentrations using the factor applied to lumber for these effects (18), a 25 percent reduction for possible splits and checks and a conditioning adjustment. The combined factor on the clear wood 5th percentile value is 5.47 exclusive of the conditioning adjustment (197).

Tabulated compression design values perpendicular to grain, $F_{c\perp}$, in Table 6A represent the average proportional limit stress for small clear specimens reduced 1/1.5 for ring orientation and an adjustment for conditioning. No adjustments are made to average clear wood modulus of elasticity values for application to piles.

Tabulated design values, except modulus of elasticity, for Pacific Coast Douglas fir, red oak and red pine in Table 6A contain a 10 percent reduction for conditioning treatment. This factor is based on the Boulton process adjustment in ASTM D2899. Comparable values for southern pine contain a 15 percent reduction for conditioning, the factor for steam conditioning in D2899.

The species designation Pacific Coast Douglas fir listed in Table 6A refers to Douglas fir growing west of the summit of the Cascade Mountains in Washington, Oregon and northern California and west of the summit of the Sierra Nevada Mountains in other areas of California (17). Values for red oak in Table 6A apply only to the species northern red oak, (*Quercus rubra*) and southern red oak (*Quercus falcata*).

6.2.2-Other Species or Grades

Where piles of species other than those listed in 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.

6.3-ADJUSTMENT OF DESIGN VALUES

6.3.2-Load Duration Factor, C_D

As shown in Table 6.3.1, the load duration factor, C_D, is applicable to compression design values perpendicular to grain, $F_{c\perp}$. These pile design values are based on proportional limit stresses and, in accordance with ASTM D245 (18), are subject to load duration adjustments.

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. These exclusions were introduced in the 1977 edition for preservative oxides and the 1982 edition for fire retardant chemicals.

6.3.5-Untreated Factor, C_u

Increases in design values tabulated in Table 6A for piles that are air-dried before treating or are used untreated (see Commentary for 6.1.4.2) represent removal of the conditioning adjustments that are incorporated in the values for all properties except modulus of elasticity.

Design values in Table 6A for Pacific Coast Douglas fir, red oak and red pine contain a 10 percent reduction (1/1.11) for conditioning, assumed to be the Boulton or boiling-under-vacuum process. These values also are applied to piles that have been kiln dried prior to treatment. Tabulated strength values for southern pine piles contain a 15 percent reduction (1/1.18) for conditioning which is assumed to be by the steaming-and-vacuum process.

6.3.6-Fire Retardant Treatment

(See Commentary for 2.3.6.)

6.3.7-Beam Stability Factor

A round member can be considered to have a d/b ratio of 1 and therefore, in accordance with 3.3.3.1, lateral support for beam buckling is not required.

6.3.8-Size Factor, C_F

Bending design values, F_b, for round timber piles that are larger than 13.5 inches in diameter at the critical section in bending are adjusted for size using the same equation

$$C_F = \left(\frac{12}{d}\right)^{1/9} \qquad \text{(C6.3-1)}$$

used to make size adjustments with sawn lumber Beams & Stringers and Posts & Timbers (see Commentary for 4.3.2.2). When applied to round timbers, equation C6.3-1 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 (see Commentary for 2.3.8).

6.3.9-Form Factor

Pile bending design values include an adjustment relating the results of strength tests of full-size piles to the results of test of small clear rectangular specimens selected from the same piles. Thus the effect of form is included in the tabulated values.

6.3.11-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, applicable to Douglas fir and southern pine, provides for an increase in the design value as the critical section moves from the pile tip toward the pile butt. The factor is limited to 10 percent as this is the adjustment for tip end location used in the establishment of compression design values parallel to grain, F_c, for softwood species. As only limited data are available for red pine, the C_{cs} adjustment is not applied to this species.

The compression design value parallel to grain of red oak does not decrease with increase in height in the tree and the 10 percent tip end adjustment factor is not used in the establishment of F_c values for this species group (16).

6.3.13-Single Pile Factor, C_{sp}

Design values in Table 6A are considered applicable to piles used in clusters. Where piles are used such that each is expected to carry its full portion of the design load, multiplication of tabulated compression design values parallel to grain, F_c, and bending design values, F_b, by a C_{sp} factor of 0.80 (1/1.25) and 0.77 (1.30), respectively, may be appropriate.

It is the designer's responsibility to determine the applicability of the C_{sp} factors, designated as factors of safety in ASTM D2899, to the specific design. In making such evaluations, it is to be noted that the tabulated design values apply to the weakest material in the pile located in the pile tip; that the cross-sectional area of the pile at any location along its length may be larger than those associated with the minimum butt and tip diameters specified in ASTM D25; and that the full design load commonly does not reach the pile tip because of the support given by soil friction (16).