Steel piling in marine applications: Types, durability and installation

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Demand for larger and deeper berthing facilities at harbours and ports is constantly increasing to satisfy the expansion of world trade.

The Port Engineer has a range of construction techniques available when planning new structures, and steel piling is often the material of preferred choice for qualities of robustness, reliability, and speed of installation compared to other options.

This paper presents an overview of steel pile types, their durability, and the methods of installation and driving equipment most commonly used in maritime situations.

Steel pile types

Bearing piles
Universal H Piles are low displacement piles particularly beneficial for penetrating dense strataums and hard rock. They are generally used in buried structures where the pile shaft is fully supported to prevent buckling failure about the weak axis of the profile. Soil heave and transmission of ground vibrations during installation are low compared to other pile types.

Tubular Section Piles are the most widely used steel bearing pile type and are suitable for supporting deep water structures such as jetties and dolphins. They are available in a large range of diameters, wall thickness and steel quality. A symmetrical radius of gyration allows long unrestrained lengths in open water to resist buckling failure and provide flexural strength for horizontal berthing and environmental forces.

Fabricated Box Piles are formed by connecting together individual sheet piles to form close sided sections. They can be transported from the rolling mill in single bars to be welded together on the job site. By using special corner elements and driving sequentially, it is possible to create significant load bearing foundations without the need for heavy pile driving equipment. In respect of design and installation, they have similar attributes to tube piles.

Interlocking piles for earth retaining structures
Interlocking steel sheet piles supported by tie rods and anchoring systems are prolific in harbour works. However, the demand to build very deep structures often requires profiles which have much greater strength and robustness than standard proprietary pile sections.

CombiWalls and High Modulus Walls consist of tubes, box or I section ‘primary’ members interlocked with ‘secondary’ panels of Z or U profile sheet piles, and are used for deep water berths because of their high strength characteristics.

Straight Web Piles are commonly used in circular cofferdams to form self supporting gravity structures for dock closures, quay walls and breakwaters. Maximum depths and diameters of cells are limited only by strength of the bulb interlocks and also practicalities associated with installation.

Durability of steel structures
Up until the mid 1980’s it was accepted that corrosion of steel piles in marine applications was most severe in the splash and intertidal zone just above low water. However, engineers have become increasingly aware of a sinister form of bacterially induced concentrated rust termed ‘accelerated low water corrosion’ (ALWC) which manifests itself as a bright orange bloom giving off a pungent odour when disturbed. The rate of corrosion is extreme, and, unlike other corrosion mechanisms, ALWC is unpredictable as to where it will occur and its severity.

Selecting the right type of pile and other design criteria can create sustainable solutions to the problem of concentrated corrosion.

The design life of the steel depends on the combined effect of imposed stresses and corrosion. For earth retaining walls, avoiding maximum stresses at or near low water by astute positioning of tie rods is desirable. Steel grades can be improved so that corrosion does not impair the strength to the same degree and the same effect can be achieved by selecting heavier section piles to provide a sacrificial thickness of steel. Protective coatings can also be used to delay the onset of rusting. High quality durable paint systems increase effective life by up to 20 years.

Cathodic protection, although expensive, is being specified more often by engineers in reaction to the increased awareness of concentrated corrosion. Impressed current systems have long life expectancy but high maintenance costs. Sacrificial anodes have a shorter life, but once fixed, the piling can be left to function without further attention.

For bearing piles in open water, the axial stresses are constant along the pile shaft and therefore uniform thickness and closed geometry are generally desirable. Tube piles fit this criteria, but H piles are to be avoided in these conditions as all surfaces of web and flanges are exposed to corrosion.

Pile installation

Panel driving using pile guide frames
Port engineers will be familiar with the well established panel driving technique using trestles and guide frames for installing continuous walls. When operating over water this method is often the only practical means of installation and ensures good control.
and accuracy during pile penetration. Safe means of pitching and interlocking each pile are available by using automatic pile threaders, or if conditions allow, a piling operator can engage the piles working from a manrider basket suspended from the service crane jib. Vibratory equipment is often used to secure the piles into the seabed prior to backdriving with percussive hammer.

The panel driving method is the best means to overcome obstructions such as isolated boulders.

**Pitch and drive techniques**

Hydraulic ‘Leader’ rigs are a very efficient method of installing continuous walls. The rigs are mounted on excavator base machines with winch and mast to lift and support the piles. They offer full control of pile alignment and are extremely productive when used with vibratory drivers in cohesionless soils. Each pile is pitched and driven to full depth prior to interlocking subsequent piles. The same technique is used with Pile Pressing machines, which are better when driving in cohesive soils. An advantage of these methods is that pile clenching is carried out at ground level which is not only safer, but allows piling to continue during high winds. A disadvantage is that the piles have a tendency to forward lean during driving because of the difference in interlock friction between leading and trailing clutches. It is sometimes necessary to include special taper piles to correct the lean.

Both pile guide frames and pitch and drive systems are used for driving steel bearing piles.

**Piling equipment**

Vibratory pile drivers are manufactured with centrifugal forces up to 5000 kNm as standard. They operate on the principal of liquefying the soil to reduce skin friction and end bearing, allowing the pile to penetrate with little effort. Narrow bodied models enable driving of single sheet pile sections, which is particularly advantageous when driving secondary piles in ‘Combi’ retaining walls. High frequency and resonance free machines can limit vibration transmission to neighbouring vulnerable dock structures. Vibrodrivers are very efficient in granular soils with density SPT values up to 50. Beyond this limit, it is usually necessary to ‘back drive’ the piles using impact hammers.

Hydraulic impact hammers have all but replaced diesel, pneumatic and drop hammers due to their high efficiency ratings (up to 90 per cent of indicated energy is delivered to the pile). For marine works, hammer energy ratings of up to 200 kNm are common and double acting ‘power down’ machines operate at much higher speeds than conventional ‘free fall’ hammers, thereby limiting the duration and intrusion of noise nuisance. In this respect, it is essential to ensure correct alignment of the hammer so that the impact energy is transmitted axially into the pile. Leg guides can be fitted to suit all types of piles whether driven singly or in panels.

**Summary**

A brief review of steel piling applications in maritime construction has been presented. The Federation of Piling Specialists and Dew Construction welcome further enquiries on this paper and other general piling matters.