Steel Piling and Its Uses

Steel piling is commonly used in construction. Piles are commercially available in a variety of shapes, sizes, and materials. Common piling materials include steel, aluminum, concrete, FRP-composite, and vinyl. Steel is by far the dominant material, although the use of corrosion-resistant composite and vinyl piling is increasing. Because of their inherent corrosion resistance, composite and vinyl piles are not painted. In theory, these materials can be advantageous in a corrosive marine environment. In practice, however, their use is limited to light and medium duty applications, such as marine and freshwater bulkheads and smaller retaining walls. This article gives an overview of steel piling and its uses; reasons for coating it; shop coating of new steel piling; and ways to access, inspect, and perform maintenance coating of installed steel piling.

Steel Piling and Its Uses

Steel piling is available in a variety of shapes, lengths, thicknesses, and alloys. Several ASTM standards describe some of the salient characteristics of steel piling: ASTM A857/A857M-07, Standard Specification for Steel Sheet Piling, Cold Formed, Light Gauge; ASTM A328/A328M-07, Standard Specification for Steel Sheet Piling; and
Steel piling comes in many shapes, including H, U, Z, and flat sections. Combinations of shapes can be used to fulfill specific engineering and aesthetic requirements. Piles typically have integral interlocks that allow the piles to be connected as they are installed in the field. Optional interlock bars and corners facilitate the installation of virtually any configuration, but interlocks have a small degree of play and are not watertight. Sealants and seal welding are used for applications that require the structure to be water impermeable. Performed after field installation, seal welding creates a simple continuous weld that provides a watertight seal. Alternatively, flexible organic sealants are applied to piling structures prior to field installation, which also facilitates future maintenance painting.

Piling is used for many structures, both temporary and permanent. Examples include retaining walls, quay walls, bridge abutments, seawalls, bulkheads, cofferdams, basements, underground parking garages, in-ground hazmat containment barriers, load bearing foundations (e.g., water tanks), groin walls for beach erosion, and wing walls for bridges and culverts. Sheet piling has even been installed as a barrier along sections of the shared border between the U.S. and Mexico.

### To Coat or Not to Coat

Pilings used for temporary structures are not typically coated. In fact, the vast majority of piling for both temporary and permanent structures is installed without a coating system or any other means of corrosion protection. Paints are sometimes used for visibility and aesthetics, such as on the pile walls of basements and underground parking garages, land-sited retaining walls, and water storage tank foundations. In general, atmospheric exposed sheet piling is coated to improve appearance.

For pilings installed in corrosive environments, piling manufacturers suggest that protective coatings, thicker steel, or higher yield strength steel be used to ensure that the design life of the structure is met. Higher yield strength steel compensates for loss of section caused by corrosion but does not prevent corrosion itself. For piling installed in corrosive environments, often only a relatively small area is exposed to highly corrosive elements. For example, consider a marine bulkhead constructed of 50-foot-long piles. If the combined depth of the low water, tidal, and splash zones (the most corrosive areas) is a modest 5 feet, then only 5% of the total area of the piles will be subject to high rates of corrosion. Coating, sometimes supplemented with cathodic protection, can be a more cost-effective approach than over-engineering the structure in part or as a whole.

Alternatively, thicker piles overall or piles reinforced with additional sectional thickness in the zone of greatest corrosion can also be used. (A pile can be reinforced by welding plates or another section of piling onto the main piling to add thickness just to the area where the corrosion rate is highest. Reinforcement eliminates the need to use a thicker pile over the entire length [height] of the piles.) Selecting a higher yield strength steel can effectively increase section thickness. For example, a higher yield strength steel that increases section thickness by 30% may only modestly increase the cost by approximately 2%. In some cases, the zones of greatest corrosion may not match the areas that are most highly stressed. Piles have bending forces from side loads, but the loads are not equal. So the bending forces in piles are not like those caused by grabbing a stick at both ends and bending it. In the latter case, the maximum load is at the center, right where you expect the stick to break. The static and dynamic loads on a pile will vary with height based on how deep the pile is driven, whether it has tiebacks and where they are, the relative depth of the water, tidal height changes, and wave action. So the maximum bending force that will collapse...
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the wall is not necessarily at the center of the pile. The area with the highest corrosion rates may or may not coincide with the location of highest loading.

Designers are encouraged to use cost engineering to aid in the decision process. Major suppliers of sheet piling have compiled general information and tools to assist the designer in selecting the most cost-effective approach to achieve the desired durability.

The general order of environmental corrosiveness is: saltwater > freshwater > soil > atmospheric. This rank order is a broad generalization, and, within these categories, the severity can be further subdivided, yielding overlaps and disorder within the generalized ranking.

Sheet pile installed in undisturbed natural soils does not need to be coated. In practice, pilings used to construct seawalls, bulkheads, and retaining walls will be backfilled on the soil side, which may increase the corrosion rate and require protective coatings or design compensation. (Corrosion rates are higher for backfilled areas due to soil aeration, affecting about the first 10 feet below soil grade.) Some soils, such as aggressive natural soils and fills, may be as corrosive as or more corrosive than seawater and will also warrant the use of protective coatings or corrosion compensation through design. In its guide specification for engineering in tropical regions, the U.S. Navy has specific guidelines for protecting sheet pile in tropical marine environments, with special consideration given to pile driven in coralline soils with low resistivity.² In this case, coatings are used to protect the soil side of pile structures.

Sheet pile continuously immersed in seawater has a low enough corrosion rate that painting is not required. However, mill scale on sheet piling may facilitate pitting of bare steel in seawater immersion. Therefore, piling to be immersed in seawater is usually painted for corrosion protection and sometimes supplemented by application of either impressed current or sacrificial cathodic protection. If the piling is to be coated for immersion service, the mill scale is first removed as part of surface preparation.

The marine tidal zone and, especially, the low water level, are quite aggressive, so piling in these areas is usually coated for protection and may again be supplemented by cathodic protection. The marine splash zone is also very aggressive, and piling in the splash zone is usually painted; however, cathodic protection is not applicable. Exposed pile above the splash zone is typically treated the same as the splash zone.

**Coating of New Sheet Piling**

If a new sheet pile structure is to be coated, application almost always occurs within a shop facility. Surface preparation and shop coating offer tremendous cost savings over field coating. Piles are typically cleaned using centrifugal blast machines to achieve either an SSPC-SP 6, Commercial Blast Cleaning, or SSPC...
SP 10, Near White Blast Cleaning.

Shop-applied coating systems are usually two- or three-coat systems. The types of products used are variable, but generally they are the same types used for any similar industrial application. Epoxy primers and intermediate coats are typical, with polyurethane topcoats used for preservation of appearance. Coating suppliers and end users have not conferred royal status to any single coating material or system. Most systems offered and specified for immersion and soil applications have film builds of 12 mils and up.

The only U.S.-based standard for coating sheet pile is ASTM A950/A950M-99 (2007), Standard Specification for Fusion-Bonded Epoxy-Coated Structural Steel H-Piles and Sheet Piling. The powdered coating is electrostatically applied and heat cured. Fusion-bonded epoxy (FBE) coatings have good edge retention and few pinholes in the finished product. Like other epoxy coatings, FBE is tough and well-suited to the rigors of shipping and field installation. FBE has only fair resistance to cathodic disbondment and is not the best choice for use with cathodic protection.

The traditional workhorse coating for protecting sheet piling is coal tar epoxy (CTE), covered under the standard SSPC-Paint 16. CTE is well-suited to buried soil, freshwater and marine immersion, and tidal and splash zone exposures. CTE does not perform well in direct sunlight and is available only in black and dark reds; it is not used for its aesthetic properties. CTE is more flexible and impact-resistant than many epoxy coatings, and it retains these properties even at low temperatures. Coating flexibility and impact resistance help reduce coating damage before and during piling installation. The U.S. Army Corps of Engineers (USACE) and other owners specify CTE for use on permanent sheet pile structures. USACE also specifies an epoxy zinc-rich primer for marine applications. The nominal two-coat thickness of CTE is 18 mils. USACE also allows the use of two- and three-coat epoxy polyamide systems on sheet pile. Polyamide systems may also be enhanced by application over an epoxy zinc-rich primer.

Other coating materials have been shown to be well suited to protect sheet piling. One study showed that the long-term performance of flame-sprayed aluminum with a topcoat sealer gave the best protection in a cold water marine environment, and a polyester glass flake coating gave the best protection in a warm water marine exposure. CTE with a zinc-rich primer performed well at both of the locations.

A research program sponsored by the American Association of State Highway and Transportation Officials in cooperation with the Federal Highway Administration produced a report that provides recommendations for metallizing systems to use on sheet piling and provides a standard practice. USACE recommends aluminum thermal spray coatings for piling exposed to seawater.

In addition to metallized coatings, hot-dip metal coated pilings, including zinc, zinc/aluminum alloy, and aluminum are commercially available. Hot-dip metal coatings on sheet pile offer the same economies as for other applications. Interested specifiers should refer to literature available from the American Galvanizers Association. The designer should consider the size of piling that will be used on a project because there are practical limits on the overall length of a sheet that can be dipped into the galvanizing bath. The designer should also consider whether the added cost of providing corrosion protection to both soil and water sides is warranted.

The world's largest steel producer recommends CTE at a nominal 18-mil thickness or glass-filled epoxy for seawater immersion. For freshwater immersion, the company recommends a 12-mil thick system of epoxy polyamine coatings.

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primer and epoxy polyamide topcoat. For aesthetic purposes, the system can be supplemented with an aliphatic polyurethane topcoat. The company also recommends epoxy/polyurethane systems for atmospherically exposed piling.

**Inspection and Maintenance of Coated Sheet Piling**

All coatings eventually reach the end of their service life when they no longer protect the underlying surface. Maintenance schedules and repair options are evaluated by means of inspection.

**Access and Inspection of Sheet Pile**

Inspection of coated sheet pile is challenging because direct access to the coated surface is generally limited. In practice, inspection is often performed by trained divers, but devices have been developed for remote inspection, including robotic crawlers and manually positioned instruments. Divers and remote instruments can conduct visual observations as well as perform physical measurements, including pit depth, ultrasonic steel thickness, film thickness, and electrochemical processes.

Soil side inspection is generally not possible; however, the soil side is usually the area of least concern because of the generally low rate of steel corrosion in most soils (except as noted earlier). In some cases, soil resistivity is measured as a means of assessing the relative severity of the soil side exposure.

Direct inspection may be conducted if the structure can be dewatered. Direct access allows evaluation by qualified non-diving inspectors in a dry environment. With few exceptions, dewatering of a structure is seldom a practical alternative. Portable limpet dams (essentially miniature portable cofferdams) have been developed to facilitate inspection as well as maintenance of sheet piling in the dry. The width and depth of access are limited by practical considerations. Installation and movement of the device is straightforward and fairly rapid. The limpet dam must be customized to match the specific shape and profile of the piling. When the limpet dam is configured with straight sidewalls and a bottom with a toothed design matching the piling profile, the dam can be securely attached to the pile wall, and the contained area is dewatered by pumping it dry.

The results of the inspection can be used to determine the necessary course of action. Sometimes the pile structure may warrant structural repair, rather...
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than just maintenance painting. In such a case, structural repair may be accomplished by welding additional steel plate to the affected piles to increase sectional thickness and strength. Sometimes, a new sheet pile wall must be installed, typically by driving new piles in front of the existing piles. The new and old walls can be connected with tie rods to take advantage of the existing anchorage of the old piling structure.

**Access and Maintenance Painting**

Access for maintenance painting has the same limitations as for inspection. Dewatering may be accomplished with a limpet dam or other damming devices that allow the water elevation to be lowered to the extent necessary to perform maintenance operations in the dry. Earthen, rock, pile, and inflatable dams may be suitable for blocking inlets or isolating sections of canals. Dewatering is accomplished by pumping out water. From a practical standpoint, the water does not need to be removed all of the way to the mud line. In fact, complete dewatering may compromise the integrity of the piling walls and may harm the local animal and plant life. Most repairs will be performed in the zones of highest corrosion, which is near the waterline in freshwater and from the low waterline through the splash zone in seawater.

The dewatering of open water structures such as seawalls and other waterfront structures may require the construction of a cofferdam. This practice can be quite expensive and may negatively impact commerce or security. Where dewatering cannot be accomplished, it may be necessary to utilize divers to perform surface preparation and coating application underwater.

While many types of coatings are suitable for use on new sheet piling, the same is not true for the maintenance of sheet pile structures. If dewatering is a practical alternative, and if dry conditions can remain long enough, then most of the coatings mentioned for shop application on new piles may be used. Coating selection is limited however, when productivity is paramount and coated surfaces must be returned rapidly to wet service. Suitable systems are those that either cure very rapidly or cure underwater. Such products may include 100% solids epoxy, polysulfide-modified epoxy, and polyurea applied by plural-component spray. If it is not sealed, metallizing may be used to return piling to service immediately. If sealed with a fast-cure product, metallized piling may be returned to service rapidly.
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Coating Sheet Pile Structures

Products specifically formulated for underwater application are not widely available. There are perhaps six to eight manufacturers of such products. Applying coatings underwater is both difficult and slow because of the surface preparation quality required; poor initial adhesion; and potential application defects, including floating, lifting, and sagging.

Underwater surface preparation may include hand cleaning, grinding, and water and abrasive blasting with zero-thrust equipment. Removal of all loose coating and loose rust as well as all marine organisms is generally specified.

Underwater coatings are applied by roller, brush, or trowel. Older products, referred to as splash zone putties, were mixed and applied with a gloved hand. The putty-like coatings worked but were very slow to apply. Newer products are applied using pressure-fed rollers and brushes. Products available for underwater application are 100% solids, including epoxy polyamine and polysulfide-modified epoxy coatings. The addition of fiber reinforcement to these products reportedly improves application properties by reducing floating.9

Summary

Permanent sheet pile structures are either designed with a corrosion allowance or coated to achieve the required design life. Surface preparation and coating are best accomplished in the fabrication shop. Techniques are available to inspect sheet pile structures installed in seawater and freshwater. If maintenance coating is necessary, operations should be performed in the dry, but if dewatering is impractical, underwater-applied coatings may be used.

References

1. ASTM International, West Conshohocken, PA.

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