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TIMBER PILES

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Repair of warn and damaged timber piles are made using the patented pile repair system, PileMedic® by QuakeWrap. Repair work using this system are made with minimal service interruption. Photo courtesy of QuakeWrap Inc.

TIMBER PILE BRIDGES

A GUIDE FOR TIMBER PILING SPECIFICATIONS, CONDITION ASSESSMENTS, EFFECTIVE MAINTENANCE & REPAIRS OPTIONS

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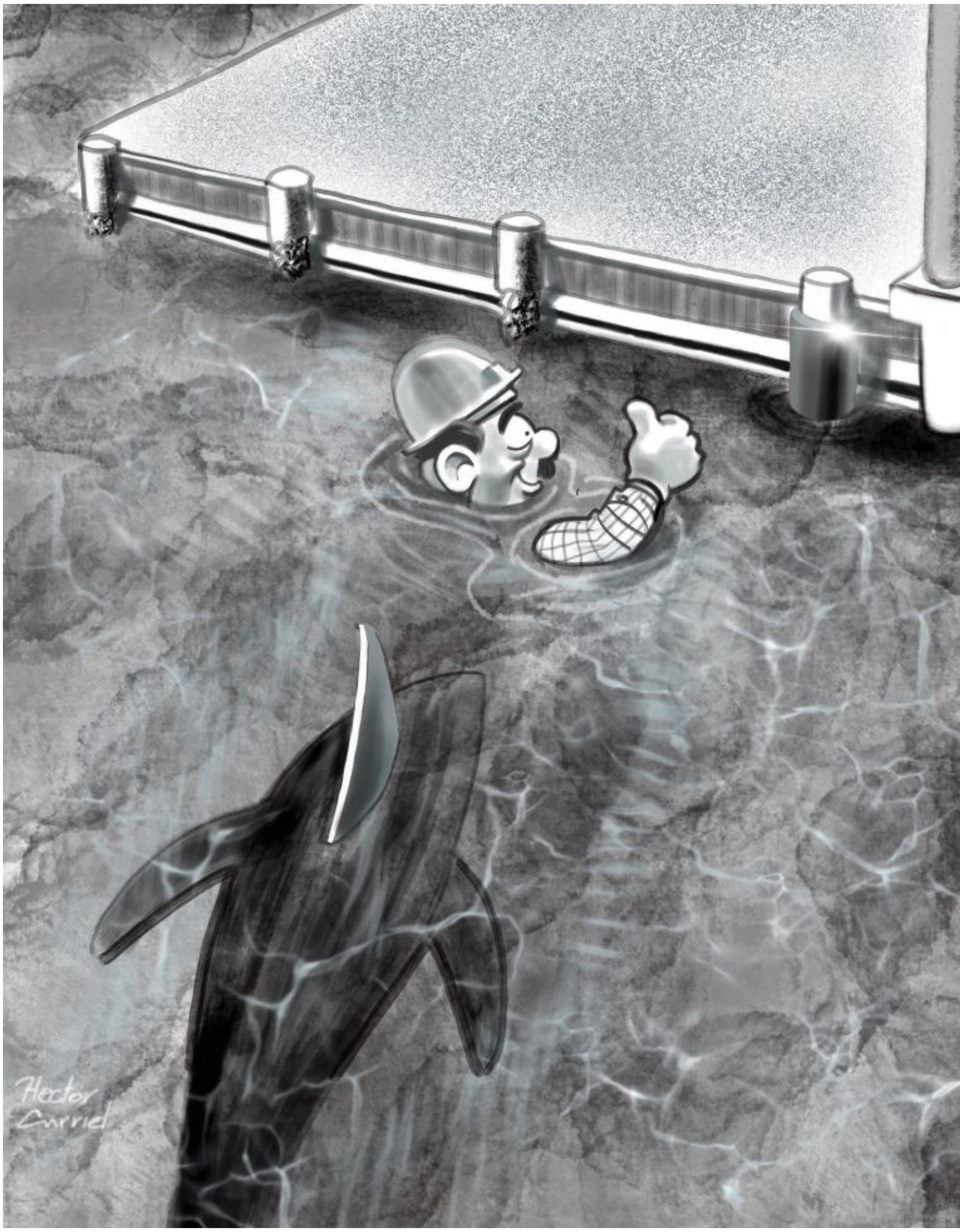
INTRODUCTION & BACKGROUND

Timber piles have been utilized around the world for thousands of years. History reveals that the Neolithic tribes in Switzerland used natural (untreated) logs as pilings to support homes built on the region's shoreline for almost 6,000 years. Archeologists have found a similar use of timber piling for bridges spanning the Tiber River dating back to 620 B.C. Standards exist today to ensure replicable strength values and durability that provide a consistent level of quality and service for the market place. These standards provide consistency in design applications with various types of timber piles. They also provide direction to engineers and bridge owners on cost-effective ways to maintain and repair piles. This article provides an overview of assessing the condition of timber pile, common maintenance practices and cost effective repair techniques.

Timber piles are a unique product in that they are made from a natural material and are subject to variations in species, size, straightness, and strength. In North America, there are two predominant species used for timber piles, Southern Pine and Douglas fir, which are protected by preservatives to ensure long service life. There are other types of wood species utilized such as Bald Cypress and other such species that provide better natural durability.



SPECIFICATION AND TREATMENT OF TIMBER PILES

Often forests are managed specifically for use in manufacturing piles. These forests are maintained for 35+ years to create timber piles. Sustainability is built in by growing more trees than are harvested, and the enhanced durability of preservative-treated timber pilings allows forests more time to produce mature trees.

While growing timber for piling, it is important that the material characteristics be reproducible. The American Society for Testing and Materials (ASTM) first developed standards for timber piles in 1915, titled ASTM D25, Standard Specification for Round Timber Piles.

TIMBER PILES ARE A UNIQUE PRODUCT IN THAT THEY ARE MADE FROM A NATURAL MATERIAL AND ARE SUBJECT TO VARIATIONS IN SPECIES, SIZE, STRAIGHTNESS, AND STRENGTH. IN NORTH AMERICA, THERE ARE TWO PREDOMINANT SPECIES USED FOR TIMBER PILES, SOUTHERN PINE AND DOUGLAS FIR, WHICH ARE PROTECTED BY PRESERVATIVES TO ENSURE LONG SERVICE LIFE.

Worn timber piles under a commercial pier before repair using the patented PileMedic® by QuakeWrap system. Photo courtesy of QuakeWrap Inc.

These rules established minimum criteria to ensure that each tree produced for piling creates a replicable timber pile and performs as intended. Standard D25 is updated periodically and focuses primarily on the quality, straightness, and size of piling.

ASTM D25 specifies that piles shall be of any species of wood for which strength values are provided for in ASTM D2555, Standard Practice for Establishing Clear Wood Strength Values. ASTM D25 ensures quality by requiring that each pile be of sound wood, establishing a minimum number of growth rings per inch and a minimum percentage of summerwood in the outer 50 percent of a pile tip. The standard also provides requirements for the straightness of each pile, taper, spiral grain, and the size and number of knots allowed to ensure consistency while accommodating minor variations in this naturally grown product.

The standard also addresses the size of timber piles by providing minimum tip and butt dimensions for each of the designated lengths. These minimum dimensions ensure a predictable taper for each pile so designers can calculate the diameter at any location along its length. Tables are provided for both Southern Pine and Douglas Fir that allow a designer to specify a tip or butt circumference.

For an end-bearing pile, a tip circumference is specified. The table provides a corresponding minimum pile butt circumference, measured three feet from the large end (butt) of the pile, based on the designated length. Conversely, for piles that rely primarily on skin friction, a butt circumference is specified. The table provides a corresponding minimum tip circumference, based on a designated length of the pile. There is also a table that specifies minimum tip size.

Timber piles in the United States and Canada classify this butt measurement by a Class. Sizes of Class A (14-inch butt) and Class B (12-inch butt) piles are for designers that prefer those designations. The American Wood Council publishes design values for timber piles conforming to ASTM D25 titled, "National Design Specification for Wood Construction." These strength values are used in determining the bearing capacity, lateral capacity, and allowable driving stress of a pile.

To ensure a long service life in harsh environments, wood requires preservative treatment. Standards are written by the American Wood Protection Association (AWPA), a group of consumers, scientists, and wood preserving companies, to ensure consistency of treatment for all variations of preservatives, wood species, and treatment processes. American Wood Protection Association has published these standards for over 110 years. A Use Category System for all wood products is provided in the front of their Book of Standards.

The guide describes minimum treatment levels for various exposure conditions to ensure long service life for all treated wood products. The Use Category System Standard U1 is used by specifiers to determine the appropriate treatment for a particular service condition. There are five major Use Categories depending on service conditions where the wood will be used. Timber piles are found in two of the Use Categories. Foundation piles and piles used on land or in freshwater are listed in UC4C, Commodity Specification E: Round Timber Piling. Piling used in saltwater environments are listed in UC5, Commodity Specification G: Marine Applications. Timber piles used in marine applications are further divided into subcategories UC5A, UC5B, and UC5C. These subcategories are based on geographical regions and specify the amount of preservative needed to provide optimum protection. The Use Category subdivisions for timber piles in marine applications list the prescribed treatments that are approved by the EPA and the retention levels for the common preservatives used. These preservatives are Creosote and Creosote solutions, Chromated Copper Arsenate (CCA), and Ammoniacal Copper Zinc Arsenate (ACZA).

When using specifications for round timber piles, a sample specification

A USE CATEGORY SYSTEM FOR ALL WOOD PRODUCTS IS PROVIDED IN THE FRONT OF THEIR BOOK OF STANDARDS. THE GUIDE DESCRIBES MINIMUM TREATMENT LEVELS FOR VARIOUS EXPOSURE CONDITIONS TO ENSURE LONG SERVICE LIFE FOR ALL TREATED WOOD PRODUCTS. THE USE CATEGORY SYSTEM STANDARD U1 IS USED BY SPECIFIERS TO DETERMINE THE APPROPRIATE TREATMENT FOR A PARTICULAR SERVICE CONDITION.

The patented PileMedic® system from QuakeWrap can be adapted quickly to most field conditions when repairing timber marine piles. Here PileMedic® laminates are prepared to wrap a timber pile in close quarters under a bridge in Montana. Photo courtesy of QuakeWrap Inc.

may be written, such as Southern Pine/Douglas Fir piles shall conform to ASTM D25, unused, clean peeled, uniformly tapered, one piece from butt to tip. Specify butt or tip diameters from tables listed in the ASTM D25 standard, including the pile length. The preservative portion could be addressed as follows. Pressure treatment shall be in accordance with the following AWPA Use Category Standard: UC4C, UC5A, UC5B, or UC5C. Handling, storage, and field fabrication, including the treatment of cut ends or penetrations, shall be in accordance with AWPA M4.

To properly treat timber piles with preservative, moisture must first be removed from the cellular structure (lumens) of the wood so that it may receive the preservative. Once a timber pile is sufficiently dry, it is placed into a pressurized cylinder. The cylinder undergoes a period of vacuum and then is flooded with liquid preservative, which is then pressurized, forcing preservative into the wood cells. Once sufficient preservative has been absorbed, a final vacuum is used to ensure that excess preservative is not retained in the wood cell, and the piles are removed from the cylinder. Analytical testing is conducted to ensure the preservative has penetrated the wood and that the proper retention levels have been met according to the AWPA standards. It is important to note that in some piling, the preservative treatment does not penetrate the entire pile, but creates a protective envelope around the pile's circumference. It is important to avoid puncturing or damaging this protective envelope prior to or during installation. Should the outer area of the pile become damaged, or if the pile is cut or drilled after treatment, the protective envelope will need to be repaired. AWPA M4 standard provides procedures for the proper handling, storage, and field treatment of timber piles to address any repairs that may be needed.

PENTACHLOROPHENOL TREATMENT

One of the best treatments for timber piles is Pentachlorophenol (Penta), a synthetic preservative treatment that is used only for heavy construction timbers such as railway ties, utility poles and bridge timbers. Pentachlorophenol, being an oil-based preservative treatment, has low solubility and is water repellent therefore has a very low leach out rate.

Over 60 years ago, Pentachlorophenol was formulated to contain high levels of toxicity to act as a mass defoliant. Produced as polychlorinated dioxins 2,3,7,8-T or 2,4,5-T, Pentachlorophenol was highly toxic and ultimately dangerous to humans. These formulations are now banned or heavily restricted and the Pentachlorophenol formulation used to preservative-treat timber has a completely different dioxin with a much lower toxicity but still must be handled with care — same as for any treated timber. Therefore by minimizing direct contact with immediate water environment, TRS significantly reduces impact on the environment. All components are pre-fabricated in the factory where it is cut to length and all holes drilled before treatment. Where possible; avoid any cutting, drilling of treated timber whether in the factory or on site however, when it is required, appropriate PPE must be worn.

Heavy duty wood preservatives, such as Penta, are applied to wood in specialized high pressure treatment cylinders at wood treatment facilities. With oil-borne preservatives such as Penta, bleeding after application can occur. To reduce this, timbers are vacuum-treated, extracting excess treatment solution that has not been fixed in the wood. Performing a double vacuum treatment is a standard practice for penta-treated wood intended for use in sensitive environments, such as open water locations. These vacuuming procedures reduce the chance that the Penta and carrier solution will migrate into the environment through water runoff.

Over the last 30 years, there have been multiple examinations by US, Canadian and private agencies of treated timber's environmental effects on organisms and surrounds. Penta readily degrades in the environment by chemical, microbiological, photolysis and photochemical processes. Photolysis appears to be a significant process for degradation since a measured photolysis half-life has been reported to be 52 minutes in running water under sunlight.

COMMON FACTORS CAUSING TIMBER PILE DETERIORATION

Wood deteriorates for numerous reasons, and as deterioration implies this adversely affects woods properties. The two primary causes of deterioration in wood are: biotic (living) agents and physical (nonliving) agents. In many cases the agents that first alter the wood, provide the conditions for other agents to attack (e.g. insects bring woodpeckers). The effectiveness of an inspection of deteriorated wood depends upon the inspector's knowledge of the agents of deterioration. A well-trained inspector is essential for accurately assessing wood deterioration.

PILE DETERIORATION DUE TO BIOTIC AGENTS

Biotic, or living, organisms that attack wood include bacteria, fungi, insects, and marine borers. As living organisms, they require certain conditions for survival such as moisture, oxygen, temperature, and food, which is usually the wood. When the basic necessary living conditions are available biotic agents of wood deterioration are free to proliferate, but if any one of them is removed the wood is safe from further biotic attack. Geographical regions tend to have higher moisture content due to average temperature and relative humidity.

The patented PileMedic® system from QuakeWrap can be adapted quickly to most field conditions when repairing timber marine piles. Here PileMedic® laminates are prepared to wrap a timber pile in close quarters under a bridge in Montana. Photo courtesy QuakeWrap Inc.

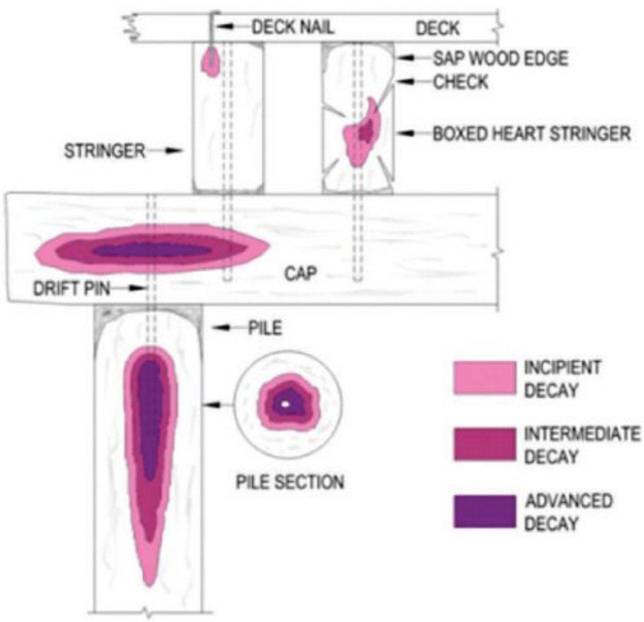
BACTERIA

In very wet environments bacteria can colonize untreated wood. Bacterial damage can include softening of the wood surface, increased permeability, and even degradation of chemical preservatives so that the wood becomes more susceptible to less chemically tolerant organisms. Usually the process bacterial attack is very slow, but under extensive exposure for long periods, damage can become significant.

FUNGI

When exposed to favorable conditions, most types of wood become an attractive food source for a variety of decay-producing fungi. The fungi require moderate temperature, oxygen, and a moisture content of approximately 22% or greater (oven dry basis) to become active. Decay progresses most rapidly at temperatures between 50°F and 95°F, outside this range decay growth slows considerably, and ceases when the temperature drops as low as 35°F or rises as high as 120°F. Over 82% of all timber bridge/pile degradation is due to decay causing fungi. It is known that with as little as a 10% loss in Specific Gravity (SG) up to an 80% loss in compression perpendicular to grain strength and a 75% loss in bending strength can occur in wood. Wood can be too wet for decay also. If the wood is water-soaked, the supply of oxygen may be inadequate to support development of typical decay fungi. Thus, wood will not decay, and decay already present from prior infestation will not progress if appropriate conditions are not met.

Decay fungi may be generally classified into two categories by the appearance on the wood surface.



Shows the level of decay that occurs in timber due to the use of vertical fasteners. Vertical fasteners increase the rate of decay in timber as they allow moisture to travel down the fastener into the heartwood of the cap, stringers, corbels and piles, therefore increasing the moisture content in the middle of these elements.

1. **Brown Rot** | Appears darker and can crack across the grain. Brown rot fungi attack the cellulose in the wood fibers. The brown color is due to the remaining lignin (the binder which holds the cellulose structure together), which is not consumed by the fungi. The decayed wood tends to form into small cubic shaped sections, which is a sign of advanced decay.
2. **White Rot** | Appears lighter in color and does not crack across the grain until severely degraded. In contrast to brown rot, white rot consumes both the lignin and cellulose and leaves the surface appearing generally intact, but with little or no significant mechanical strength. The surface of the decayed wood tends to have a “white” appearance.

WHEN EXPOSED TO FAVORABLE CONDITIONS, MOST TYPES OF WOOD BECOME AN ATTRACTIVE FOOD SOURCE FOR A VARIETY OF DECAY-PRODUCING FUNGI. THE FUNGI REQUIRE MODERATE TEMPERATURE, OXYGEN, AND A MOISTURE CONTENT OF APPROXIMATELY 22% OR GREATER (OVEN DRY BASIS) TO BECOME ACTIVE.

WOOD DETERIORATION DUE TO VERTICAL FASTENERS

The figure above shows the level of decay typically found due to vertical fasteners. The use of vertical drifts pins to attach caps to pile tops allow excess moisture into bright wood behind treatment. Side plates and horizontal through bolts should be used instead. A similar occurrence happens to the base of the column when they are sitting directly on concrete. The timber soaks up the water from the concrete, which accelerates decay. Further, wrapping cavitated piles with concrete above oxygen level leads to accelerated decay as the concrete holds the moisture content in the wood above the threshold for decay which is generally considered to be 22%

CONDITION ASSESSMENT INSPECTIONS

There are many ways to assess damage to a pile bridge. However, the amount of experience an inspector has greatly impacts the cost and accuracy of the assessment. Multiple types of tests will help pinpoint specific issues and increase the reliability of inspections. It is recommended that a standard set of assessment tools be employed to standardize condition assessment inspections.

VISUAL ASSESSMENT

An experienced and well trained eye can spot many maintenance problems with a timber pile bridge. Color changes in the wood can indicate structural failure. There are several types of corrosion that are visible to the naked eye; such as split, cracked, or crumbling wood. The following visual signs should be noted in the assessment report.

IDENTIFYING DEFECTS

Following are physical properties and defects that can may indicate areas of concern and should be noted and scheduled for future maintenance inspections.

Checks: Separations in the wood that run parallel to the growth rings at the end grain of a bridge member. Checks are considered none structure defects accounted for in the current standards. Only when checks are severe in depth and length should down rating be considered.

Decay at Fasteners: Deterioration found at the holes and cuts used to connect the wood bridge members.

End Grain Decay: Deterioration at the ends of the timber members that extend into the member that is parallel to the wood grain.

Splitting: Damage that extends perpendicular through the board to an adjacent face.

Surface Decay: The exterior of a timber member can deteriorate from various sources including insects, mold, sapwood stains, and microorganisms that feed on wood.

Ultraviolet Degradation: The surface of the wood turns gray from weathering and is not generally considered a significant contributor to timber degradation from a structural point of view.

COMMON TESTING METHODS

There are various methods available to test the wood to identify the specific type of deterioration, if any. Some of these tests are subjective. Other tests use tools that specifically measure the potential source of the deterioration, such as an electronic moisture meter. The best inspection methods are nondestructive testing (NDT) methods that don't cause damage to the structural integrity of the timber member.

PROBING AND PICK TESTS

PROBING

Use a sharp, pointed tool (like an awl) to poke at problem areas identified in the visual inspection. The affected areas are 'soft' spots that indicate decay from fungi or insect damage.

Use an inspection probe to find pockets of decay near the wood's surface. Splinter patterns can also be tested for. You will not be able to easily probe

Repair of warn and damaged timber piles are made in Montana using the patented pile repair system, PileMedic® by QuakeWrap. Repairs are made with minimal service interruption. Photo courtesy of QuakeWrap Inc.