CHAPTER 3.0
TIMBER PILE PROPERTIES

3.1 INTRODUCTION

The design of timber pile foundations requires a firm understanding of the mechanical properties of the timber pile. There are generally two species of timber used for the manufacture of timber piles : Douglas Fir and Southern Yellow Pine. Other species such as Caribbean Pine, Lodgepole Pine, Red Oak, and Red Pine are also used on occasion.

ASTM D 25 *Standard Specification for Round Timber Piles* establishes physical properties and manufacturing requirements and ASTM D 2899 *Standard Practice for Establishing Stresses for Round Timber Piles* provides the procedures for developing timber piling stresses from small clear specimens. The strength properties are derived from clear wood strength of small specimens tested in accordance with ASTM D 2555 *Standard Test Method for Establishing Clear Wood Strength Values.*

Recent research (Bodig and Arnette, 2000) on full-scale strength testing has been conducted on approximately 100 Southern Yellow Pine piles and 100 Douglas Fir piles. This research has demonstrated that currently used allowable design stresses are conservative. A new ASTM standard for developing timber piling stresses based on full scale tests is under development. A condensed report will soon be available.

3.2 ALLOWABLE STRESS DESIGN

The selection of material properties for piles must consider both static and dynamic stresses. A pile must be able to withstand the dynamic stresses induced in the pile during the driving process, as well as the static stresses that the pile is subjected to in service.

The allowable stresses for timber piles published in this manual are based on the American Forest & Paper Association (AFPA) publication, *Manual for Engineered Wood Construction – Allowable Stress Design, Supplement Timber Poles and Piles* and procedures outlined in the ASTM standards referenced above. Allowable stresses and pile capacity are tabulated in section 3.3 and maximum butt and tip dimensions versus pile length are presented in section 3.4. Section 3.5 reviews the procedures to determine the allowable stresses for timber piles from small clear wood specimens. Section 3.6 provides an analytical method for determining allowable stresses using reduction factors to account for load duration, temperature, pressure treatment, etc.

3.3 TABULATION OF ALLOWABLE STRESS AND PILE CAPACITY

Table 3-1 provides recognized allowable stresses for timber piles, as published by the American Forest and Paper Association. The values provided in table 3-1 are applicable for pile groups, with wet exposures, at normal temperature range (i.e., <100°F), and with a ″normal″ load duration factor of 1. The tabulated values are given for piles treated with a preservative using a steam conditioning or Boultonizing processes. For piles that are air dried or kiln-dried prior to treating stresses may be increased by 11% to 18% (see section 3.6).

Table 3-1
Allowable Stress Values for Treated Round Timber Piles Graded in Accordance with ASTM D25

Species	Axial Compression (F_c) (psi)	Bending (F_b) (psi)	Shear Perpendicular to the Grain (F_v) (psi)	Compression Perpendicular to the Grain ($F_{c\perp}$) (psi)	Modulus of Elasticity (E) (psi)
Southern Pine[1]	1200	2400	110	250	1,500,000
Douglas Fir[2]	1250	2450	115	230	1,500,000
Lodgepole Pine	1150	1700	80	270	1,000,000
Red Oak[3]	1100	2450	135	350	1,250,000
Red Pine[4]	900	1900	85	155	1,280,000

1. Southern Pine design values apply to Loblolly, Longleaf, Shortleaf, and Slash Pines.
2. Pacific Coast Douglas Fir design values apply to this species as defined in ASTM D 1760
3. Red Oak design values apply to Northern and Southern Red Oak
4. Red Pine design values apply to Red Pine grown in the United States

3.3.1 Pile Capacity

Table 3-2 provides compression strength parallel-to-the-grain as a function of the specified pile tip circumference (ASTM D25). The allowable values are only applicable when the pile tip circumference is specified in accordance with ASTM D25. The values presented in Table 3-2 do not consider buckling capacity of timber piles.

The tip of the pile represents the smallest circumference and lowest strength section of a pile. Additional capacity may be computed at other locations in the pile by considering the increased cross-sectional area away from the tip using linear taper and specified butt circumference.

Table 3-2 for allowable design capacities is based on the following conditions :

- Timber piles meet ASTM D25
- In-service temperature range < 100°F
- Wet service conditions
- Timber piles have had preservative treatment
- Compression members fully laterally supported (fully embedded in soil)
- Piles in a cluster (pile groups)
- Critical location for compression parallel to the grain is the tip of the pile.

When these conditions do not occur the pile capacity should be adjusted using the adjustment factors presented in Table 3-10.

3.4 PILE SIZE SPECIFICATIONS

The natural taper of timber piles is a factor in the design formula. The natural taper of Southern pine is approximately 0.1 in/ft throughout the length. Douglas fir has a smaller taper within 20 feet of the butt. The result is often a smaller tip for a given butt size in Douglas fir and other western species.

Table 3-3 provides specified butt circumferences with corresponding minimum tips sizes for Southern pine. Table 3-4 provide specified tip circumferences with corresponding minimum butt circumferences for Southern Pine. The corresponding tables for Douglas fir and other western species are in Tables 3-5 and 3-6.

Table 3-2
Allowable Pile Capacity in Compression (kips)

Timber Species	Allowable Pile Capacity in Compression (kips)					
	Pile Tip Diameter (inches)					
	7	8	9	10	11	12
Southern Pine	46	60	76	94	114	136
Douglas Fir	48	63	80	98	119	141

Table 3-3 Southern Pine Foundation Piling – Specified Butt Circumferences with Corresponding Minimum Tip Circumferences [A,B,C,D,E] (from ASTM D25 - Table X1.3)

[Approximate Diameters in Brackets]

Required Minimum Circumference, in. 3 ft from Butts	22 [7]	25 [8]	28 [9]	31 [10]	35 [11]	38 [12]	41 [13]	44 [14]	47 [15]	50 [16]	57 [18]
Length (ft)	Minimum Tip Circumferences, in.										
20	16 [5.1]	16 [5.1]	18 [5.7]	21 [6.7]	25 [8.0]	**28 [8.9]**	**31 [9.9]**	**34 [10.8]**	**37 [11.8]**	40 [12.7]	47 [15.0]
25	16 [5.1]	16 [5.1]	17 [5.4]	20 [6.4]	24 [7.6]	**27 [8.6]**	**30 [9.5]**	**33 [10.5]**	**36 [11.4]**	39 [12.4]	46 [14.6]
30	16 [5.1]	16 [5.1]	16 [5.1]	19 [6.0]	23 [7.3]	**26 [8.3]**	**29 [9.2]**	**32 [10.2]**	**35 [11.1]**	38 [12.1]	45 [14.3]
35				18 [5.7]	22 [7.0]	**25 [8.0]**	**28 [8.9]**	**31 [9.9]**	**34 [10.8]**	37 [11.8]	44 [14.0]
40				17 [5.4]	21 [6.7]	**24 [7.6]**	**27 [8.6]**	**30 [9.5]**	**33 [10.5]**	36 [11.4]	43 [13.7]
45					20 [6.4]	**23 [7.3]**	**26 [8.3]**	**29 [9.2]**	**32 [10.2]**	35 [11.1]	42 [13.4]
50					19 [6.0]	**22 [7.0]**	**25 [8.0]**	**28 [8.9]**	**31 [9.9]**	34 [10.8]	41 [13.0]
55						**21 [6.7]**	**24 [7.6]**	**27 [8.6]**	**30 [9.5]**	33 [10.5]	40 [12.7]
60						**20 [6.4]**	**23 [7.3]**	**26 [8.3]**	**29 [9.2]**	32 [10.2]	39 [12.4]
65						19 [6.0]	**22 [7.0]**	**25 [8.0]**	**28 [8.9]**	31 [9.9]	38 [12.1]
70						18 [5.7]	**21 [6.7]**	**24 [7.6]**	27 [8.6]	30 [9.5]	37 [11.8]
75							**20 [6.4]**	23 [7.3]	26 [8.3]	29 [9.2]	36 [11.4]
80							19 [6.0]	22 [7.0]	25 [8.0]	28 [8.9]	35 [11.1]
85							18 [5.7]	21 [6.7]	24 [7.6]	27 [8.6]	34 [10.8]

Commonly available sizes are shown within the bold outline:

[A] Where the taper applied to the butt circumferences calculate to a circumference at the tip of less than 16 in., the individual values have been increased to 16 in. to ensure a minimum of 5-in. tip for purposes of driving.
[B] To convert to metric dimensions, 1 in. = 25.4 mm.
[C] Class A piles are all those listed with a specified required minimum circumference of 44 in. at 3 ft from butt.
[D] Class B piles are those listed with a specified required minimum circumference at 3 ft from butt of 35 in. and lengths of 20 to 25 ft minimum circumference at 3 ft from butt of 38 in. and lengths of 20 to 50 ft, and minimum circumference at 3 ft from butt of 41 in. and lengths of 55 to 80 ft.
[E] Southern Yellow Pine piles are generally available in lengths shorter than 70 ft or girth of less than 50 in. at 3 ft from butt. The purchaser should inquire as to availability of sizes below the lines.

Table 3-4 Southern Pine Foundation Piling – Specified Tip Circumferences with Corresponding Minimum Butt Circumferences [A,B] (from ASTM D25 – Table X1.5)

[Approximate Diameters in Brackets]

Required Minimum Tip Circumference, In.	16 [5]	19 [6]	22 [7]	25 [8]	28 [9]	31 [10]	35 [11]	38 [12]
Length (ft)	Minimum Circumferences 3 ft from Butt, in.							
20	19 [6.0]	**22 [7.0]**	**25 [8.0]**	**28 [8.9]**	**31 [9.9]**	**34 [10.8]**	38 [12.1]	41 [13.0]
25	20 [6.4]	**23 [7.3]**	**26 [8.3]**	**29 [9.2]**	**32 [10.2]**	**35 [11.1]**	39 [12.4]	42 [13.4]
30	21 [6.7]	**24 [7.6]**	**27 [8.6]**	**30 [9.5]**	**33 [10.5]**	**36 [11.4]**	40 [12.7]	43 [13.7]
35	22 [7.0]	**25 [8.0]**	**28 [8.9]**	**31 [9.9]**	**34 [10.8]**	**37 [11.8]**	41 [13.0]	44 [14.0]
40		**26 [8.3]**	**29 [9.2]**	**32 [10.2]**	**35 [11.1]**	**38 [12.1]**	42 [13.4]	45 [14.3]
45		**27 [8.6]**	**30 [9.5]**	**33 [10.5]**	**36 [11.4]**	39 [12.4]	43 [13.7]	46 [14.6]
50			**31 [9.9]**	**34 [10.8]**	**37 [11.8]**	40 [12.7]	44 [14.0]	47 [15.0]
55			**32 [10.2]**	**35 [11.1]**	**38 [12.1]**	41 [13.0]	45 [14.3]	48 [15.3]
60			**33 [10.5]**	**36 [11.4]**	39 [12.4]	42 [13.4]	46 [14.6]	49 [15.6]
65			**34 [10.8]**	**37 [11.8]**	40 [12.7]	43 [13.7]	47 [15.0]	50 [15.9]
70			**35 [11.1]**	**38 [12.1]**	41 [13.6]	44 [14.0]	48 [15.3]	51 [16.2]
75			**36 [11.4]**	39 [12.4]	42 [13.4]	45 [14.3]	49 [15.6]	52 [16.6]
80			37 [11.8]	40 [12.7]	43 [13.7]	46 [14.6]	50 [15.9]	53 [16.9]
85			38 [12.1]	41 [13.0]	44 [14.0]	47 [15.0]	51 [16.2]	54 [17.2]
90			39 [12.4]	42 [13.4]	45 [14.3]	48 [15.3]	52 [16.6]	55 [17.5]

Commonly available sizes are shown within the bold outline: Dimensions for ASTM Table X1.1 minimum 8 inch tip size, sometimes known as natural taper piles, are shown in column for 8 inch diameter tips. These are for piles up to 45 ft. in length.

[A] To convert to metric dimensions, 1 in. = 25.4 mm

[B] Piles purchased as “8-in. and natural taper” have a required minimum tip circumference of 25 in. and are available in lengths of 20 to 45 ft.

[C] Southern Yellow Pine piles are generally available in lengths shorter than 70 ft. or girth of less than 50 in. at 3 ft. from butt. The purchaser should inquire as to availability of sizes below the lines.

TABLE 3-5 Douglas Fir Foundation Piling – Specified Butt Circumferences with Corresponding Minimum Tip Circumferences [A,B] (from ASTM D 25 – Table X1.2)

[Approximate Diameters in Brackets]

Required Minimum Circumference, in. 3 ft from Butts	22 [7]	25 [8]	28 [9]	31 [10]	35 [11]	38 [12]	41 [13]	44 [14]	47 [15]	50 [16]	57 [18]
Length (ft)	Minimum Tip Circumferences, in.										
20	16.0 [5.1]	16.0 [5.1]	16.0 [5.1]	18.0 [5.7]	**22.0 [7.0]**	**25.0 [8.0]**	**28.0 [8.9]**				
25	16.0 [5.1]	16.0 [5.1]	16.0 [5.1]	17.0 [5.4]	**20.5 [6.5]**	**23.5 [7.5]**	**26.5 [8.4]**	**29.5 [9.4]**			
30	16.0 [5.1]	16.0 [5.1]	16.0 [5.1]	16.0 [5.1]	**19.0 [6.0]**	**22.0 [7.0]**	**25.0 [8.0]**	**28.0 [8.9]**			
35				16.0 [5.1]	**18.0 [5.7]**	**21.0 [6.7]**	**24.0 [7.6]**	**27.0 [8.6]**	**30.0 [9.5]**		
40				16.0 [5.1]	**17.0 [5.4]**	**20.0 [6.4]**	**23.0 [7.3]**	**26.0 [8.3]**	**29.0 [9.2]**		
45					**16.5 [5.3]**	**18.5 [5.9]**	**21.0 [6.7]**	**24.0 [7.6]**	**27.0 [8.6]**	30.0 [9.5]	
50					16.0 [5.1]	**17.0 [5.4]**	**19.0 [6.0]**	**22.0 [7.0]**	**25.0 [8.0]**	28.0 [8.9]	
55						**16.5 [5.3]**	**17.5 [5.6]**	**20.3 [6.5]**	**23.3 [7.4]**	26.3 [8.4]	31.3 [10.0]
60						**16.0 [5.1]**	**16.0 [5.1]**	**18.6 [5.9]**	**21.6 [6.9]**	24.6 [7.8]	31.6 [10.0]
65						**16.0 [5.1]**	**16.0 [5.1]**	**17.3 [5.5]**	**18.9 [6.0]**	21.9 [7.0]	28.9 [9.2]
70						16.0 [5.1]	**16.0 [5.1]**	**16.0 [5.1]**	**16.2 [5.2]**	19.2 [6.1]	26.2 [8.3]
75							**16.0 [5.1]**	**16.0 [5.1]**	**16.1 [5.1]**	17.6 [5.6]	24.0 [7.6]
80							16.0 [5.1]	**16.0 [5.1]**	**16.0 [5.1]**	16.0 [5.1]	21.8 [6.9]
85							16.0 [5.1]	**16.0 [5.1]**	**16.0 [5.1]**	16.0 [5.1]	20.6 [6.6]
90							16.0 [5.1]	**16.0 [5.1]**	**16.0 [5.1]**	16.0 [5.1]	19.5 [6.2]
95							16.0 [5.1]	**16.0 [5.1]**	**16.0 [5.1]**	16.0 [5.1]	18.8 [6.0]
100							16.0 [5.1]	**16.0 [5.1]**	**16.0 [5.1]**	16.0 [5.1]	18.0 [5.7]
105										16.0 [5.1]	17.0 [5.4]
110										16.0 [5.1]	16.0 [5.1]
115											16.0 [5.1]
120											16.0 [5.1]

Commonly available sizes are shown within the bold outline:

[A] Where the taper applied to the butt circumferences calculate to a circumference at the tip of less than 16 in., the individual values have been increased to 16 in. to ensure a minimum of 5-in. tip for purposes of driving.
[B] To convert to metric dimensions, 1 in. = 25.4 mm.

TABLE 3-6 Douglas Fir Foundation Piling – Specified Tip Circumferences with Corresponding Minimum Butt Circumferences [A,B] (from ASTM D 25 - Table X1.4)

[Approximate Diameters in Brackets]

Required Minimum Tip Circumference, In.	16 [5]	19 [6]	22 [7]	25 [8]	28 [9]	31 [10]	35 [11]	38 [12]
Length (ft)	Circumferences 3 ft from Butt, in.							
20	21.0 [6.7]	24.0 [7.6]	**27.0 [8.6]**	**30 [9.5]**	**33.0 [10.5]**	**36.0 [11.5]**	40.0 [12.7]	43.0 [13.7]
25	22.8 [7.1]	25.3 [8.1]	**28.3 [9.0]**	**31.3 [10.0]**	**34.3 [10.9]**	**37.3 [11.9]**	41.3 [13.1]	44.3 [14.1]
30	23.5 [7.5]	26.5 [8.4]	**29.5 [9.4]**	**32.5 [10.3]**	**35.5 [11.3]**	**38.5 [12.3]**	42.5 [13.5]	45.5 [14.5]
35	24.8 [7.9]	27.8 [8.8]	**30.8 [9.8]**	**33.8 [10.8]**	**36.8 [11.7]**	**39.8 [12.7]**	43.8 [13.9]	46.8 [14.9]
40	26.0 [8.3]	29.0 [9.2]	**32.0 [10.2]**	**35.0 [11.1]**	**38.0 [12.1]**	**41.0 [13.0]**	45.0 [14.3]	48.0 [15.3]
45	27.3 [8.7]	30.3 [9.6]	**33.3 [10.6]**	**36.3 [11.6]**	**39.3 [12.5]**	42.3 [13.5]	46.3 [14.7]	49.3 [15.7]
50	28.5 [9.1]	31.5 [10.0]	34.5 [11.0]	**37.5 [11.9]**	**40.5 [12.9]**	43.5 [13.8]	47.5 [15.1]	50.5 [16.1]
55	29.8 [9.5]	32.8 [10.4]	35.8 [11.4]	**38.8 [12.4]**	**41.8 [13.3]**	44.8 [14.3]	48.8 [15.5]	51.8 [16.5]
60	31.0 [9.9]	34.0 [10.8]	37.0 [11.8]	**40.0 [12.7]**	**43.0 [13.7]**	46.0 [14.6]	50.0 [15.9]	53.0 [16.9]
65	32.3 [10.3]	35.3 [11.2]	38.3 [12.2]	**41.3 [13.1]**	**44.3 [14.1]**	47.3 [15.1]	51.3 [16.3]	54.3 [17.3]
70	33.5 [10.7]	36.5 [11.6]	39.5 [12.6]	**42.5 [13.5]**	**45.5 [14.5]**	48.5 [15.4]	52.5 [16.7]	55.5 [17.7]
75	34.8 [11.1]	37.8 [12.0]	40.8 [13.0]	**43.8 [13.9]**	**46.8 [14.9]**	49.8 [15.9]	53.8 [17.1]	56.8 [18.1]
80	36.0 [11.5]	39.0 [12.4]	42.0 [13.4]	**45.0 [14.3]**	**48.0 [15.3]**	51.0 [16.2]	55.0 [17.5]	58.0 [18.5]
85	37.3 [11.9]	40.3 [12.8]	43.3 [13.8]	**46.3 [14.7]**	**49.3 [15.7]**	52.3 [16.6]	56.3 [17.9]	59.3 [18.9]
90	38.5 [12.3]	41.5 [13.2]	44.5 [14.2]	**47.5 [15.1]**	**50.5 [16.1]**	53.5 [17.0]	57.5 [18.3]	60.5 [19.3]
95	39.8 [12.7]	42.8 [13.6]	45.8 [14.6]	**48.8 [15.5]**	**51.8 [16.5]**	54.8 [17.4]	58.8 [18.7]	61.8 [19.7]
100	41.0 [13.0]	44.0 [14.0]	47.0 [15.0]	**50.0 [15.9]**	**53.0 [16.9]**	56.0 [17.8]	60.0 [19.1]	
105	42.3 [13.5]	45.3 [14.4]	48.3 [15.4]	**51.3 [16.3]**	54.3 [17.3]	57.3 [18.2]		
110	43.5 [13.8]	46.5 [14.8]	49.5 [15.8]	**52.5 [16.7]**	55.5 [17.7]	58.5 [18.6]		
115	44.8 [14.3]	47.8 [15.2]	50.8 [16.2]	**53.8 [17.1]**	56.8 [18.1]			
120	46.0 [14.6]	49.0 [15.6]	52.0 [16.6]	**55.0 [17.5]**	58.0 [18.5]			

Commonly available sizes are shown within the bold outline: Dimensions for ASTM Table X1.1 minimum 8 inch tip size, sometimes known as natural taper piles, are shown in column for 8 inch diameter tips. These are for piles up to 45 ft. in length.

[A] To convert to metric dimensions, 1 in. = 25.4 mm

[B] Piles purchased as "8-in. and natural taper" have a required minimum tip circumference of 25 in. and are available in lengths of 20 to 45 ft.

Table 3-7 Sizes of Class A, B and 8 Inch Minimum Tip Piles

Length (ft)	8 inch min. tip pile*	Dia. 3 ft from butt x tip dia.	
		Class A	Class B
To 40	See 8 inch tip sizes column in tables 3-4 & 3-6	14” @ 3’ x 9”	12” @ 3’ x 8”
40 to 54		14” @ 3’ x 9”	12” @ 3’ x 7”
55 to 74		14” @ 3’ x 8”	13” @ 3’ x 7”
75 to 90		14” @ 3’ x 7”	13” @ 3’ x 6”
> 90		14” @ 3’ x 6”	13” @ 3’ x 5”

* Also known as NYC Building Code Pile

TABLE 3-8 Sizes of Timber Pile per Canadian Standards Association (Can3-056)

Diameter at Extreme Butt or Large End inches [centimeters]	14 [36]	13 [33]	12 [30]	11 [27]	10 [24]
Length feet	Diameter at Tip inches [centimeters]				
Up to 20	10 [25]	10 [25]	9 [23]	8 [20]	7 [18]
20 to 34	10 [25]	9 [23]	8 [20]	7 [18]	6 [15]
35 to 44	9 [23]	8 [20]	7 [18]	6 [15]	-
45 to 59	8 [20]	7 [18]	7 [18]	-	-
60 to 69	8 [20]	7 [18]	6 [15]	-	-
70 to 89	7 [18]	6 [15]	-	-	-
90 to 105	6 [15]	5 [13]	-	-	-

TABLE 3-9 Residential Bulkhead and Dock Piling

Diameter at Butt (inches)	Southern Pine Length (feet)	Douglas Fir Length (feet)
8	12-30	12-30
10	16-35	16-35
12	20-40	20-40

3.5 WORKING STRENGTH BASED ON SMALL CLEAR WOOD SPECIMENS

The method presented is this section is based on ASTM D 2899. Small clear wood samples of timber piles may be used to determine the allowable design strengths. Section 3.5 provides guidance on determining the working strength of timber piles using the small clear wood specimens. Section 3.6 provides guidance on how to determine the allowable strength of species based on the working strength values determined in Section 3.3.

3.5.1 Axial Compressive Stress

The working stress in static compression parallel to the grain for green untreated timber piles ($C\underline{\Uparrow}$) is determined per ASTM D 2899 using the following equation:

$$C\underline{\Uparrow} = (S - 1.645SD)/ 1.88 \tag{3-1}$$

where : *S* = Average small clear crushing strength determined from ASTM D 2555
SD = Standard deviation of small clear crushing strength.

For dynamic stresses (short term stresses due to pile installation), the working stress parallel to the grain is three times the static working stress parallel to the grain for green untreated timber piles ($C\underline{\Uparrow}$).

3.5.2 Extreme Fiber Bending Stress

The extreme fiber bending stress for timber piles (*f*) is determined per ASTM D 2899 using the following equation :

$$f = (S - 1.645SD)/ 2.04 \tag{3-2}$$

where : *S* = Average small clear bending strength determined per ASTM D 2555
SD = Standard deviation of small clear bending strength.

For dynamic stresses (short term stresses due to pile installation) the working stress for small clear wood bending strength is three times the static working stress for small clear wood bending strength for green untreated timber piles (*f*).

3.5.3 Compressive Stress Perpendicular to the Grain

The working stress in compression, perpendicular to the grain, for green untreated timber piles ($C\perp$) is determined per ASTM D 2899 using the following equation:

$$C\perp = S / 1.5 \tag{3-3}$$

where : *S* = Average proportional limit stress of small clear specimens determined per ASTM D 2555

3.5.4 Shear Stress Perpendicular to the Grain

The working stress in horizontal shear perpendicular to the grain for green untreated timber piles (σ) is determined per ASTM D 2899 using the following equation:

$$\sigma = (S - 1.645SD)/ 5.47 \tag{3-4}$$

where : *S* = Average small clear shear strength specimens determined per ASTM D 2555
SD = Standard deviation of small clear shear strength.

3.5.5 Modulus of Elasticity

The average small clear modulus of elasticity values determined per ASTM D 2555 shall be taken as the values for timber piles.

3.6 ALLOWABLE STRESS

The allowable stress is determined from the working stress, as determined using the equations in sections 3.5, multiplied by factors that account for wood fiber density, duration of load, service temperature, pressure treatment, pile size, effect of single pile versus group pile, critical section and bearing area.

3.6.1 Load Duration

Wood stress properties are affected by the duration of the maximum applied load. The shorter the duration, the greater the maximum load that can be carried. Design values for round timber piles established in this manual are based on short-term tests. Normal load duration values in this manual represents a load that fully stresses a member to its allowable design value for a cumulative duration of 10 years (dead plus live load). For a duration of load greater than 10 years, the working stress is reduced by 10% (typically dead load, no live load).

3.6.2 Temperature

The strength of wood is a function of the in-service temperature of the wood. Wood at higher temperatures is not as strong as the same material at lower temperatures. Wood heated to temperatures above 100°F for extended periods of time lose strength. The correction factor for temperature should be selected from Table 3-10.

3.6.3 Pressure Treatment

Timber piles should be treated in accordance with American Wood-Preservers' Association standards (see chapter 11 on specifications). The non-treated load correction factor provided in Table 3-9 applies for piles that are either air-dried prior to treatment or are not treated.

3.6.4 Size

The average bending stress of round wood sections based on standard beam formulas is greater than that of matched rectangular sections. However, the section modulus of a round beam is less than (1/1.18) that of a square beam of equivalent cross sectional area by approximately the same ratio of the rounded member to that of a rectangular member.

The clear wood bending stress in ASTM D 2555 is based on rectangular sections. The correction factor for size applies only to bending stress and is determined using the following equation :

$$C_f = (12/d)^{1/9} \leq 10 \qquad (3\text{-}5)$$

where : d = pile diameter (greater than 13.5 inches)

For pile diameters less than 13 inches the adjustment factor for size is 1.0.

3.6.5 Load Sharing

Timber piles are commonly connected by reinforced concrete caps or equivalent distribution elements, resulting in the pile cluster deforming as a single member under axial or bending load. The load carrying capacity of these pile clusters is greater than the sum of the individual pile capacities as a result of load sharing.

Table 3-10
Adjustment Factors for Timber Piles

Factors		Compression Parallel	Bending	Horizontal Shear	Compression Perpendicular	Modulus of Elasticity
Load Duration (C_{ld})	≤ 10 yrs	1.0	1.0	1.0	1.0	na
	> 10 yrs	0.9	0.9	0.9	0.9	na
Temperature (C_t)	T≤100°F	1.0	1.0	1.0	1.0	1.0
	100°<T≤ 125°F	0.7	0.7	0.7	0.7	0.9
	125°<T≤ 150°F	0.5	0.5	0.5	0.5	0.9
Untreatment Factor (C_u)	Southern Pine	1.18	1.18	1.18	1.18	1.0
	Douglas Fir	1.11	1.11	1.11	1.11	1.0
Size(C_f)		1.0	$C_f = (12/d)^{1/9} \le 10$	1.0	1.0	1.0
Load Sharing (C_{ls})	Single pile	0.8	0.77	na	Na	na
	Cluster	1.0	1.0	na	Na	na

3.6.6 Allowable Stress

The allowable stress is determined from the working stress multiplied by factors that account for wood fiber density, duration of load, service temperature, pressure treatment, pile size, effect of single pile versus group pile, critical section and bearing area. The following equation shall be used to determine the allowable stress of round timber piles ($C_{\parallel a}$, f_a, $C_{\perp a}$, σ_a, E_a):

$$\text{Allowable stress} = (\text{working stress } C_{ld} \times C_t \times C_u \times C_f \times C_{ls}) \qquad (3\text{-}6)$$

The minimum pile butt and tip diameters specified in ASTM D25 should be the basis for design.

3.7 PRESERVATIVE PROCESS

Timber piles are potentially susceptible to biological attack from fungi, marine borers and insects. Pressure treatment of timber piles has proven to be an effective means of protection from biological attack. There are two broad types of wood preservatives used in today's pressure treating process for timber piles; oil-borne systems (primarily creosote), and waterborne preservative systems (Chromated Copper Arsenate (CCA) and Ammoniacal Copper Zinc Arsenate (ACZA)). ACZA is primarily used for Douglas fir.

The American-Wood Preserver's Association (AWPA) develops and maintains Preservative and Treating Standards for various products and uses including land, freshwater and marine piling. These standards should be reviewed and referenced to identify preservative treatment. In Canada, the Canadian Standards Association standard CSA 080.3 is the treatment standard for timber piles. The following is a general description of the most common preservatives used in piling applications.

3.7.1 Creosote

Creosote has been widely used to protect wood from biological attack since 1865. It is a distillate of tar produced by the carbonization of bituminous coal consisting of various polyaromatic hydrocarbons over a wide range of boiling temperatures. Common applications for creosote pressure treated timber products include timber piling for foundations on land, in fresh water, and in salt water, bridge timber and railroad ties.

3.7.2 Chromated Copper Arsenate (CCA)

Chromated Copper Arsenate (CCA) is a formulation of copper, chromium and arsenic, dissolved in an acidic aqueous solution. It was first developed in 1933 and has been widely used throughout the world as a wood preservative for 60 years. CCA combines the fungicidal properties of copper with the insecticidal properties of arsenic pentoxide. In CCA the fixation of arsenic and copper is dependent on the presence of chromium.

3.7.2.1 **CCA Industrial Uses**

CCA label holders are voluntarily withdrawing CCA treated wood from the retail trade effective December 31, 2003. However, existing inventories may be sold for an indefinite period.

Although CCA is completely safe for use in all markets where it has been traditionally used, other preservative treatments, which are approved and included in AWPA Standards, are available for the retail market.

The EPA has recognized the continued use of CCA for industrial uses and includes foundation piling, marine piling and structures, utility poles and construction poles in the list of approved industrial uses.

3.7.3 Ammoniacal Copper Zinc Arsenate (ACZA)

Ammoniacal Copper Zinc Arsenate (ACZA) is an improved formulation of the original Ammoniacal Copper Arsenate (ACA) and has been available since the early 1980's and has now replaced ACA in the AWPA Preservative Standards. The proportions of copper, zinc and arsenic in ACZA are 2:1:1 respectively. ACA and ACZA are alkaline preservative systems and were formulated to achieve consistent penetration in the treatment of refractory, or difficult to treat wood species (i.e., Douglas Fir).

3.7.4 CCA and ACZA

Both CCA and ACZA in a waterborne form are carried into the wood cells within a closed pressure chamber. The metal oxides injected into the wood during treatment react with the wood fibers resulting in a bonding or fixation of the chemical in the wood. This forms an insoluble compound and fixes the chemical within the wood fibers to resist leaching and provide long term protection of timber piles in service.

CCA and ACZA are commonly used for foundation piling and for both fresh and salt water piling as well as for marine structures. CCA is olive green in color and is commonly used for treatment of wood used for residential decks and fences. ACZA is a turquoise green and is primarily used in commercial structures where Douglas Fir is used.

3.7.5 Preservative Retention

The required amount of preservative that should be retained by timber piles is a function of the application that the pile will be used for and the preservative. Land use piles require less preservative than water use piles, and salt water applications require higher retention levels of preservatives than fresh water applications. Table 3-11 provides guidelines on amount of preservative required for each application.

3.7.6 Pentachlorophenol and Copper Naphthenate

Although pentachlorophenol and copper naphthenate are recognized in AWPA Standards for use in land or fresh water piling, their use for this purpose is rare. These preservatives are **not** recommended for use in AWPA Standards for salt water installations.

3.8 DURABILITY CONSIDERATIONS

Timber piles should be treated with a preservative to prevent degradation of the wood from insect attack. Typical environments where degradation is a concern exist when the pile is exposed to alternate wetting and drying cycles or located above the water table. Insect damage reduces the service life of timber piles significantly, unless the pile is treated with a wood preservative. The most common treatments for timber piles are Creosote, Chromated Copper Arsenate (CCA) for Southern Yellow Pine and other species, and Ammoniacal Copper Zinc Arsenate (ACZA) for Douglas Fir. Treated timber piles are durable structural elements.

Durability of round timber piles is a function of site specific conditions. **FHWA has concluded that :**

- **Foundation piles submerged in ground water will last indefinitely**
- Fully embedded, treated foundation piles partially above the groundwater with a concrete cap will last 100 years or longer.
- Treated trestle piles over land will last about 75 years in northern areas and about 40 years in southern areas of the United States.

- Treated piles in fresh water will last about five to ten years less than land trestle piles in the same area

- For treated piles in brackish water, the longevity should be determined by the experience in the area

- Treated marine piles will last about 50 years in northern climates and 25 years in southern climates.

Round timber pile treatment should be in accordance with the American Wood Preservers' Association standard, C3-99 *Piles-Preservative Treatment by Pressure Processes.*

3.9 ENVIRONMENTAL CONSIDERATIONS

Timber piling is a major material used to construct piers, docks buildings , walkways, and decks used in and above aquatic environments. The pressure treated wood products industry is committed to assuring its products are manufactured and installed in a manner which minimizes any potential for adverse impacts to these important environments. To achieve this objective the industry has developed and encourages the use of Best Management Practices (BMPs). The BMPs for treated timber piles are available from AWPI.

There are a variety of treatments and treated wood products approved for use in or above aquatic environments. Because of inherent differences in the treatment chemical and the processes there are also a number of BMPs. While the goal of the BMPs is common (i.e., to minimize the migration or leaching of treating chemicals into the environment) the methods for achieving the goal vary. It is the responsibility of the treating firm to assure that the materials leaving the plant destined for use in aquatic environments have been produced in accordance with the BMPs.

To assure timber piles utilized in aquatic environments incorporate BMPs the following steps should be followed:

1. Specify the appropriate material in terms of performance as defined in the American Wood Preservers' Association Standards.
2. Specify that the material be produced in compliance with the industry standards BMPs.
3. Require assurance that the products were produced in compliance with the BMPs.

Table 3-11
Preservative Assay Retention Requirements

Use Category	Creosote (pcf) Southern Pine	Creosote (pcf) Douglas Fir	Waterborne (CCA or ACZA) (pcf) Southern Pine CCA	Waterborne (CCA or ACZA) (pcf) Douglas Fir ACZA
Foundation	12	17	0.8	1.0
Land & Fresh Water	12	17	0.8	1.0
Marine				
N. of Delaware[1] or San Francisco[1]	16	16	1.5	1.5
S. of New Jersey[2] or San Francisco[2]	20	20	2.5	2.5
Dual Treatment[3]	20	20	1.0	1.0

1. Where Teredo is expected and Limnoria tripunctata is not expected, creosote or creosote solutions provide adequate protection.
2. Where Teredo and Limnoria tripunctata are expected and where pholad attack is not expected, either dual treatment, or high retentions of CCA for Southern Pine or ACZA for Douglas fir provide maximum protection.
3. In those areas where Limnoria tripunctata and pholad attack is expected or known, dual treatment provides the maximum protection.