Timber Piling Design

Presented by Dean Matthews, P.E.
for the Timber Piling Council

Timber Piling Council

- **The Timber Piling Council provides technical information, and promotes the use of timber piles in the construction industry.**
- **Photograph shows American Airlines Terminal at JFK where 11,000 timber piles were installed.**

Council Affiliations

- Deep Foundations Institute
- Pile Driving Contractors Association
- Southern Forest Products Association
- Southern Pressure Treaters Association
- American Forest & Paper Association
- American Society of Civil Engineers
- American Society of Testing and Materials
- American Wood Protection Association
- Treated Wood Council
- Western Wood Preservers Institute

History

- **Placing a log vertically into soft or unsuitable soil for a structural support is credited to Neolithic tribes around 6,000 years ago, in what is now Switzerland.**
- **Homes were built on platforms supported by piles in lakes for protection from wildlife.**
- **Evidence of these structures still exists today.**

Roman Civilization

- **Around 1620 B.C., the Romans built a timber bridge spanning the Tiber River which lasted over 1,000 years.**
- **Some roads and aqueducts were supported on timber piles. They were still in good condition 1,900 years later.**

Roman Civilization

- **Buildings in the Roman cities of Ravenna and Venice were built on wood piles from 100 B.C. to 400 A.D.**
- **The first bridge across the River Thames in London was built by the Romans about 60 A.D. on timber piles.**

Today's Treating Plant

- **The modern age of wood preserving began in England in 1832.**
- **The first treating plant in the U.S. was built in 1848.**
- **Today's plants have the latest in environmental protection features.**
- **Drip pads are protected from leakage with heavy duty liners below the concrete, and drippage is recaptured and recycled.**

Foundation Piling

- **Timber piling resists attack from both alkaline and acidic soil. Corrosion protection is not required.**
- **Unaffected by electrolysis from stray electrical currents.**
- **Installs with standard, readily available equipment.**
- **Takes advantage of plentiful, renewable resource.**
- **Has lowest cost per ton of load carrying capacity of any deep foundation material, and is easy to install.**

Marine Piling

- **Resists battering by wind, wave, storms and tides as wood is a resilient material.**
- **Excellent serviceability for marinas, dolphins and fenders.**
- **Wood's high damping characteristics provide built-in shock resistance against hurricanes and earthquakes.**

Durability

The Federal Highway Administration (FHWA) has concluded:

- **Foundation piles submerged in ground water will last indefinitely.**
- **Fully embedded, treated, concrete capped foundation piles partially above the groundwater will last 100 years or longer.**

Long Lasting Structures

Well known structures on timber piles include:

- **San Francisco Ferry Terminal.**
- **London Bridge.**
- **Seine River bridges in Paris were designed for 100 ton loads.**
- **Royal Palace in Amsterdam.**
- **Berlin Castle and Opera House.**

Industry Statistics

- 90% of timber piles in North America are Southern Pine, the balance is Douglas fir.
- Of Southern Pine piles, 95% are treated with CCA.
- Preservatives used for timber piling are: CCA, creosote, and ACZA (for Douglas fir).
- Copper Azole (CA-B) is now available for piling. CA-B is AWPA approved for Use Category 4C, which includes Fresh Water Piling and Foundation Piling.

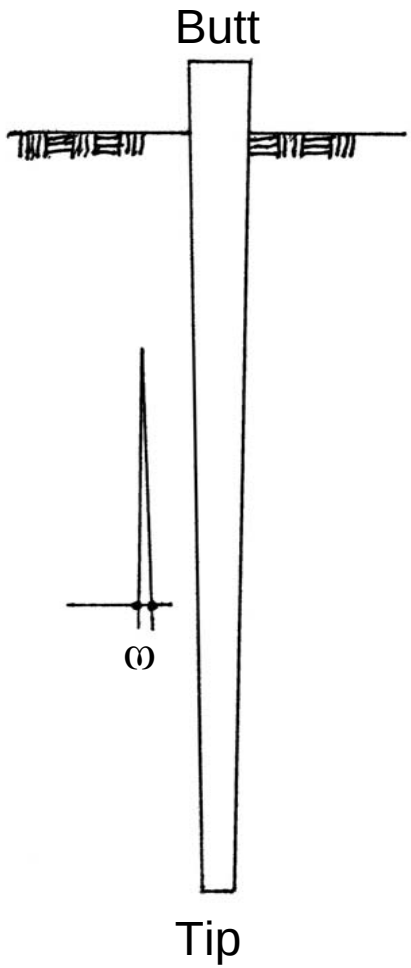
Resort & Marina Design

- Chesapeake Bay resort has 140-slip marina with berths up to 65 ft.
- Marina – 2,000 timber piles, CCA treated 2.5 pcf.
- Approach bridges – timber piles, heavy timber framing, CCA treated 0.60 pcf; roadway surface 3-inch decking.
- Golf course bridges – similar construction with piles, timbers and decking.
- Tee supported on timber piles.

Coastal Residential Design

- **This house, built on piles in Pearlington, MS, is reported to be the only house that survived flooding from Hurricane Katrina.**
- **Water came within several inches of the pile girders, but never entered the house.**
- **Similarly constructed beach houses meeting coastal wind load standards line the coast from New Jersey to Mississippi.**

Timber Pile Foundations



- **Piles are generally associated with difficult foundation conditions and weak sub-surface soils.**
- **Piles transmit forces from the super-structure to a lower stratum that has sufficient bearing value to support the completed structures and all applied loads.**
- **End-bearing piles primarily transfer loads through the tip.**
- **Friction piles primarily transfer loads through tangential skin friction.**
- **The natural taper of a timber piles (1” change in diameter per 10 ft.), increases the friction reaction and is recognized in the design formula.**

Design Values

Piling design values for normal load duration and wet conditions of use. In pounds per square inch.[1]

Property	Southern Pine[2]	Douglas fir[3]
Compression Parallel to Grain, F_c	1,200	1,250
Extreme Fiber in Bending, F_b	2,400	2,450
Horizontal Shear, F_v	110	115
Compression Perpendicular to Grain, $F_{c\perp}$	250	230
Modulus of Elasticity, E	1,500,000	1,500,000

Source: Values are from ANSI/AF&PA NDS-2005, National Design Specification for Wood Construction, Supplement for Timber Poles and Piles.

[1] A form factor for bending members of circular cross section is incorporated in the allowable unit stresses for extreme fiber in bending listed in the table.

[2] Southern pine values apply to longleaf, slash, loblolly and shortleaf pine.

[3] Douglas fir values apply to Pacific Coast Douglas fir.

Original Stress Development

- **Historically, stresses were based on tests of small clear samples, adjusted for wood characteristics such as knots and knot clusters.**
- **ASTM Standard D2899 provides the procedure for developing working stresses from these tests.**
- **Allowable stresses were originally developed by the U.S. Forest Products Laboratory.**

Samples for Testing

- **Samples for these tests were selected in growing regions where piling is produced in proportion to the amount used for piling.**
- **Southern Pine piling was sampled from sites in Virginia, Georgia and Florida.**
- **Douglas fir piling was sampled from sites in Oregon, Washington and British Columbia.**

Full-Scale Testing

- **Tests on full scale pile pieces were completed in 1999 and 2000.**
- **The tests were specifically conducted to develop design stresses. They were run by EDM International of Ft. Collins, CO, an independent laboratory.**

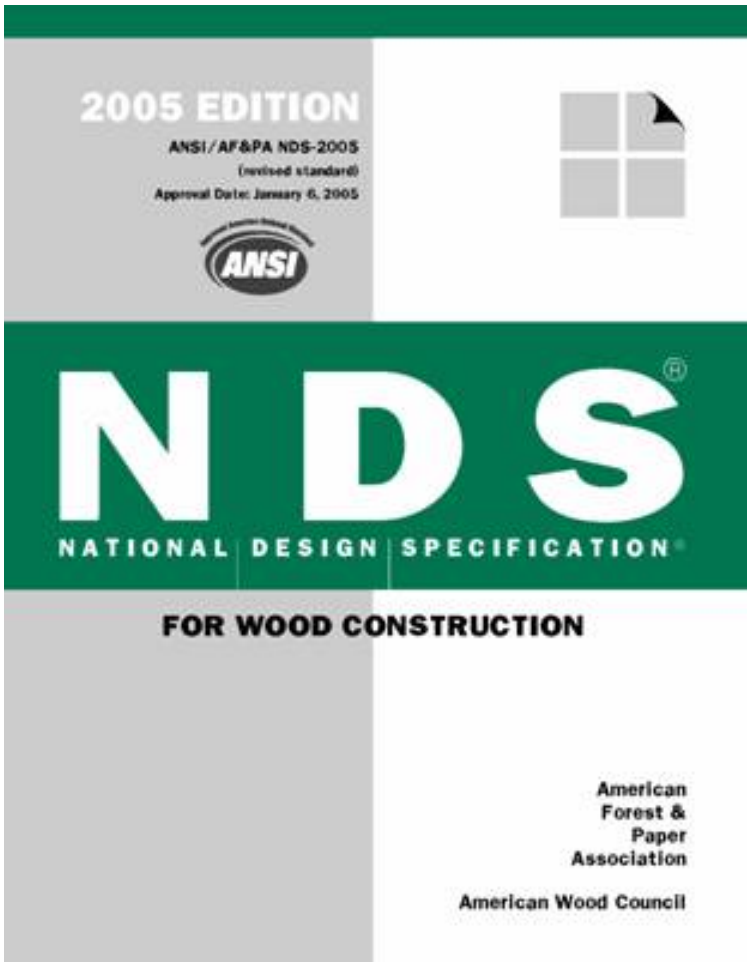
Bending Tests

- **Bending tests were run first.**
- **A horizontal force was applied by a cable attached to the tip of the pile.**
- **Tests showed bending stresses could be 36% to 53% higher than currently allowed for bending design.**

Compression Tests

- **Following the bending tests, 3-foot specimens were cut from both the butt and tip ends.**
- **Tests showed compression stresses could be increased up to 12% more than is currently allowed for compressive design.**

National Design Specification



- **Timber Piling Council full-scale testing program demonstrated that allowable stresses currently published in the widely recognized National Design Specification (NDS) are conservative.**
- **The tests also demonstrated that today's trees are just as strong as ever.**
- **The new ASTM standard, D7381, provides the protocol for developing stresses from full scale tests.**

Load Tests

- **Many field load tests have been conducted on piles**
- **These many tests determine that the actual load carrying capacity of timber piles significantly exceeds design values with a wide margin of safety.**
- **Test procedure is ASTM D1143.**

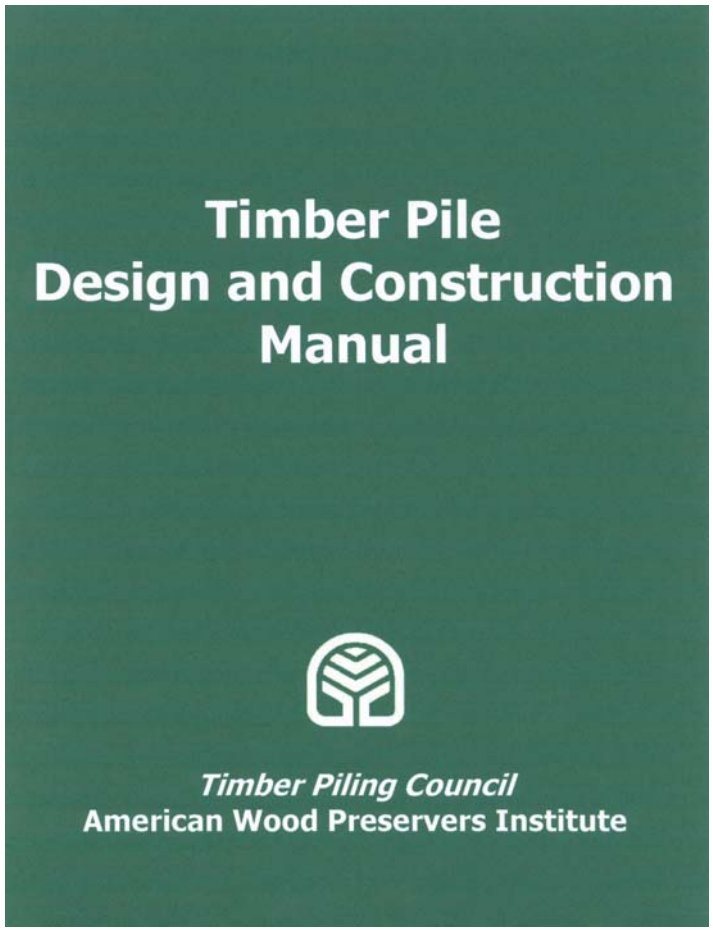
Test vs. Design Loads

Southern Pine Piles

LOCATION	PILE SIZE			TEST LOAD (tons)	NO. OF TESTS	DESIGN LOAD (tons)
	Length	Butt	Tips			
Donaldsonville, LA	80’ and up		Class B	140 & 150	1	60
Mobile, AL	60’	14”	9.5”	140		65
Virginia Beach, VA	76’		Class A	100		50
Charleston, SC	75.8’	14”	8.25”	118	1	50
South Pierce, FL	70’	14”	7”	100		50
Port Arthur, TX	65’	14”-15”	8”-9”	150	5	75
Chicago, IL	43.7’-44.3’		Class B	80 & 150	2	40
Chicago, IL	43.5’-48.2’		Class A	100 & 142	2	40
Portsmouth, VA	86’		Class A	100[1]	4	50
Virginia Beach, VA	40’			100[1]	1	50
Scotland, LA	53’	15”	8”	100	12	40

[1] Not to failure
Source: AWPI Data

Timber Piling Manual



- **Design Procedure.**
- **Foundation and Marine Piles.**
- **Timber Piling Data.**
- **Pile Group Design.**
- **Load Testing.**
- **Geo-technical Guidelines.**
- **Guide Specifications.**
- **Pile Installation.**

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(11.1)	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. = 25.4mm.

[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.

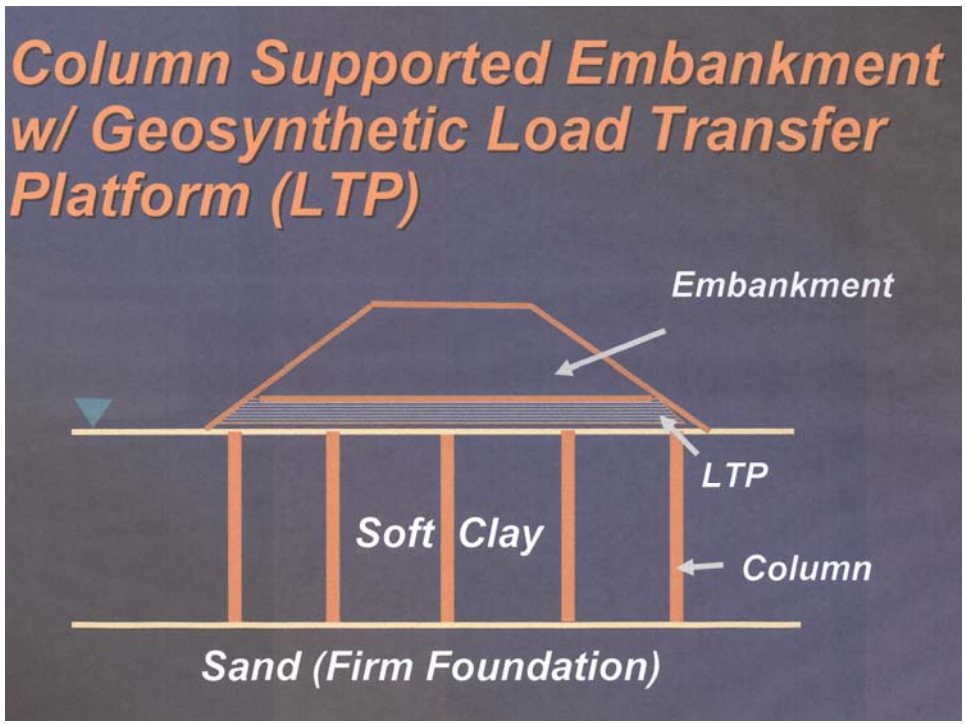
Piling Standards

- **ASTM D25 prescribes whitewood requirements before treatment, such as straightness, knot size and knot clusters.**
- **AWPA standards prescribe penetration and retention requirements based on type of preservative and exposure conditions.**
- **Original AWPA Standards based on performance of creosote. New preservatives have to be equal in performance.**

AWPA Use Category System

- System simplifies use of AWPA Standards.
- UC 1 Interior construction, dry.
- UC 2 Interior construction, damp.
- UC 3 Exterior construction, above ground.
- UC 4 Ground and fresh water contact.
- UC 5 Salt water contact, marine construction.

Embankments



- **Timber pile supported embankment.**
- **Piles supported layers of geosynthetic material and compacted soil.**
- **Piles installed on grid about 9’ o.c. each way.**
- **More economical than removing soil and replacing with compacted material.**

Quality Control

- **Before treatment, piling is inspected and classified by size and conformance to ASTM D 25 Standards.**
- **Quality control inspectors at the plant monitor treating processes, sample and inspect piling throughout the manufacturing process.**
- **After treatment, the piling is checked for penetration and retention according to AWPA Standards.**

Preservative Retentions

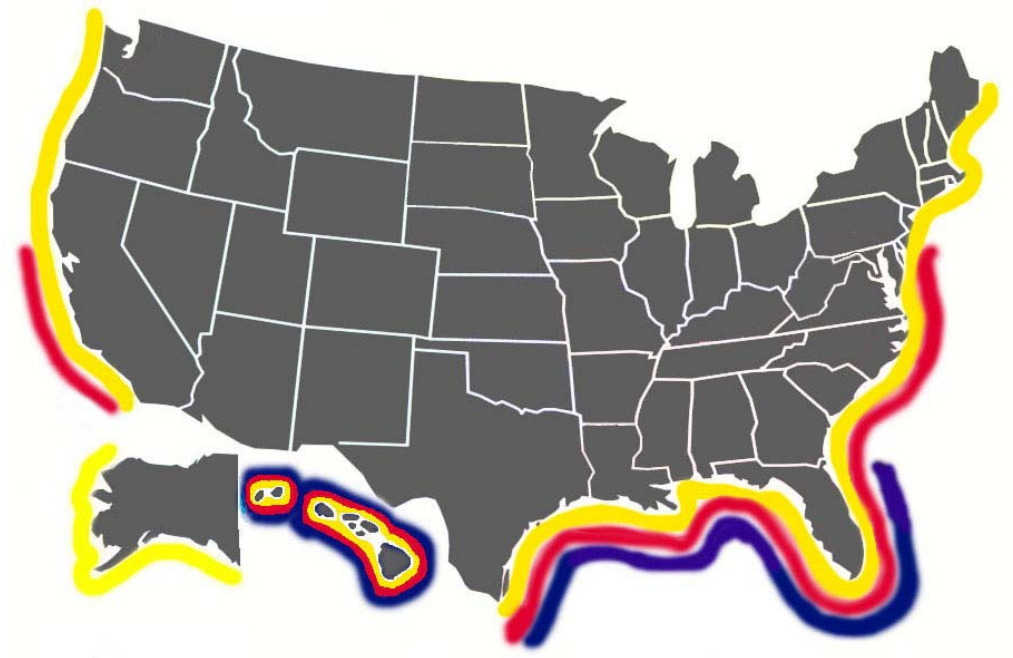
	CCA [pcf]		ACZA [pcf]	Creosote [pcf]	
	Southern Pine		Douglas fir	Southern Pine	Douglas fir
Foundation	0.8		1.0	12.0	17.0
Fresh Water	0.8		1.0	12.0	17.0
Marine: Saltwater[1]	1.5		1.5	16.0	16.0
Marine: Saltwater[2]	2.5		2.5	20.0	20.0
Dual Treatment[3]	1.0		1.0	20.0	20.0

[1] North of the New Jersey/Delaware border in the East, and north of San Francisco in the West.

[2] South of the New Jersey/Delaware border in the East, and south of San Francisco in the West. Timber Piling Council members treat to this level, although AWPA Standards require less treatment north of this border.

[3] Treatment for tropical water—first treatment CCA, second treatment creosote.

Marine Borers



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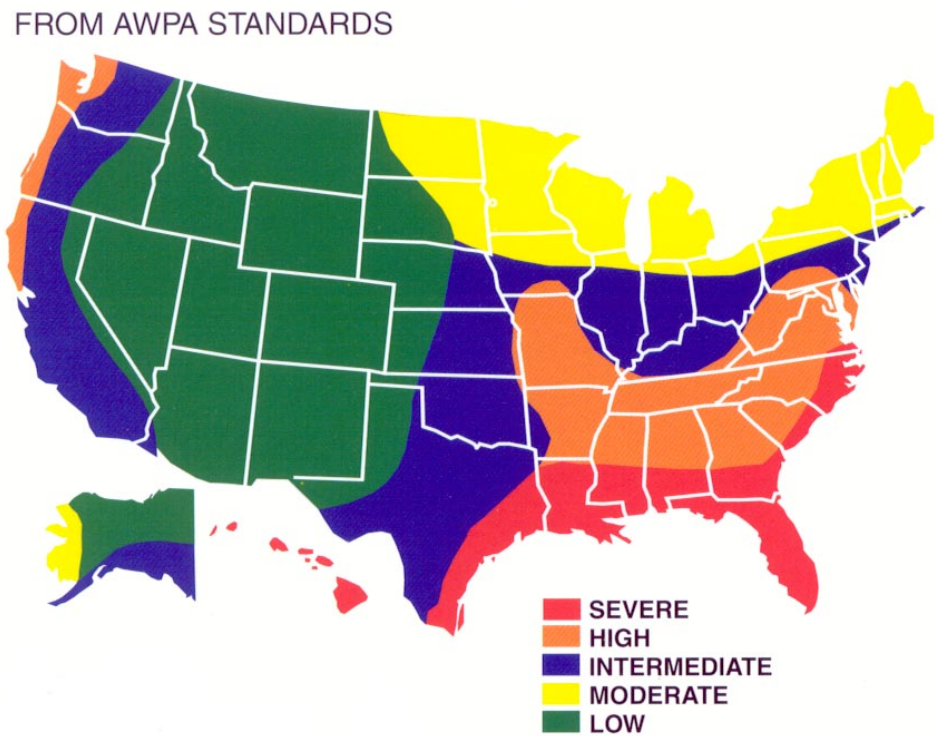
Termites & Carpenter Ants



- **Wood in contact with the ground will decay if not preservative treated.**
- **Studies show the red, orange and blue regions to be the most subject to deterioration.**
- **All piling must be pressure treated.**
- **The Formosan termite is now in some places in the South.**

Environment

- **Only EPA approved preservatives are used for any pressure treated wood application.**
- **It takes less energy to produce timber piling than other types of materials.**
- **Easy to dispose of cut-offs; they go to landfills.**
- **Treated wood is not a hazardous waste and meets EPA's TCLP (leaching) provisions.**

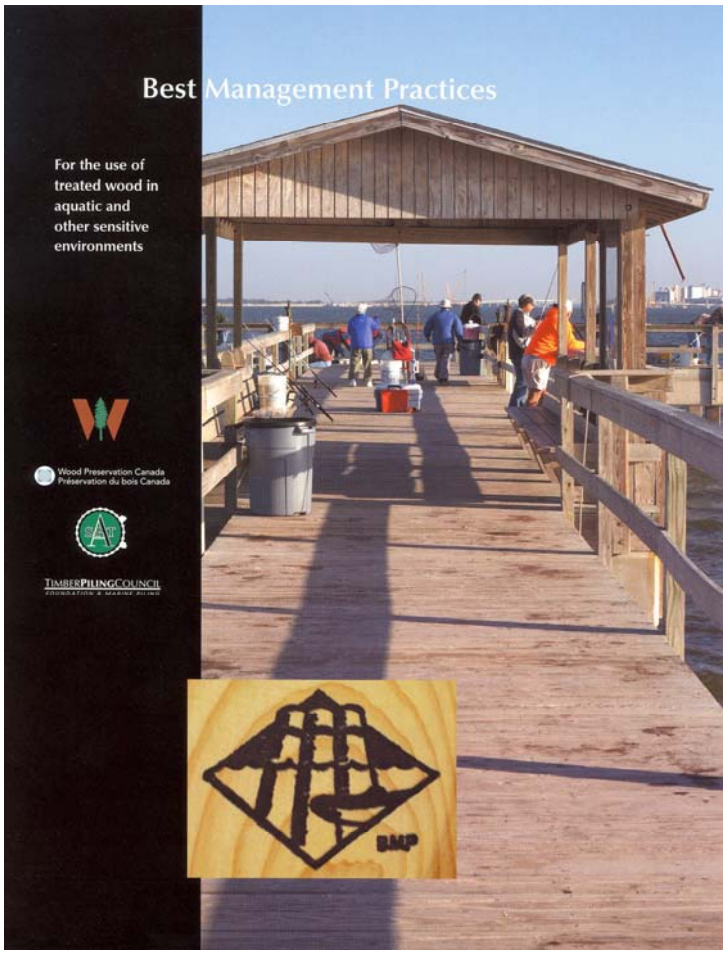
Treated Wood in Aquatic Environments

- **Extensive empirical science and risks assessments have shown that in most applications, treated piling does not pose significant adverse environmental risks.**
- **"Pressure treated wood has a long history of safe use in aquatic environments with no published report describing significant loss of biological integrity associated with its proper use." Source: *Treated Wood in Aquatic Environments,* WWPI, 2006.**

Contaminated Sites or Stagnant Water

- **Where very large numbers of piles are proposed for use in highly sensitive, poorly flushed and/or previously contaminated waters a risk assessment is advised to evaluate conformance with local regulatory limits for water and sediment quality.**
- **Guidance risk assessment can be accessed at Western Wood Preservers Institute's web site: www.wwpinstitute.org.**

Specifying BMPs



- **Best available science shows pressure treated wood poses minimal risk to aquatic environments when:**
- **Used in accordance with AWPA specifications.**
- **Used following guidance provided by documents such as Consumer Information Sheets, Consumer Safety Information Sheets or treated wood Material Safety Data Sheets (MSDS).**
- **Produced using BMP's.**

New Preservatives

- **Chemical producers voluntarily withdrew CCA from the consumer marketplace in 2003.**
- **CCA is still used for industrial purposes, including piling, bulkheads, utility poles and round fence posts.**
- **Non-arsenical treatments have been approved in AWPA Standards since the late 1980's. These include Copper Azole (CA) and Ammoniacal Copper Quat (ACQ), preservatives which provide the same resistance to decay and insects as CCA.**
- **The new preservatives are more corrosive to fasteners so it is imperative to follow industry recommendations to use hot dipped galvanized or stainless steel fasteners.**

CCA Uses Permitted by EPA

- **Timber Piles for Land, Foundation or Fresh Water uses:** AWPA Use Category 4C.
- **Timber Piles and Timbers for Salt Water uses:** AWPA Use Categories 5A, 5B, and 5C.
- **Timber Piles and Guard Rail Posts, etc. for Highway Construction:** AWPA Use Category 4A.
- **Dock Surfaces for Salt Water Construction:** AWPA Use Category 5A and 5B.
- **Pole Frame Construction:** AWPA Use Category 4B.
- **Round Fence Posts:** AWPA Use Category 4b.
- **Permanent Wood Foundations.** AWPA Use Category 4B.

Fresh & Saltwater Uses

Timber Piles

- **UC4C. Freshwater. 0.80 CCA, 0.80 ACQ, 12.0 Creosote.**
- **UC5A,B,C. Saltwater. 2.5 CCA, 20.0 Creosote or Dual Treatment.**

Structural Lumber

- **UC4A. Freshwater. 0.21 CA, 0.40 ACQ, 10.0 Creosote.**
- **UC4B. Saltwater Splash Zone. 0.60 CCA, 0.31 CA, 0.60 ACQ, 12.0 Creosote.**
- **UC5A,B,C. Saltwater Immersion. 2.5 CCA, 20.0 Creosote (Cross-bracing).**

Decking, Handrails

- **UC3B Freshwater. 0.10 CA, 0.25 ACQ.**
- **UC3B. Saltwater. 0.10 CA, 0.25 ACQ.**
- **Effective January 1, 2005 for decking and handrails.**

Refer to page 10 of Marine Structures Brochure.

Southern Pine Resource

- Grown on managed timber-lands throughout the South.
- A renewable natural resource; fourth generation forests or more are now growing Southern Pine trees.
- The U.S. has about the same amount of forest area today as 100 years ago.
- Forests have expanded nearly 10 million acres in the last decade. Source: United Nations satellite tracking.
- No old growth trees are used to produce timber piling.

Managed Forest

- The stands in the background were selected to provide 70 ft. and 75 ft. long timber piles.
- The small trees in the foreground are three years old and will be timber piles in about 40 years.
- This stand was thinned after about 20 years of growth.
- Today, trees are harvested from forests that were naturally seeded.

Pile Installation

- **Pile driving process is a test of the piling material. Whether wood, steel or concrete, the material is severely stressed during driving.**
- **With driven piles you can inspect the material before driving.**
- **Hammer manufacturers have very sophisticated equipment including, hammers that drive 300 ft. long piles, and hammers that drive piles under water.**

Field Cuts and Re-treatment

- **Cut surfaces must be field treated in accordance with AWPA Standard M-4.**
- **2% copper naphthenate is recommended.**
- **Same as requirement for pressure treated sill plates when they bear on concrete slabs or walls.**

Summary

- **The unsurpassed timber pile!**
- **Proven by time and tests.**
- **The recognized economical piling.**
- **Environmentally sound and safe.**

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