Chapter 18

Round Timbers and Ties

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Contents

Round timbers and ties represent some of the most efficient uses of our forest resources. They require a minimum of processing between harvesting the tree and marketing the structural commodity. Poles and piles are debarked or peeled, seasoned, and often treated with preservative prior to use as structural members. Construction logs are usually shaped to facilitate construction. Ties, used for railroads, landscaping, and mining, are slab-cut to provide flat surfaces. Because these products are relatively economical to produce, compared with glulam, steel, and concrete products, they are commonly used throughout the United States.

Standards and Specifications

Material standards and specifications listed in Table 18–1 were created through the joint efforts of producers and users to ensure compatibility between product quality and end use. These guidelines include recommendations for production, treatment, and engineering design. They are updated periodically to conform to changes in material and design technology.

Material Requirements

Round timber and tie material requirements vary with intended use. The majority of uses involve exposure to harsh environments. Thus, in addition to availability, form, and weight, durability is also an important consideration for the use of round timbers and ties. Availability reflects the economic feasibility of procuring members of the required size and grade. Form or physical appearance refers to visual characteristics, such as straightness and occurrence of knots and spiral grain. Weight affects shipping and handling costs and is a function of volume, moisture content, and wood density. Durability is directly related to expected service life and is a function of treatability and natural decay resistance. Finally, regardless of the application, any structural member must be strong enough to resist imposed loads with a reasonable factor of safety. Material specifications available for most applications of round timbers and ties contain guidelines for evaluating these factors.

Table 18–1. Standards and specifications for round timbers and ties[a]

			Engineering design stresses	
Product	Material requirements	Preservative treatment	Procedures	Design values
Utility poles	ANSI O5.1	TT-W-571 AWPA C1,C4,C35	—	ANSI O5.1
Construction poles	ANSI O5.1	TT-W-571 AWPA C23	ASTM D3200	ASAE EP 388
Piles	ASTM D25	TT-W-571 AWPA CI,C3	ASTM D2899	NDS
Construction logs	(See material supplier)	—	ASTM D3957	(See material supplier)
Ties	AREA	TT-W-571 AWPA C2,C6 AREA	—	AREA

[a]ANSI, American National Standards Institute; ASTM, American Society for Testing and Materials; ASAE, American Society of Agricultural Engineers; AREA, American Railway Engineers Association; NDS, National Design Specification (for Wood Construction); AWPA, American Wood-Preservers' Association.

Availability

Material evaluation begins with an assessment of availability. For some applications, local species of timber may be readily available in an acceptable form and quality. However, this is not normally the case. Pole producers and tie mills are scattered throughout heavily forested regions. Their products are shipped to users throughout North America.

Poles

Most structural applications of poles require timbers that are relatively straight and free of large knots. Poles used to support electric utility distribution and transmission lines (Fig. 18–1) range in length from 6 to 38 m (20 to 125 ft) and from 0.13 to 0.76 m (5 to 30 in.) in diameter, 1.8 m (6 ft) from the butt. Poles used to support local area distribution lines are normally <15 m (<50 ft) long and are predominately Southern Pine.

Hardwood species can be used for poles when the trees are of suitable size and form; their use is limited, however, by their weight, by their excessive checking, and because of the lack of experience in preservative treatment of hardwoods. Thus, most poles are softwoods.

The Southern Pine lumber group (principally loblolly, longleaf, shortleaf, and slash) accounts for roughly 80% of poles treated in the United States. Three traits of these pines account for their extensive use: thick and easily treated sapwood, favorable strength properties and form, and availability in popular pole sizes. In longer lengths, Southern Pine poles are in limited supply, so Douglas-fir, and to some extent western redcedar, Ponderosa pine, and western larch, are used to meet requirements for 15-m (50-ft) and longer transmission poles.

Douglas-fir is used throughout the United States for transmission poles and is used in the Pacific Coast region for distribution and building poles. Because the heartwood of Douglas-fir is resistant to preservative penetration and has limited decay and termite resistance, serviceable poles need a well-treated shell of sapwood that is free of checking. To minimize checking after treatment, poles should be adequately seasoned or conditioned before treatment. With these precautions, the poles should compare favorably with treated Southern Pine poles in serviceability.

A small percentage of the poles treated in the United States are of western redcedar, produced mostly in British Columbia. The number of poles of this species used without treatment is not known but is considered to be small. Used primarily for utility lines in northern and western United States, well-treated redcedar poles have a service life that compares favorably with poles made from other species and could be used effectively in pole-type buildings.

Lodgepole pine is also used in small quantities for treated poles. This species is used both for utility lines and for pole-type buildings. It has a good service record when well treated. Special attention is necessary, however, to obtain poles with sufficient sapwood thickness to ensure adequate penetration of preservative, because the heartwood is not usually penetrated and is not decay resistant. The poles must also be well seasoned prior to treatment to avoid checking and exposure of unpenetrated heartwood to attack by decay fungi.

Western larch poles produced in Montana and Idaho came into use after World War II because of their favorable size, shape, and strength properties. Western larch requires preservative treatment full length for use in most areas and, as in the case of lodgepole pine poles, must be selected for adequate sapwood thickness and must be well seasoned prior to treatment. Other species occasionally used for poles are listed in the American National Standards Institute (ANSI) O5.1 standard. These minor species make up a very small portion of pole production and are used locally.

Figure 18–1. Round timber poles form the major structural element in these transmission structures. (Photo courtesy of Koppers Co.)

Glued-laminated, or glulam, poles are also available for use where special sizes or shapes are required. The ANSI Standard O5.2 provides guidelines for specifying these poles.

Piles

Material available for timber piles is more restricted than that for poles. Most timber piles used in the eastern half of the United States are Southern Pine, while those used in western United States are coast Douglas-fir. Oak, red pine, and cedar piles are also referenced in timber pile literature but are not as widely used as Southern Pine and Douglas-fir.

Construction Logs

Round timbers have been used in a variety of structures, including bridges, log cabins, and pole buildings. Log stringer bridges (Fig. 18–2) are generally designed for a limited life on logging roads intended to provide access to remote areas. In Alaska where logs may exceed 1 m (3 ft) in diameter, bridge spans may exceed 9 m (30 ft). Building poles, on the other hand, are preservative-treated logs in the 0.15- to 0.25-m- (6- to 10-in.-) diameter range. These poles rarely exceed 9 m (30 ft) in length. Although poles sold for this application are predominately Southern Pine, there is potential for competition from local species in this category. Finally, log cabin logs normally range from 0.2 to 0.25 m (8 to 10 in.) in diameter, and the availability of logs in this size range is not often a problem. However, because logs are not normally preservative treated for this application, those species that offer moderate to high natural decay resistance, such as western redcedar, are preferred. Pole buildings, which incorporate round timbers as vertical columns and cantilever supports, require preservative-treated wood. Preservative-treated poles for this use may not be readily available.

Ties

The most important availability consideration for railroad cross ties is quantity. Ties are produced from most native species of timber that yield log lengths >2.4 m (8 ft) with diameters >0.18 m (7 in.). The American Railway Engineering Association (AREA) lists 26 U.S. species that may be used for ties. Thus, the tie market provides a use for many low-grade hardwood and softwood logs.

Form

Natural growth properties of trees play an important role in their use as structural round timbers. Three important form considerations are cross-sectional dimensions, straightness, and the presence of surface characteristics such as knots.

Poles and Piles

Standards for poles and piles have been written with the assumption that trees have a round cross section with a circumference that decreases linearly with height. Thus, the shape of a pole or pile is often assumed to be that of the frustum of a cone. Actual measurements of tree shape indicate that taper is rarely linear and often varies with location along the height of the tree. Average taper values from the ANSI O5.1 standard are shown in Table 18–2 for the more popular pole species. Guidelines to account for the effect of taper on the location of the critical section above the groundline are given in ANSI O5.1. The standard also tabulates pole dimensions for up to 15 size classes of 11 major pole species.

Taper also affects construction detailing of pole buildings. Where siding or other exterior covering is applied, poles are generally set with the taper to the interior side of the structures to provide a vertical exterior surface (Fig. 18–3). Another common practice is to modify the round poles by slabbing to provide a continuous flat face. The slabbed face permits more secure attachment of sheathing and framing members and facilitates the alignment and setting of intermediate wall and corner poles. The slabbing consists of a minimum cut to provide a single continuous flat face from the groundline to the top of intermediate wall poles and two continuous flat faces at right angles to one another from the groundline to the top of corner poles. However, preservative

Figure 18–2. Logs are used to construct logging bridges in remote forest areas.

Table 18–2. Circumference taper

Species	Centimeter change in circum-ference per meter	Inch change in circum-ference per foot[a]
Western redcedar	3.7	0.38
Ponderosa pine	2.4	0.29
Jack, lodgepole, and red pine	2.5	0.30
Southern Pine	2.1	0.25
Douglas-fir, larch	1.7	0.21
Western hemlock	1.7	0.20

[a]Taken from ANSI O5.1.

penetration is generally limited to the sapwood of most species; therefore slabbing, particularly in the groundline area of poles with thin sapwood, may result in somewhat less protection than that of an unslabbed pole. All cutting and sawing should be confined to that portion of the pole above the groundline and should be performed before treatment.

The American Standards for Testing and Materials (ASTM) D25 standard provides tables of pile sizes for either friction piles or end-bearing piles. Friction piles rely on skin friction rather than tip area for support, whereas end-bearing piles resist compressive force at the tip. For this reason, a friction pile is specified by butt circumference and may have a smaller tip than an end-bearing pile. Conversely, end-bearing piles are specified by tip area and butt circumference is minimized.

Straightness of poles or piles is determined by two form properties: sweep and crook. Sweep is a measure of bow or gradual deviation from a straight line joining the ends of the pole or pile. Crook is an abrupt change in direction of the centroidal axis. Limits on these two properties are specified in both ANSI O5.1 and ASTM D25.

Construction Logs

Logs used in construction are generally specified to meet the same criteria for straightness and knots as poles and piles (ASTM D25). For log stringer bridges, the log selection criteria may vary with the experience of the person doing the selection but straightness, spiral grain, wind shake, and knots are limiting criteria. Although no consensus standard

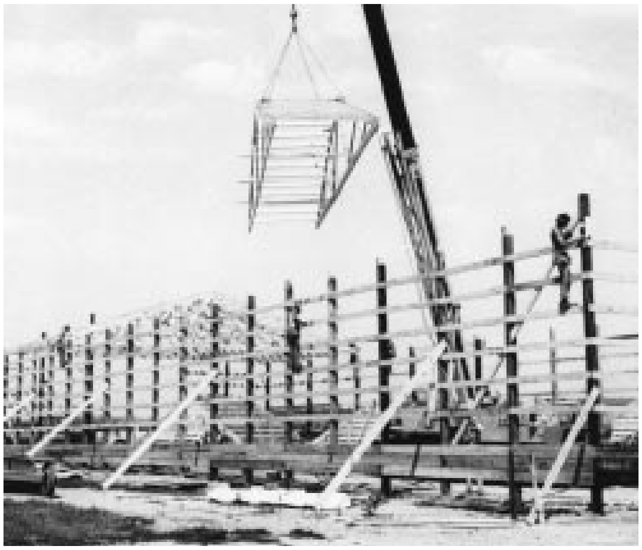

Figure 18–3. Poles provide economical foundation and wall systems for agricultural and storage buildings.

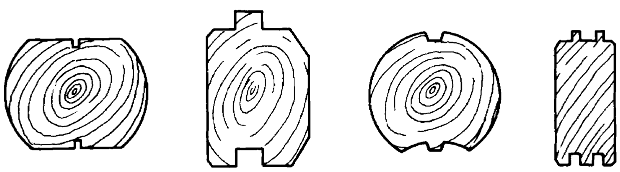

Figure 18–4. Construction logs can be formed in a variety of shapes for log homes. Vertical surfaces may be varied for aesthetic purposes, while the horizontal surfaces generally reflect structural and thermal considerations.

is available for specifying and designing log stringers, the *Design Guide for Native Log Stringer Bridges* was prepared by the USDA Forest Service.

Logs used for log cabins come in a wide variety of cross-sectional shapes (Fig. 18–4). Commercial cabin logs are usually milled so that their shape is uniform along their length. The ASTM D3957 standard, a guide for establishing stress grades for building logs, recommends stress grading on the basis of the largest rectangular section that can be inscribed totally within the log section. The standard also provides commentary on the effects of knots and slope of grain.

Ties

Railroad ties are commonly shaped to a fairly uniform section along their length. The AREA publishes specifications for the sizes, which include seven size classes ranging from 0.13 by 0.13 m (5 by 5 in.) to 0.18 by 0.25 m (7 by 10 in.). These tie classes may be ordered in any of three standard lengths: 2.4 m (8 ft), 2.6 m (8.5 ft), or 2.7 m (9 ft).

Weight and Volume

The weight of any wood product is a function of its volume, density, moisture content, and any retained treatment substance. An accurate estimate of volume of a round pole would require numerous measurements of the circumference and shape along the length, because poles commonly exhibit neither a uniform linear taper nor a perfectly round shape. The American Wood Preservers' Association (AWPA) Standard F3 therefore recommends volume estimates be based on the assumption that the pole is shaped as the frustum of a cone (that is, a cone with the top cut perpendicular to the axis), with adjustments dependent on species. The volume in this case is determined as the average cross-sectional area A times the length. Estimates of average cross-sectional area may be obtained either by measuring the circumference at mid-length ($A = C_m^2/4\pi$) or taking the average of the butt and tip diameters ($A = \pi(D + d)^2/16$) to estimate the area of a circle. The AWPA recommends that these estimates then be adjusted by the following correction factors for the given species and application:

Oak piles	0.82
Southern Pine piles	0.93
Southern Pine and red pine poles	0.95

Tables for round timber volume are given in AWPA Standard F3. The volume of a round timber differs little whether it is green or dry. Drying of round timbers causes checks to open, but there is little reduction of the gross diameter of the pole.

Wood density also differs with species, age, and growing conditions. It will even vary along the height of a single tree. Average values, tabulated by species, are normally expressed as specific gravity (SG), which is density expressed as a ratio of the density of water (see Ch. 4). For commercial species grown in the United States, SG varies from 0.32 to 0.65. If you know the green volume of a round timber and its SG, its dry weight is a product of its SG, its volume, and the unit weight of water (1000 kg/m^3 (62.4 lb/ft^3)). Wood moisture content can also be highly variable. A pole cut in the spring when sap is flowing may have a moisture content exceeding 100% (the weight of the water it contains may exceed the weight of the dry wood substance). If you know the moisture content (MC) of the timber, multiply the dry weight by (1 + MC/100) to get the wet weight.

Finally, in estimating the weight of a treated wood product such as a pole, pile, or tie, you must take into account the weight of the preservative. Recommended preservative retentions are listed in Table 14–3 in Chapter 14. By knowing the volume, the preservative weight can be approximated by multiplying volume by the recommended preservative retention.

Durability

For most applications of round timbers and ties, durability is primarily a question of decay resistance. Some species are noted for their natural decay resistance; however, even these may require preservative treatment, depending upon the environmental conditions under which the material is used and the required service life. For some applications, natural decay resistance is sufficient. This is the case for temporary piles, marine piles in fresh water entirely below the permanent water level, and construction logs used in building construction. Any wood members used in ground contact should be pressure treated, and the first two or three logs above a concrete foundation should be brush treated with a preservative–sealer.

Preservative Treatment

Federal Specification TT–W–571 (U.S. Federal Supply Service (USFSS)) covers the inspection and treatment requirements for various wood products including poles, piles, and ties. This specification refers to the AWPA Standards C1 and C3 for pressure treatment, C2 and C6 for treatment of ties, C8 for full-length thermal (hot and cold) treatment of western redcedar poles, C10 for full-length thermal (hot and cold) treatment of lodgepole pine poles, and C23 for pressure treatment of construction poles. The AREA specifications for cross ties and switch ties also cover preservative treatment. Retention and types of various preservatives recommended for various applications are given in Table 14–3.

Inspection and treatment of poles in service has been effective in prolonging the useful life of untreated poles and those with inadequate preservative penetration or retention. The Forest Research Laboratory at Oregon State University has published guidelines for developing an in-service pole maintenance program.

Service Life

Service conditions for round timbers and ties vary from mild for construction logs to severe for cross ties. Construction logs used in log homes may last indefinitely if kept dry and properly protected from insects. Most railroad ties, on the other hand, are continually in ground contact and are subject to mechanical damage.

Poles

The life of poles can vary within wide limits, depending upon properties of the pole, preservative treatments, service conditions, and maintenance practices. In distribution or transmission line supports, however, service life is often limited by obsolescence of the line rather than the physical life of the pole.

It is common to report the average life of untreated or treated poles based on observations over a period of years. These average life values are useful as a rough guide to the service life to be expected from a group of poles, but it should be kept in mind that, within a given group, 60% of the poles will have failed before reaching an age equal to the average life.

Early or premature failure of treated poles can generally be attributed to one or more of three factors: (a) poor penetration and distribution of preservative, (b) an inadequate retention of preservative, or (c) use of a substandard preservative. Properly treated poles can last 35 years or longer.

Western redcedar is one species with a naturally decay-resistant heartwood. If used without treatment, however, the average life is somewhat less than 20 years.

Piles

The expected life of a pile is also determined by treatment and use. Wood that remains completely submerged in water does not decay although bacteria may cause some degradation; therefore, decay resistance is not necessary in all piles, but it is necessary in any part of the pile that may extend above the permanent water level. When piles that support the foundations of bridges or buildings are to be cut off above the permanent water level, they should be treated to conform to recognized specifications such as Federal Specification TT-W-571 and AWPA Standards C1 and C3. The untreated surfaces exposed at the cutoffs should also be given protection by thoroughly brushing the cut surface with coal-tar creosote. A coat of pitch, asphalt, or similar material may then be applied over the creosote and a protective sheet material, such as metal, roofing felt, or saturated fabric, should be fitted over the pile cut-off in accordance with AWPA Standard M4. Correct application and maintenance of these materials are critical in maintaining the integrity of piles.

Piles driven into earth that is not constantly wet are subject to about the same service conditions as apply to poles but are generally required to last longer. Preservative retention requirements for piles are therefore greater than for poles (Table 14–3). Piles used in salt water are subject to destruction by marine borers even though they do not decay below the waterline. The most effective practical protection against marine borers has been a treatment first with a waterborne preservative, followed by seasoning with a creosote treatment. Other preservative treatments of marine piles are covered in Federal Specification TT–W–571 and AWPA Standard C3 (Table 14–3).

Ties

The life of ties in service depends on their ability to resist decay and mechanical destruction. Under sufficiently light traffic, heartwood ties of naturally durable wood, even if of low strength, may give 10 or 15 years of average service without preservative treatment; under heavy traffic without adequate mechanical protection, the same ties might fail in 2 or 3 years. Advances in preservatives and treatment processes, coupled with increasing loads, are shifting the primary cause of tie failure from decay to mechanical damage. Well-treated ties, properly designed to carry intended loads, should last from 25 to 40 years on average. Records on life of treated and untreated ties are occasionally published in the annual proceedings of the American Railway Engineering Association (AREA) and AWPA.

Strength Properties

Allowable strength properties of round timbers have been developed and published in several standards. In most cases, published values are based on strength of small clear test samples. Allowable stresses are derived by adjusting small clear values for effects of growth characteristics, conditioning, shape, and load conditions as discussed in applicable standards. In addition, published values for some species of poles and piles reflect results of full-sized tests.

Poles

Most poles are used as structural members in support structures for distribution and transmission lines. For this application, poles may be designed as single-member or guyed cantilevers or as structural members of a more complex structure. Specifications for wood poles used in single pole structures have been published by ANSI in Standard O5.1. Guidelines for the design of pole structures are given in the ANSI National Electric Safety Code (NESC) (ANSI C2).

The ANSI O5.1 standard gives values for fiber stress in bending for species commonly used as transmission or distribution poles. These values represent the near-ultimate fiber stress for poles used as cantilever beams. For most species, these values are based partly on full-sized pole tests and include adjustments for moisture content and pretreatment conditioning. The values in ANSI O5.1 are compatible with the ultimate strength design philosophy of the NESC, but they are not compatible with the working stress design philosophy of the *National Design Specification* (NDS).

Reliability-based design techniques have been developed for the design of distribution–transmission line systems. This approach requires a strong database on the performance of pole structures. Supporting information for these design procedures is available in a series of reports published by the Electric Power Research Institute (EPRI).

Piles

Bearing loads on piles are sustained by earth friction along their surface (skin friction), by bearing of the tip on a solid stratum, or by a combination of these two methods. Wood piles, because of their tapered form, are particularly efficient in supporting loads by skin friction. Bearing values that depend upon friction are related to the stability of the soil and generally do not approach the ultimate strength of the pile. Where wood piles sustain foundation loads by bearing of the tip on a solid stratum, loads may be limited by the compressive strength of the wood parallel to the grain. If a large proportion of the length of a pile extends above ground, its bearing value may be limited by its strength as a long column. Side loads may also be applied to piles extending above ground. In such instances, however, bracing is often used to reduce the unsupported column length or to resist the side loads.

The most critical loads on piles often occur during driving. Under hard driving conditions, piles that are too dry (<18% moisture content at a 51-mm (2-in.) depth) have literally exploded under the force of the driving hammers. Steel banding is recommended to increase resistance to splitting, and driving the piles into predrilled holes reduces driving stresses.

The reduction in strength of a wood column resulting from crooks, eccentric loading, or any other condition that will result in combined bending and compression is not as great as would be predicted with the NDS interaction equations. This does not imply that crooks and eccentricity should be without restriction, but it should relieve anxiety as to the influence of crooks, such as those found in piles. Design procedures for eccentrically loaded columns are given in Chapter 8.

There are several ways to determine bearing capacity of piles. Engineering formulas can estimate bearing values from the penetration under blows of known energy from the driving hammer. Some engineers prefer to estimate bearing capacity from experience or observation of the behavior of pile foundations under similar conditions or from the results of static-load tests.

Working stresses for piles are governed by building code requirements and by recommendations of ASTM D2899. This standard gives recommendations for adjusting small clear strength values listed in ASTM D2555 for use in the design of full-sized piles. In addition to adjustments for properties inherent to the full-sized pile, the ASTM D2899 standard also provides recommendations for adjusting allowable stresses for the effects of pretreatment conditioning.

Design stresses for timber piles are tabulated in the NDS for wood construction. The NDS values include adjustments for the effects of moisture content, load duration, and preservative treatment. Recommendations are also given to adjust for lateral support conditions and factors of safety.

Construction Logs

Design values for round timbers used as structural members in pole or log buildings may be determined following standards published by ASTM and ASAE. The ASTM standard refers pole designers to the same standard used to derive design stresses for timber piles (D2899). The ASAE standard (EP388), which governed the derivation of construction poles for agricultural building applications, is being revised. The future revision will be designated EP560 and will deal only with round wood poles. Derivation of design stresses for construction logs used in log homes is covered in ASTM D3957, which provides a method of establishing stress grades for structural members of any of the more common log configurations. Manufacturers can use this standard to develop grading specifications and derive engineering design stresses for their construction logs.

Ties

Railroad cross and switch ties have historically been overdesigned from the standpoint of rail loads. Tie service life was limited largely by deterioration rather than mechanical damage. However, because of advances in decay-inhibiting treatment and increased axle loads, adequate structural design is becoming more important in increasing railroad tie service life.

Rail loads induce stresses in bending and shear as well as in compression perpendicular to the grain in railroad ties. The AREA manual gives recommended limits on ballast bearing pressure and allowable stresses for cross ties. This information may be used by the designer to determine adequate tie size and spacing to avoid premature failure due to mechanical damage.

Specific gravity and compressive strength parallel to the grain are also important properties to consider in evaluating cross tie material. These properties indicate the resistance of the wood to both pull out and lateral thrust of spikes.

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