Design of Timber Foundation Piling for Highway Bridges and Other Structures

James S. Graham, P. E., National Timber Piling Council, Rye, NY

Abstract

Presented information on structures supported by treated timber piling, including details of the East Side (FDR) Drive in New York City. Determined the average and mean Factor of Safety of the Engineering News Formula for 43 site-specific cases. Showed examples of present-day design for timber piling supported by friction, end bearing, or a combination of both. Considered practical and theoretical geotechnical design criteria. Furnished timber piling and preservative specifications. Reviewed durability for foundation, fresh water, and marine piling. Addressed environmental considerations. Concluded that local Geotechnical engineers apply empirical experience to design treated round timber foundation piling.

Keywords: design, durability, Engineering News Formula, environmental, factor of safety, preservative, specifications, timber piling.

Introduction

Starting in 1865, treated round timber piles supplied most of the deep foundation support for highway bridges and other structures in the United States. The first treated piles installed were for the Taunton River Bridge, Taunton, Massachusetts. The U.S. Army Corps of Engineers alone used over six million timber piles to construct the Locks and Dams for the Inland Waterway System.

The purpose of this paper is to introduce highway engineers to the subject, Design of Timber Foundation Piling for Highway Bridges and Other Structures.

East River Drive, New York, NY

An example of the extensive use of treated timber piling in the past was Manhattan's 11,265.41 meter (7 mile) long East River Drive in New York City, constructed between circa 1935 and May 25, 1942.

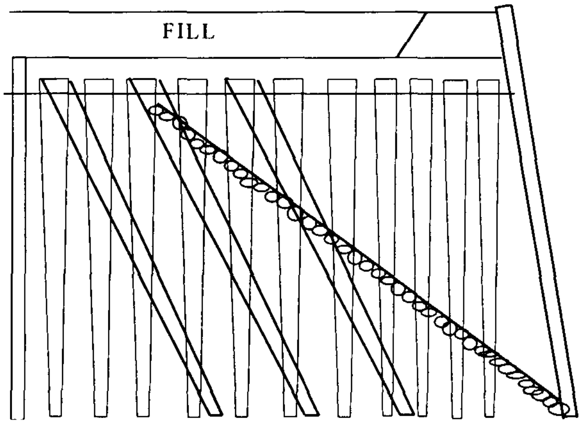


Figure 1—Timber Pile Relieving Platform, East River Drive, New York, NY

According to Ralph Mann, (Mann, 1942) "For 6920.18 meters (4.3 miles) a relieving platform supported on creosoted piles was built on the bulkhead line established by the U.S. Engineer Corps, which is usually from 30.48 to 76.2 m (100 to 250 ft.) out from the former shore line, in water from 6.10 to 9.14 m (20 to 30 ft.) deep." The piles were 355.60 mm (14 inch) diameter, 0.91 m (3 ft.) from the Butt, treated with 256.32 to 288.36 kg/m^3(16 to 18 pcf) (gage) creosote for the Southern Yellow Pine and 192.24 to 224.28 kg/m^3(12 to 14 pcf) (gage) for the longer Douglas Firs. Installed in bents was a total of about 77,000 treated timber piles, as shown on Figure No. 1. Spacing of the bents were from 1.22 to 1.684 m(4 to 5-1/2 ft.)apart.

The East River Drive is still very much in heavy use today, some 60 years after original construction. Recent surveys on the 60 year timber piling show about 1.60 mm (1/16 inch) attack by limnoria tripunctata at creosote retention levels less than 112.14 kg/m^3(7 pcf). (Altiero, 1996). Attack was greater south of 45th street where the East River has higher salinity levels.

Recently rebuilt on dual-treated Class B Southern Pine piles 19.81 m (65 ft.) long is a section near 14th Street. New York State D.O.T. and TAMS Consultants, Inc. decided to use the product again since it lasted 60 years in such a harsh environment as the East River. They improved the expected life by specifying a dual treatment of 16.02 kg/m^3(1.0 pcf) Chromated Copper Arsenate (CCA) and 320.40kg/m^3(20 pcf) creosote, in accordance with American Wood Preservers' Association (AWPA) Standard C 3, Piles, Preservative Treatment by Pressure Process. (AWPA, 1995)

Experienced New York City engineers specify relatively lightly loaded timber piles for the docks surrounding Manhattan by driving the piles to a predetermined depth, not to a bearing capacity formula. The river muds regain their strength after driving, that is, the pore-water pressure dissipates. But for the East River Drive, the heavy relieving platform required installing timber piling through, "3.05 to 6.10 m (10 to 20 ft.) of soft mud which overlies an equal thickness of more stable material that develops hard driving where the piles "take-up" either in sand or on rock." (Mann, 1942)

Engineering News Formula

Nearly every timber piling job specifies the Engineering News (EN) Formula for driving or capacity criteria (1). Wellington developed the formula in 1893 for timber piling driven with a drop hammer, as published in Engineering News magazine. (Chellis, 1961) However, no publications since then address the actual safety factor using the EN Formula.

Engineering News Formula

$$\text{Design Capacity, N(lbs)} = \frac{2\ WH}{S + 0.1} \qquad (1)$$

Where: W = weight of the hammer, N(lbs)
H = height of drop, m(ft)
S = final set of pile, mm(inch) per blow

Always present the EN Formula as a bearing graph for site-specific hammer and capacity conditions. A good rule-of-thumb for the commonly used Vulcan No. 1, 20,325 Nm (15,000 ft. lb.) hammer, is design capacity (tons) equals hammer strokes per 0.3 m (ft), as shown on the bearing graph on Figure 2. Some common rules for installing timber piles are as follows:

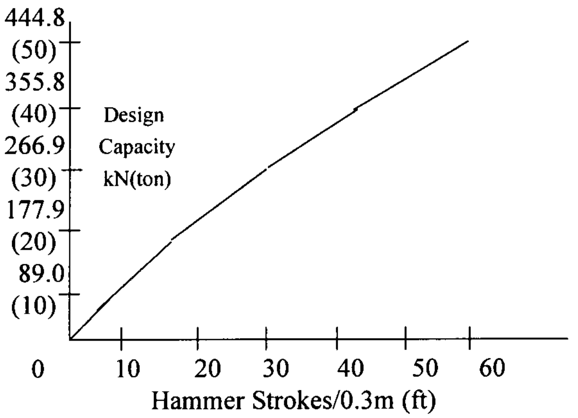


Figure 2—EN Formula Bearing Graph for 20,325 Nm (15,000 ft. lb.) hammer

1. Drive a timber pile no more than 60 strokes per 0.3 m (ft.) [5 strokes per 25.4 mm (inch)] with a 20,325 Nm (15,000 ft. lbs) hammer.

2. The normal capacity of a timber foundation pile is 266.9 kN (30 ton). Occasionally engineers specify 355.8 kN (40 ton) capacity where soil conditions permit. Beach front house piles often use only 89.0 kN (10 ton) capacity.

Research indicates 43 examples where driving resistance correlates load tests to failure to determine the actual safety factor of the Engineering News Formula. This research, presented in Table No. 1, includes job sites, soil conditions, pile sizes and lengths, hammer types, driving records, and load test capacities at failure.

The theoretical factor of safety of the Engineering News Formula is 6.0, but analysis of these 43 sites indicates the average factor of safety is about 4.0 and the median about 3.4. The lowest value, 1.6, was for a highway bridge over Charlemont Creek in Portage County, Ohio, constructed in 1942 during WW II.

Recent Examples of Timber Foundation Piling

Following are three recent examples of treated timber foundation piling: J.F. Kennedy International Airport, New York, NY (friction piles in sand); Comfort Inn, Exton, PA (end-bearing piles on rock); and Atlantic City High School, Atlantic City, NJ (friction and end-bearing):

J.F. Kennedy International Airport, New York, NY (friction piles in sand)

A portion of Jamaica Bay Marshlands, located on the southern shore of Long Island, was filled in the early 1940's with hydraulically transported sand, to elevation 3.66 m (12 ft.) MSL to construct J.F. Kennedy International Airport (formerly Idlewild). The 2.44 to 4.88 m (8 to 16 ft.) thick sand fill was placed over organic deposits, 0.61 to 3.35 m (2 to 11 ft.) thick, which were over a 30.48 to 38.10 m (100 to 125 ft.) natural sand deposit, that is, glacial outwash upper Pleistocene deposits of the Wisconsin Age, as shown on Figure 3. (Graham, 1990)

To minimize differential settlements for a 1990 Cargo Terminal building at Kennedy Airport in New York, some 1000 ASTM D-25, Class B, Southern Pine, 12.19 m (40 feet) long Timber Foundation piles were pressure-treated with creosote per AWPA C 3 specifications to a retention of 411.41 kg/m^3 (12 pcf) in the outer 50.80 mm (2 inches) and installed as the deep foundation. The timber piles were supplied by NTPC member companies in accordance with the New York City Building Code, i.e., ASTM D-25, 8274 kPa (1200 psi) allowable design stress, minimum 203.20 mm (8 inch) tip uniform taper, for 266.88 kN (30 ton) capacity friction piles.

The pile driving contractor used Vulcan No. 1 hammers with a rated energy of 20,325 Nm (15,000 ft. lbs.), and drove the timber piles to a resistance of 35 blows per 0.30m (foot) to allow extra capacity for dragdown, etc. The piles were installed into 254.00 to 304.80 mm (10 to 12 inch) diameter, 3.05 m (10 foot) deep, pre-augured holes. Lima 703 and 803 cranes were used, with fixed leads. No expensive load tests were required for the 266.88 kN (30 ton) capacity piles per the New York City Building Code. (At the present time, almost 8000 treated Class B's with 203.20 mm (8 inch) diameter tip timber piles are being installed for the new Terminal One project at Kennedy.)

El +3.66m (12 ft) Top of Ground
Gray-brown, medium to fine, hydraulic
SAND fill, relative density 30 to 60%
2.44 to 4.88 m (8 to 16 ft.) thick

0

Gray organic silty CLAY with layers
of brown peat, water content = 70%
for clay, 90 to 400% for peat
.61 to 3.35 m (2 to 11 ft.) thick
-3.05m (-10 ft)

-6.10m (-20 ft)
Gray-brown, medium to fine SAND
with traces of silt and/or fine gravel,
generally medium dense
30.48 to 38.10 m (100 to 125 ft.) thick
-9.14m (-30 ft)

[Top of rock estimated to be at least
213.36 m (700 ft.) beneath the surface.]

Figure 3—Generalized Soil Profile
J.F. Kennedy International Airport

Comfort Inn, Exton,PA (end-bearing on rock)

In 1983, to support a new Comfort Inn in Exton, PA, a 355.84 kN (40 ton) capacity timber pile foundation was installed to end-bearing on rock. (Graham, 1989) Test borings at the site indicated the top of rock was about 6.10 m (20 feet) beneath the ground surface.

Overlaying the rock was 1.52 m (5 feet) of coarse, 47 blows per 0.3 m(f) sand and a 1.52 m (5 foot) layer of 22 to 33 blows per 0.3 m(f) fine sand, over which lay a 3.05 m (10 foot) mixture of 8 to 14 blows per 0.3 m(f) sand, silt and clay. Conditions were considered ideal for driving timber piles, especially since the overburden materials contained no boulders or other obstructions. Almost 120 timber piles, 6.10 to 7.32 m (20 to 24 ft) long, ASTM Class B, 12-3-8 were pressure-treated with creosote to 192.24 kg/m^3 (12 pcf) per AWPA Standard C 3. The contractor drove the timber piles with an MKT 9B3 double-acting air hammer. The 9B3 is rated at 11,856.25 Nm (8,750 ft. lbs.) of energy per blow. A Manitowoc 2900 truck crane was used to handle 14.63 m (48 foot) leads, the hammer and pile driving. An Ingersoll-Rand, Corp Mem, Roanoke, VA, 1050 air compressor was used to power the MKT 9B3 hammer.

Atlantic City High School, Atlantic City, NJ (friction and end-bearing)

The Great Island site of the Atlantic City High School is an island in Lakes Bay, located between Atlantic City and the mainland. (Graham, 1993) According to the Soils & Foundation Report, "... Atlantic City is underlain by stratified granular soils of alluvial origin, possibly interspersed with recent organic alluvium, overlying sands and gravels of the Cape May Formation, as shown on Table No. 4. Bedrock exists at very substantial depths, many hundreds of meters (feet)...", as shown on Table No. 4.

Approximately 3000 Southern Pine timber piles, 15.24 m (50 ft.) long, for 311.36 kN (35 ton) capacity, ASTM D-25 and sized to a minimum tip and butt diameters of 203.20 and 304.80 mm (8 and 12 inches) (12-3-8), respectively. Treatment was specified to be creosote in accordance with AWPA C 3 specifications. The butt cut-offs were coated with two coats of hot creosote, followed by one coat of coal tar pitch, allowing sufficient time between applications permitting absorption of each coat, as described in AWPA M 4.

Using a Manitowoc 2900 Crane, the contractor installed the 311.36 kN (35 ton) capacity timber piles with a Vulcan No. 1 hammer rated at 20,325 Nm (15,000 ft. lbs) of energy powered by an Ingersol Rand 900 compressor. The piles were driven to 37 blows per last 0.3 m (ft.) in accordance with the Engineering News Formula with the tips penetrating into the very dense basal SAND stratum or very stiff to hard CLAY or clayey SILT. An ICE 1250 auger was used to predrill approximately 9.75 m (32 ft.) below working grade; the lower 6.10 m (20 ft.) of auger was 304.80 mm (12 inch) diameter while the upper portion was 406.40 mm (16 inch) diameter. The auger was mounted on the side of the "fixed leader." An A-frame moon beam controlled the vertical and horizontal alignment of the fixed leader and "spotted" the auger and the piles.

El 6.10 to 7.92 m (20 to 26 ft)
SURCHARGED in 1992

El 3.81 m (12.5 ft) finished floor slab
3.05 m (10 ft)
GWL top of ground El 1.52 to 3.05 m (5 to 10 ft)

0 hydraulic SAND FILL prior to 1978

-3.05 m (-10 ft) very soft organic SILT
with layers of PEAT
-6.10 m (-20 ft) loose silty fine SAND trace shells

-9.14 m (-30 ft) compact to very dense basal SAND

-12.19m (-40 ft)

-15.24 m (-50 ft) very stiff to hard silty CLAY or
clayey SILT
-18.29 m (-60 ft)
compact to very dense basal SAND
-21.34 m (-70 ft)

Figure 4—Generalized Geologic Profile
Atlantic City High School

Geotechnical Design

Design a round treated timber pile job by first obtaining information on adjacent structures and records of nearby test boring data.

Timber piling primarily are end bearing piles driven into dense sand or hard clay layers with some friction in the upper layers of softer soils. When evaluating the test boring data, look for a bearing strata some 9.14 to 18.29 m (30 to 60 ft.) deep with split spoon hammer blows of 30 per 0.3 m (ft.) or more. Stronger sub-surface soil bearing layers exist in most site-specific projects.

Perform geotechnical analysis, such as given in the Navy's DM 7.2 (NAVFAC, 1982), shown on Figure 5. The FHWA has a very complex manual on Design and Construction of Driven Pile Foundations (FHWA, 1985) and a Soils and Foundations Workshop Manual. (FHWA, 1982) Also, the Corps Design of Pile Foundations has been made available by ASCE. (ASCE, 1993) However these government manuals should be used only as a guide. Experience with using timber piling and empirical design are the most often used criteria.

Specifications for Round Timber Piling and Preservatives

Treated Round Timber Piling Specifications were presented in 1992 at the Deep Foundations Institute (DFI) in New Orleans (Graham, 1992), and are summarized below to include timber and preservatives:

Timber- Longleaf, Shortleaf, Loblolly, or Slash species of Southern Pine or Coastal Douglas Fir supplied per ASTM D 25 (ASTM, 1995).
Sizes- Class A, Class B, 203.20 mm (8 inch) tip natural taper, or use the Tables in ASTM D-25.
Treatment- AWPA C 3, Piles; C 14 Highway Construction; C 18 Marine Construction. See Table 3. (AWPA, 1995)
Quality Control- Notarized certificates furnished to the engineer with each delivery.
Field Treatment- AWPA M 4 (AWPA, 1995)
Design Stress- ASTM D-2899, 8274 kPa (1200 psi). (ASTM, 1995)

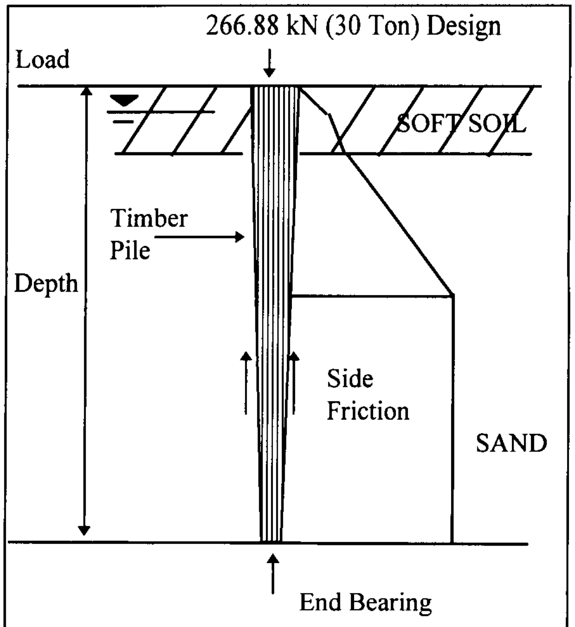
For complete timber piling installation specifications, please refer to the DFI's Treated Round Wood Piling Specifications. (Graham, 1992)

Sizes

The most common sizes of Round Timber Piling are Class B, as shown in Table 2, and 203.20 mm (8 inch) diameter tip natural taper, given on Figure 6.

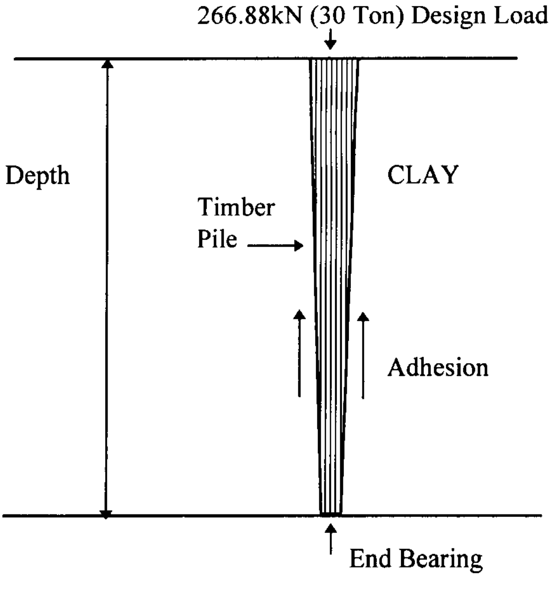
Class B piles were first proposed in circa 1915, then formally adopted by ASTM D 25 in 1937 (ASTM, 1937). About 50% of timber piles supplied today are Class B.

The 203.20 mm (8 inch) diameter tip natural piles are called the New York City pile, because they are specified in the Building Code. Often used up to 12.19 to 13.72 m (40 to 45 ft) long, they are the most economical 266.88 kN (30 ton) capacity pile.



$$Q_{ult} = P_T N_q A_T + \sum_{H=H_O}^{H=H_O+D} (K_{HC})(P_O)(\tan\delta)(S)$$

a)GRANULAR SOIL



$$Q_{ult} = C(N_{CS})\pi R^2 + C_A 2\pi RZ$$

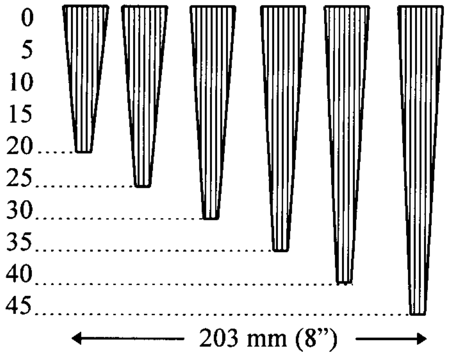
b) COHESIVE SOIL

Figure 5—Ultimate Load Capacity Equations for (a) Granular, and (b) Cohesive Soil (NAVFAC, 1982)

Table 2— Class B sizes per ASTM D 25-37 to 58

	Class B					
	0.91 m (3 ft.) from Butt				At Tip, min.	
Length, m (ft)	Min.		Max.			
	C*	D**	C	D	C	D
Under 12.2 Under (40)	965 (38)	305 (12)	1600 (63)	508 (20)	635 (25)	203 (8)
12.2 to 16.5 (40 to 54)	965 (38)	305 (12)	1600 (63)	508 (20)	559 (22)	178 (7)
16.8 to 22.6 (55 to 74)	1041 (41)	330 (13)	1600 (63)	508 (20)	559 (22)	178 (7)
22.9 to 27.4 (75 to 90)	1041 (41)	330 (13)	1600 (63)	508 (20)	483 (19)	152 (6)
Over 27.4 Over (90)	1041 (41)	330 (13)	1600 (63)	508 (20)	406 (16)	127 (5)

* C = Circumference ** D = Diameter



203.2 mm (8 Inch) Diameter Tip
Natural Taper per ASTM D 25-91

Figure 6—Natural Taper Round Timber Piling

Durability

Round timber foundation piling installed in the ground below the ground water table will last for centuries. Examples are the Companile Tower in Venice, Italy, built in 900, and an Erie Canal structure in Waterford, NY, where 80 year old untreated timber piles, extracted in February, 1996, are as good as new.

Treatment is required for Round Timber Piling installed in the ground, where a portion is above the water table. Properly treated and installed in a concrete pile cap, the piles will probably last for centuries, according to an industry study conducted until 1955. The American Wood Preservers Association (AWPA) regularly surveyed some 40 pressure-treated timber foundation pile installations throughout the country. Several of the structures were installed as early as 1922. Included in the AWPA study were grain elevators, public schools, breweries, apartment buildings, veteran's hospitals, viaducts, generating plants, bridges, oil refineries, plants, theatres, post offices, court houses, and train stations. The piles were cut-off well above the ground water level. The study was terminated because there was no reason to continue, there had been no failures.

Installed in the ground, but extending up into the air, such as at a beach house, timber piles will last as long as utility poles, about 75 years in the North and 50 in the South. Decay will occur about 0.61 m (2 ft.) below the ground surface.

Table 3—AWPA Specified Preservative Retention

	Round Southern Pine Piling	
	Creosote kg/m^3 (pcf)	CCA kg/m^3 (pcf)
Foundation	192.2	12.8
	(12.0)	(0.8)
Land & Fresh Water	192.2	12.8
	(12.0)	(.08)
Marine*	320.4/256.3	40.1/24.0
	(20.0/16.0)	(2.5/1.5)
Dual Treatment	320.4	16.0
	(20.0)	(1.0)

- 256.3 kg/m^3 (16.0 pcf) creosote or 24.0 kg/m^3 (1.5 pcf) CCA for marine use, from New Jersey and northward on the East coast of the United States.
- In those areas where Teredo and pholad attack are expected or known and where Limnoria tripunctata attack is not prevalent, creosote or creosote solution treatment will provide adequate protection.
- In those areas where Teredo and Limnoria tripunctata attack is expected or known and where pholad attack is not prevalent, either dual treatment or high retention of ACA, ACZA or CCA treatment will provide adequate protection.
- In those areas where Limnoria tripunctata and pholad attack is expected or known, the dual treatment provides the maximum protection known at present.
- A map showing areas of marine borer hazards in U.S. waters may be found in Figure 2 at the end of AWPA Standard C 3.

Round marine piling, subject to marine borer attack, will be a function of the salinity, current, and treatment. (Chellis, 1961) "Salinity ranges from 30 to 35 parts of salt per 1000 in the ocean...” The danger point for marine borer attack starts around 15 parts per thousand. Current is also a factor. Toredo will not attack above 0.72 m/s (1.4 knots) and limnoria over 0.93 m/s (1.8 knots). Creosote marine treatment lasts for about 50 years in the North and in the South about the same number of years as pounds per cubic foot of treatment. The expected life of round CCA treated piles is still unknown, but, with few exceptions, the results look excellent. One exception is the severe attack by Sphaeroma in Tarpon Springs, FL. (Johnson, 1987) Marine treatment of CCA causes brittleness, and Southern Pine treated to 40.05 kg/m^3 (2.5 pcf) should not be used for fender piling. (AFPA, 1991)

Environmental Considerations

According to the Environmental Protection Agency, round timber piling, properly treated with creosote or CCA, or dual treated with both, has no harmful effect on the environment. (Webb, 1988) Creosote is biodegradable and CCA, when fixed to the wood, does not leach out. (Graham, 1991)

National Geographic (Grall, 1992) published an article titled, Pillar of Life, showing how marine life attaches to timber piling to help the environment. The following is a quote from the Grail article:

“When a piling is driven into the bottom of the bay, life takes up residence almost immediately. Bacteria, algae, and protozoans cover the submerged surface. This “slime” provides a foothold for larger creatures to attach themselves in succession. In the summer young ivory barnacles are among the first to appear. With them come sun sponges and mosslike bryozoans, which spread over the piling by budding. Bright patches of algae such as sea lettuce soon arrive, followed by hydroids and bulbous sea squirts. Mussels use byssus threads to anchor themselves. Tubebuilder amphipods construct tunnels of mud and detritus for protection and for a niche on the crowded piling. Still others affix themselves to the shells of animals already attached. Almost every underwater part of the piling is covered with sessile species, each looking for food, shelter, and a place to propagate.”

Conclusions

Treated round timber piling have been successful for the past 130 years in the United States as deep foundations for highway bridges and other structures. Based on the Engineering News formula driving criteria, timber piles were installed to a safety factor averaging 4.0, with a mean of 3.5. Design has been based on the local Geotechnical Engineers knowledge and experience of site-specific soil and rock conditions.

Engineers refer to ASTM D 25 for timber and AWPA C 3 for preservative specifications. Piling sizes are usually Class B or 203.2 mm (8 inch) diameter tip natural taper. Durability of treated timber piles has been determined for foundation, land and fresh water, and marine conditions. Creosote and CCA were approved for use by the Environmental Protection Agency in 1986. Creosote is biodegradable and CCA, when fixed to the wood, does not leach. National Geographic published a paper showing how treated round timber piles help the marine environment.

References

AFPA. 1991. National Design Specification for Wood Construction (NDS). Washington, DC: American Forest and Paper Association. 125 p.

Altiero, Kris. 1996. Phone Conversation, Wood Advisory Services, Millbrook, NY.

ASCE. 1993. Design of Pile Foundations. New York, NY: American Society of Civil Engineers. 196 p.

ASTM. 1995. Standard Specifications for Round Timber Piles, ASTM D 25-37 to 95, West Conshohocken, PA: American Society for Testing and Materials.

AWPA. 1995. Piles-Preservative Treatment by Pressure Process. AWPA Standard C 3-95. Woodstock, MD: American Wood-Preservers’ Association, 38-51.

AWPI. 1958. Timber Piles Support 96-Ton Load in Gulf Coast Area, Wood Preservers News, Washington, DC, March, page 5.

AWPI. 1967. Timber Foundation Piles. Consulting Engineers Test in Mobile, also Timber Pile Foundations for Underpasses, Interchanges, American Wood Preservers Institute, Vienna, VA, 17-20 and 80-83.

Chellis, Robert D. 1961. Pile Foundations, 2nd Edition, McGraw-Hill Book Co., New York, 580-599.

Earle, Thomas. (not dated). Load Test Report, Baggage Claim B Renovation, Philadelphia International Airport, Thomas Earle & Sons, Inc., Collingsworth, NJ 41 p.

FHWA. 1982. Soils and Foundations Workshop Manual. Nov. 92, Geotechnical and Materials Branch. HHO-33, Washington, DC, 337.

FHWA. 1985. Manual on Design and Construction of Driven Pile Foundations. April 1995. Report No. FHWA-DP-66-1, Washington, DC: Federal Highway Administration, 684.

Goble, G.G., and Rausche, Frank. 1971. A Static and Dynamic Timber Pile Test in Monticello, Minnesota, Division of Solid Mechanics, Structures and Mechanical Design, Case Western Reserve University, Cleveland, OH.

Goble, G.G.; Cochran, David; Marcuca, Floyd. 1980. Foundation Design and Evaluation for the Winnemuca Viaduct, Engineering Geology and Foundation Section, Materials and Testing Division, Nevada State Highway Dept., 31 p.

Graham, James S. 1989. Exton, PA, 40-Ton Pile Foundation, National Timber Piling Council, Project Information Sheet Number 2, Rye, NY, p. 1.

Graham, James S. 1990. Cargo Terminal, J.F. Kennedy International Airport, New York City, National Timber Piling Council, Project Information Report Number 9, Rye, NY, 1-4.

Graham, James S. 1992. Treated Round Wood Piling Specifications, Proceedings, 17th annual members' conference, New Orleans, LA, Deep Foundations Institute, 169-191.

Graham, James S. 1993. Atlantic City High School, Great Island, Atlantic, NJ, National Timber Piling Council, Project Information Report Number 21, Rye, NY, 1-4.

Grall, George. 1992. Pillar of Life. Journal of the National Geographic Society, Washington, DC, Vol. 182, No. 1, July, 95-114.

Harper, William J., P.E. 1968. Pile Load Test, S.H.-73, Port Arthur, TX, Southwestern Laboratories, Houston, TX, 15 p.

Johnson, Bruce R. 1987. Protection of Timber Bulkheads from Marine Borers, ASCE Geotechnical Special Publication No. 7, Timber Bulkheads, Edited by James Graham, New York, NY, 16-34.

Mann, Ralph H. 1942. 72,000 Creosoted Piles in New York's East River Drive, Wood Preserving News, June, 8, 72-78.

McClurg, Verne O. 1960. Working Loads for Timber Piles. Wood Preserving News, American Wood Preservers Institute, Vienna, VA, Sept., page 7.

McClymont, Alfred, P.E. 1982. Pile Load Test, Toys R Us, McClymont Associates, Haddonfield, NJ, 14 p.

NAVFAC. 1982. Foundations and Earth Structures, DM-7.2, Alexandria, VA, Department of the Navy, Naval Facilities Engineering Command, 193-196.

PA, NY & NJ Timber Pile Test Program. 1987. PATH Main Repair Facility and Yard, The Port Authority of New York and New Jersey, prepared by Parsons Brinckerhoff Quade & Douglas, Inc., New York, NY, 100 p.

Peck, Ralph B. 1958. Highway Research Board, Special Report 36, A Study of the Comparative Behavior of Friction Piles, National Academy of Science-National Research, Publication 606, Washington, DC, 72 p.

Peck, Ralph B. 1961. Highway Research Board, Special Report 67, Record of Load Tests on Friction Piles, National Academy of Sciences-National Research Council, Publication 936, Washington, DC, 412 p.

Pittman, Col. L.C. 1962. Load Tests in South Carolina Reveal Merits of Timber Piles, Wood Preserving News, Washington, DC, page 5.

Webb, D.A.; and Gjovic, R.L. 1988. Treated Wood Products, their Effect on the Environment, Proceedings of the American Wood Preservers' Association, p ?.

Acknowledgments

I wish to thank the National Timber Piling Council member companies for their support, and Theresa Rappaport for providing the Words Version 6.0 typed print and drawings.

Table 1—Example Projects

LOCATION	PROJECT	SOIL CONDITIONS	REFERENCE	DIAMETER mm (in.)		LENGTH m (ft.)	HAMMER	EN FORMULA kN (Ton)	LOAD TEST kN (Ton)	FACTOR OF SAFETY
				butt	tip					
New Orleans, LA (1954)	Bridge over Inner Harbor	Sandy Silty CLAY	Peck 1961	393.7 (15.5)	190.5 (7.5)	18.8976 (62)	Vulcan No. 2	88.96 (10)	400.32 (45)	4.5
SAME				381 (15)	177.8 (7)	18.5928 (61)	Vulcan No. 2	133.44 (15)	489.28 (55)	3.7
SAME				355.6 (14)	203.2 (8)	18.288 (60)	Vulcan No. 2	88.96 (10)	373.632 (42)	4.2
Bonner County, ID (1952)	Sandpoint Bridge	CLAY	Peck 1961		152.4 (6)	21.9456 (72)	Vulcan No. 2	62.272 (7)	266.88 (30)	4.3
Council Bluffs, IA	Broadway Viaduct	CLAY clayey SAND SAND	Peck 1961	304.8 (12)		5.7912 (19)	Drop Hammer	88.96 (10)	355.84 (40)	4.0
Portage County, OH (1942)	Bridge Over Ravonna Ordinance Plant	silty CLAY	Peck 1961	381 (15)	177.8 (7)	13.1064 (43)	Vulcan No. 2	195.712 (22)	382.528 (43)	2.0
Lorain County, OH (1943)	Bridge over Charlemont Creek	silty CLAY	Peck 1961	322.58 (12.7)	185.42 (7.3)		Vulcan No. 2	257.984 (29)	400.32 (45)	1.6
New Orleans, LA (1956)	Greater New Orleans Bridge	silty CLAY	Peck 1961	406.4 (16)	152.4 (6)	18.288 (60)	Vulcan No. 1	35.584 (4)	222.4 (25)	6.3
SAME				406.4 (16)	152.4 (6)	21.336 (70)	Vulcan No. 1	62.272 (7)	400.32 (45)	6.4
SAME				406.4 (16)	152.4 (6)	18.288 (60)	Vulcan No. 1	26.688 (3)	266.88 (30)	10.0
New Orleans, LA (1954)			Peck 1961	406.4 (16)	152.4 (6)	24.384 (80)	Vulcan No. 1	533.76 (60)	711.68 (80)	13.3

Table 1—Continued

LOCATION	PROJECT	SOIL CONDITIONS	REFERENCE	DIAMETER mm (in.)		LENGTH m (ft.)	HAMMER	EN FORMULA kN (Ton)	LOAD TEST kN (Ton)	FACTOR OF SAFETY
				butt	tip					
Chicago, IL (1960)		HARDPAN (end-bearing)	McClurg 1960	355.6 (14)	228.6 (9)	12.8016 (42)	Vulcan No. 1	418.112 (47)	1085.312 (122)	2.6
SAME				304.8 (12)	177.8 (7)	12.8016 (42)	Vulcan No. 1	400.32 (45)	1343.296 (151)	3.3
SAME				355.6 (14)	228.6 (9)	12.8016 (42)	Vulcan No. 1	373.632 (42)	1263.232 (142)	3.4
SAME				355.6 (14)	177.8 (9)	12.8016 (42)	Vulcan No. 1	489.28 (55)	2090.56 (235)	4.3
SAME				304.8 (12)	177.8 (7)	12.8016 (42)	Vulcan No. 1	462.592 (52)	1085.312 (122)	2.3
Norfolk, VA	Waterfront	CLAY	Chellis 1961	342.9 (13.5)	203.2 (8)	17.6784 (58)	Vulcan No. 1	115.648 (13)	391.424 (44)	3.4
SAME				431.8 (17)	177.8 (7)	20.4216 (67)	Vulcan No. 1	133.44 (15)	355.84 (40)	2.7
Pike County, OH	PeePee Creek Bridge	SAND & GRAVEL	Chellis 1961	355.6 (14)	177.8 (7)	12.8016 (42)	Vulcan No. 1	231.296 (26)	631.66 (71)	2.7
Monroe County, OH	Kokasing River Bridge	SAND & GRAVEL	Chellis 1961	304.8 (12)	177.8 (7)	8.8392 (29)	Vulcan No. 2	151.232 (17)	329.152 (37)	2.2
Pike County, OH	Crooked Creek Bridge	SAND & GRAVEL	Chellis 1961			7.62 (25)	Vulcan No. 2	160.128 (18)	400.32 (45)	2.5
Burnside, LA (1956)	Hwy Research Board, Spec. Report 36	CLAY	Peck 1958	330.2 (13)	177.8 (7)	12.192 (40)	Vulcan No. 1	97.856 (11)	444.8 (50)	4.5
SAME				381 (15)	203.2 (8)	15.24 (50)	Vulcan No. 1	142.336 (16)	667.2 (75)	4.7
SAME				355.6 (14)	177.8 (7)	15.24 (50)	Vulcan No. 1	142.336 (16)	756.16 (85)	5.3

Table 1—Continued

LOCATION	PROJECT	SOIL CONDITIONS	REFERENCE	DIAMETER mm (in.)		LENGTH m (ft.)	HAMMER	EN FORMULA kN (Ton)	LOAD TEST kN (Ton)	FACTOR OF SAFETY
				butt	tip					
New Orleans, LA (prior to 1958)	S. Broad Ave. Overpass	Sandy Silty CLAY	Peck (1958)	355.6 (14)	177.8 (7)	15.8496 (52)	Vulcan No. 1	186.816 (21)	596.032 (67)	3.1
SAME				355.6 (14)	177.8 (7)	15.8496 (52)	Vulcan No. 1	266.88 (30)	640.512 (72)	2.4
New Orleans, LA (1948)	Elysian Fields Ave. Overpass	Sandy Silty CLAY	Peck (1958)	457.2 (18)	203.2 (8)	17.6784 (58)	MKT 9B3	133.44 (15)	444.8 (50)	3.3
SAME				457.2 (18)	203.2 (8)	16.1544 (53)	MKT 9B3	177.92 (20)	578.24 (65)	3.3
SAME				457.2 (18)	177.8 (7)	16.1544 (53)	MKT 9B3	133.44 (15)	489.28 (55)	3.7
New Orleans, LA	Gentilly Blvd. Overpass	SILT CLAY	Peck (1958)	393.7 (15.5)	184.15 (7.25)	17.9832 (59)	MKT 9B3	195.712 (22)	889.6 (100)	4.5
SAME				393.7 (15.5)	184.15 (7.25)	18.5928 (61)	MKT 9B3	195.712 (22)	711.68 (80)	3.6
SAME				406.4 (16)	203.2 (8)	17.0688 (56)	MKT 9B3	88.96 (10)	622.72 (70)	7.0
Monticello, MN (1971)	Bridge	fine silty SAND	Goble (1971)	312.42 (12.3)	218.44 (81.6)	7.3152 (24)	Link Belt 440	240.192 (27)	1174.272 (132)	4.8
Winnemuca, NV (1980)	I-80 Viaduct	SAND & GRAVEL	Goble (1980)	355.6 (14)	254 (10)	13.716 (45)	Delmag D-30	658.304 (74)	1245.44 (140)	1.9
Philadelphia PA	Intn'l Airport Baggage Claim B		Earle (not dated)	361.95 (14 .25)	215.9 (8.5)	7.9248 (26)	Vulcan No. 1	444.8 (50)	845.12 (95)	1.9

Table 1—Continued

LOCATION	PROJECT	SOIL CONDITIONS	REFERENCE	DIAMETER mm (in.)		LENGTH m (ft.)	HAMMER	EN FORMULA kN (Ton)	LOAD TEST kN (Ton)	FACTOR OF SAFETY
				butt	tip					
Freeport, TX (1958)	Dow Chemical Plant	CLAY & Silty SAND	AWPI (1958)	330.2 (13)	203.2 (8)	9.7536 (32)	Vulcan No. 1	391.424 (44)	711.68 (80)	1.8
SAME				307.34 (12.1)	210.82 (8.3)	9.144 (30)	Vulcan No. 1	409.216 (46)	800.64 (90)	2.0
Charleston, SC (1962)	Cooper River Bridge	CLAY (Marl)	Pittman (1962)	342.9 (13.5)	203.2 (8)	17.6784 (58)	Vulcan No. 1	160.128 (18)	1049.728 (118)	6.5
Harrison, NJ (1987)	PATH Main Repair Facility	SAND & GRAVEL	PA,NY & NJ (1987)	330.2 (13)	177.8 (7)	14.0208 (46)	Vulcan No. 1	186.816 (21)	711.68 (80)	3.8
Philadelphia PA (1982)	Toys “R” Us 3rd St. & Oregon Ave.	organic SILT over dense SAND	McClymont (1982)	355.6 (14)	203.2 (8)	10.3632 (34)	FEC 1500	231.296 (26)	640.512 (72)	2.8
Mobile, AL (1964)	I-10 @ Dauphin Island Pkwy.	CLAY & SAND over dense SAND (end bearing)	AWPI (1967)	349.25 (13.75)	241.3 (9.5)	17.0688 (56)	Vulcan No. 1	569.344 (64)	1156.48 (130)	2.0
New Orleans, LA (1965)	I-10 interchange near Lafayette-Duson	Sandy Silty CLAY	AWPI (1967)	342.9 (13.5)	203.2 (8)	10.3632 (34)	Vulcan No. 1	177.92 (20)	889.6 (100)	5.0
Port Arthur, TX (1968)	S.H.73 25th St. Overpass	Layer CLAY SAND SILT	Harper (1968)	384.175 (15.125)	222.25 (8.75)		Delmag D-12	569.344 (64)	1467.84 (165)	2.6

In: Ritter, M.A.; Duwadi, S.R.; Lee, P.D.H., ed(s). National conference on wood transportation structures; 1996 October 23-25; Madison, WI. Gen. Tech. Rep. FPL- GTR-94. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory.