Timber Piling Design

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for the Timber Piling Council

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WoodWorks

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Learning Objectives

At the end of this program, participants will be able to:

1. *Understand and Use the National Standards for Timber Piling*
2. *Properly Specify Timber Piling*
3. *Properly Specify the Preservative Treatment of Timber Piling*
4. *Understand and Use the Structural Strength Properties of Timber Piling*

Timber Piling Council

- **The Timber Piling Council provides technical information, and promotes the use of timber piles in the construction industry.**
- **The Timber Piling Council is administered by the Southern Pressure Treater's Association**
- **Photograph shows American Airlines Terminal at JFK where 11,000 timber piles were installed.**

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 Timber Piling

- **Foundations for industrial and commercial structures**
- **Foundations for bridges and other infrastructure**
- **Ports and harbors**
- **Marine construction**
- **Raised coastal construction**

Industry Statistics

- 90% of timber piles in North America are Southern Pine, the balance are Douglas fir.
- Preservatives used for timber piling are: chromated copper arsenate (CCA), creosote, and ammoniacal copper zinc arsenate (ACZA) (for Douglas fir).
- Of Southern Pine piles, 95% are treated with CCA.
- Copper azole (CA) and ammoniacal copper quat (ACQ) are now approved for Southern Pine piling.

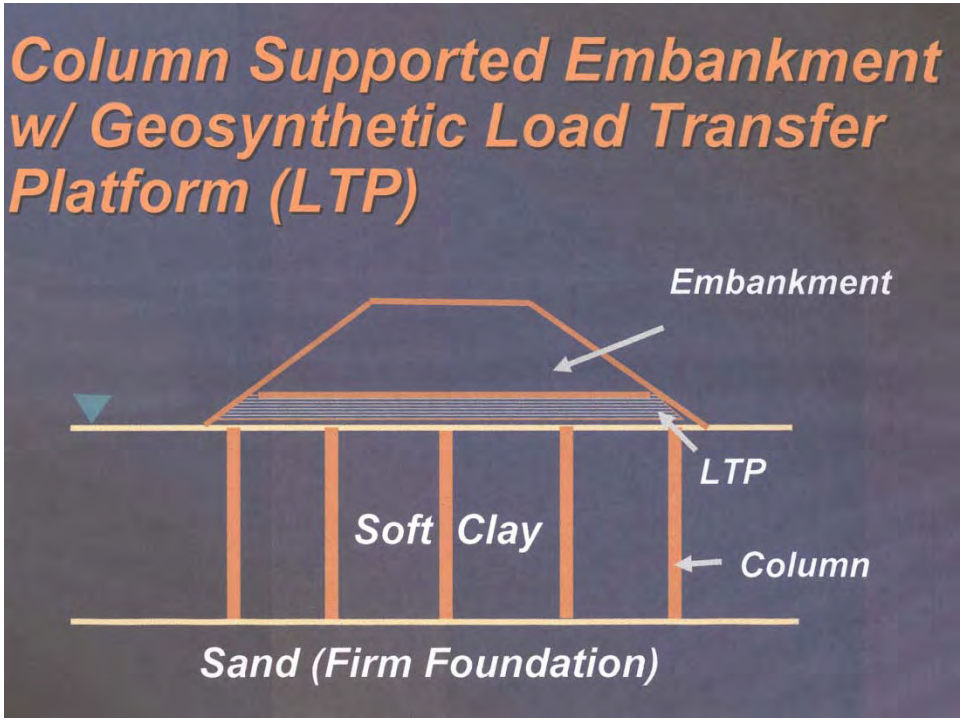
Foundation Piling

- **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.**

Foundation Piling

Foundation Piling

Civil Infrastructure



- **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.**

Marine Piling

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

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.
- Aesthetically pleasing

Coastal 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 Texas.**

Coastal Design

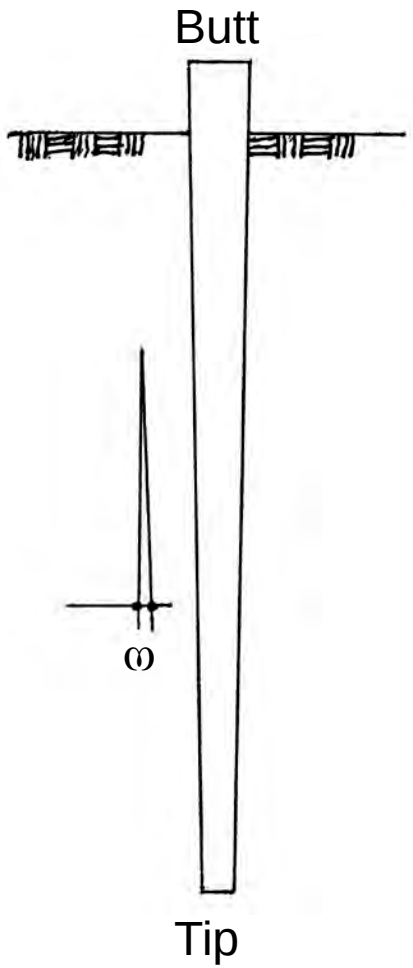
- **Commercial structure in coastal flood zone**

How Do You Design Timber Pile Foundations?

Timber Piling Manual

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

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.

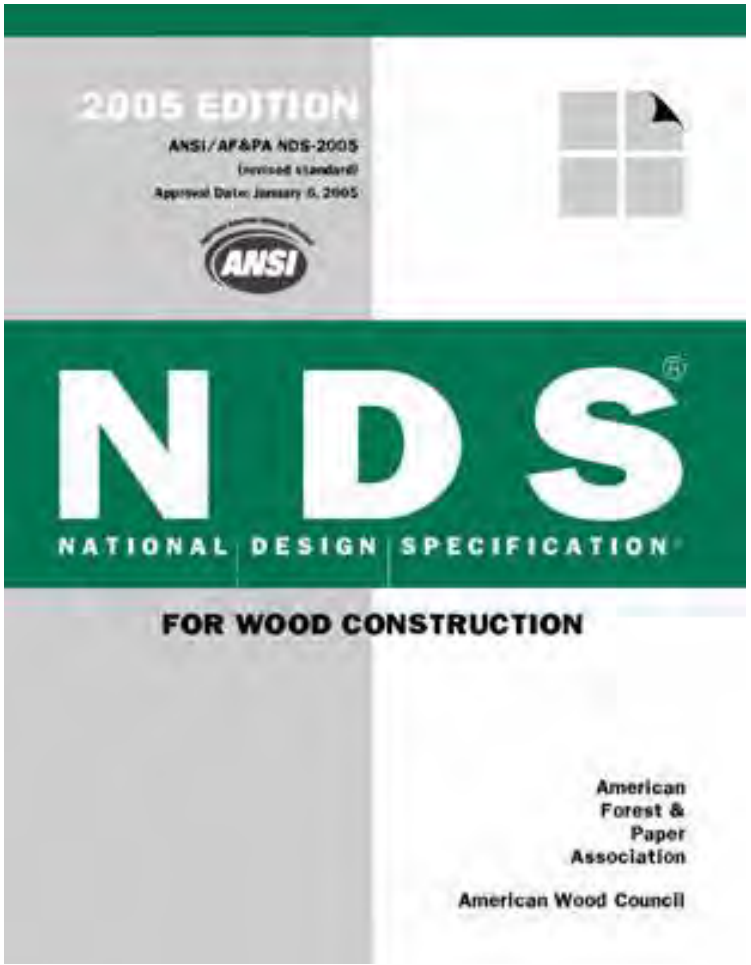
Original Strength Development

- **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.**

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.**

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.**

Impact of New SPIB Design Values

- **SPIB is in the process of lowering the design values for Southern Yellow Pine lumber**
- **This is based upon more rapid growth timber being used for lumber production**
- **ASTM D-25 contains growth rate limitations directly related to strength that have not changed**
- **ASTM D-25 requires a minimum of 6 growth rings in the outer one inch of the radius of the tip of timber piling and this requirement simply cannot be met by rapid growth material**
- **Therefore, the lowering of design values for Southern Yellow Pine lumber will have no effect on the design values for Southern Yellow Pine piling, plus the recent full-sized testing has confirmed the existing design values**

Piling Standards

- **ASTM D25 prescribes whitewood requirements before treatment, such as dimensions, straightness, knot size and knot clusters.**
- **American Wood Protection Association (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.**

ASTM D-25 Class A and B Piling

TABLE X1.1 Specified Minimum Butt and Tip Sizes for Class A and Class B Piles

Length (ft)	Pile Circumference (in.) Diameter (in.) given in brackets						
	Class A			Class B[A]			8 in. tip
	3 ft from butt		min tip	3 ft from butt		min tip	
	min	max		min	max		
Douglas Fir, Southern Pine							
Under 40	44 [14]	57 [18]	28 [9]	38 [12]	63 [20]	25 [8]	25 [8]
40-54, incl.						22 [7]	
55-74, incl.		57 [20]	25 [8]	41 [13]			
75-90, incl.		63 [20]	22 [7]			19 [6]	
Over 90			19 [6]			16 [6]	
Oak							
Under 30	44 [14]	57 [18]	28 [9]	38 [12]	57 [18]	22 [7]	
30-40, incl.			25 [8]	41 [13]	63 [20]	19 [6]	
Over 40						16 [5]	

[A] For Class B piles a minimum circumference of 34 in. (864 mm) or a diameter of 11 in. (279 mm) at a point 3 ft (1 m) from the butt may be specified for lengths of 25 ft (7.6 m) and under.

End Bearing- Natural Taper

TABLE X1.5 Specified Tip Circumferences with Corresponding Minimum Butt Circumferences for Southern Yellow Pine Piles[A,B,C]

[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]

[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. A dark horizontal line in each column designates pile sizes (above the line) which are generally available. The purchaser should inquire as to availability of sizes below the lines.

Friction Piling - Natural Taper

TABLE X1.3 Specified Butt Circumferences with Corresponding Minimum Tip Circumferences for Southern Yellow Pine Piles[A,B,C,D,E]

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]

[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. A dark horizontal line in each column designates pile sizes (above the line) which are generally available. The purchaser should inquire as to availability of sizes below the lines.

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.
- Piling are UC 4C and UC5 A,B or C

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.

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.**

Quality Control

- **Before treatment, piling are 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 are checked for penetration and retention according to AWPA Standards.**

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 of timber piling must be field treated in accordance with AWPA Standard M-4.**
- **2% copper naphthenate is recommended.**

Design Loads for Timber Piling

- **Typical loads in the 20 to 30 ton per pile range**
- **Have been designed to 75 tons in some cases**

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

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.**

Environmental Issues

- Preservatives go through rigorous EPA approval process. EPA can't approve if significant human health or environmental risk
- Timber piling are made from a renewable resource
- Treated wood is not a hazardous waste, can be disposed of in municipal landfills
- Independent Life –Cycle Assessment of CCA piling shows very favorable comparison to piling of other materials

http://www.oldcitypublishing.com/JMEE/JMEEcontents/JMEEv9n3issuecontents.html

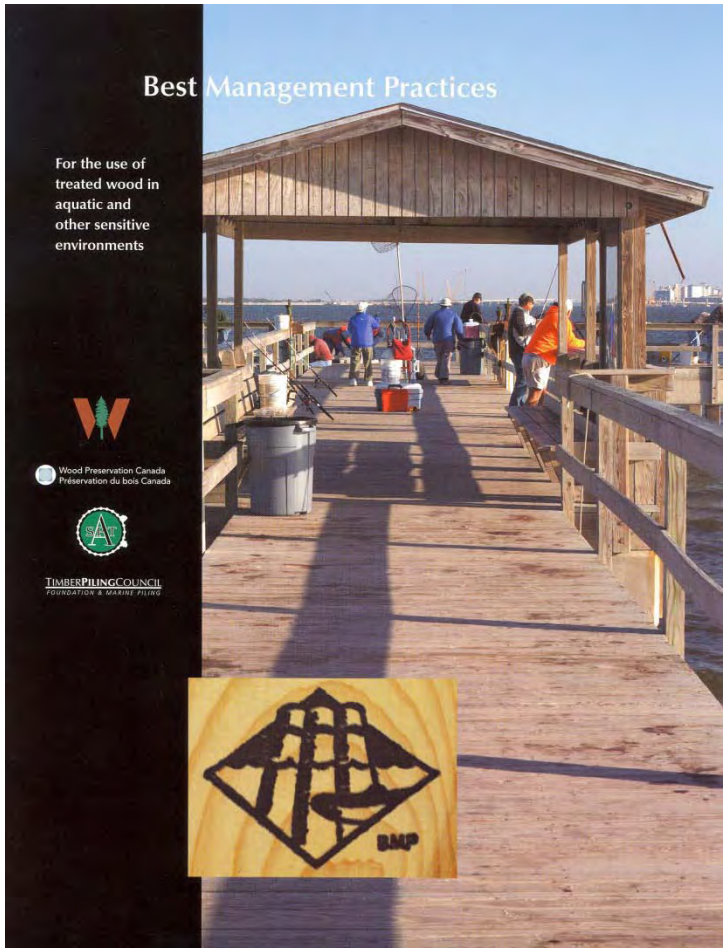
Treated Wood in Aquatic Environments

- **Extensive empirical science and risks assessments have shown that in most applications, treated piling do 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.**

Sensitive Aquatic Environments

- **Where very large numbers of piles are proposed for use in highly sensitive, or poorly flushed waters a risk assessment is advised to evaluate conformance with local regulatory limits for water and sediment quality.**
- **Software to conduct a risk assessment in these conditions is available at the Western Wood Preservers Institute's web site: www.wwpinstitute.org.**

Specifying BMPs



- **Use of Best Management Practices in the manufacturing process minimizes risk in sensitive environments**
- **Best available science shows pressure treated wood poses minimal risk to aquatic environments when used in accordance with AWPA specifications.**

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.
- In North America many more trees are planted each year than are harvested.
- 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 may be timber piles in about 40 years.**
- **This stand was thinned after about 20 years of growth.**
- **Today, most trees used for piling are harvested from forests that were naturally seeded.**

Summary

- **The unsurpassed timber pile!**
- **Proven by time and testing.**
- **The most economical piling foundation system.**
- **Produced from a renewable resource.**
- **Environmentally sound and safe.**

Timber Piling Council
800-410-2070
www.timberpilingcouncil.org

Questions?

This concludes The American Institute of Architects Continuing Education Systems Course

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