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optimally to protect vessels and quay walls. Even though they are out of sight, quay walls are never forgotten in Rotterdam.

From precise basic designs to carefully policed construction, Engineering Consultants Rotterdam Public Works probably has more experience than most. With its hard-won know-how in quay wall construction it is now actively contributing to the infrastructure and efficiency of operations in ports far from its home.



ABOUT THE AUTHORS

Henk van der Horst gained a MSc in Civil Engineering from The Technical University of Delft in The Netherlands. He joined Public Works Rotterdam in 1980 as Managing Director of the Port Engineering Division. The division plays a leading role in the technical design of the extension of the Port of Rotterdam. Henk van der Horst is a member of the PIANC association. He has presented many papers on the various concepts of port design.



Jeroen G. de Gijp is the Project Manager of the Engineering Division of Public Works Rotterdam. He graduated as a Civil Engineer from the Delft Technical University. With almost twenty years' experience in port planning and detailed design, he specialises in the foundations of quay wall construction. On this subject he has published about 30 papers. Mr. De Gijp is a member of the European EAU and member of the American Society of Civil Engineers (ASCE).

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Underwater Corrosion of Steel Sheet Piling

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ABSTRACT

Underwater corrosion of steel sheet piling is a serious problem. A combination of factors determine the corrosion rate and measurements of actual rates have shown that target lifetimes, for example 50 years for some installations, may be optimistic.

UNDERWATER CORROSION

The average general corrosion rate of marine structures in European countries can be shown to be approximately 0.125 mm per year. Sheet piling and other partially submerged structures show localised, concentrated corrosion in a narrow band below the waterline (Figure 1, 2). However, the rate at which underwater corrosion locally eats away the sheet piling can be considerably higher than can be derived from the average rates. This is due to the combined interaction of local oxygen concentration gradients, pitting effects, macrocellular potential differences, bacteriological growth and stray currents. This rate may even exceed 0.5 mm per year in some cases. An exceptional case is a sheet pile wall composed of H piles and flat sheet piles, where the piles with a flange thickness of 18 mm showed large perforations after as little as 12 years.

BEMEDY

An excellent solution consists of stopping the corrosion with a suitable chemical coating which is applied under dry conditions. A suitable coating however has to be entirely formulated in function of the numerous factors which are involved in a sound solution to the actual problem and should increase considerably the life expectancy of the structures.

The reaction mechanisms which give rise to corrosion are extremely complex and can have very destructive effects (Figure 3).

In addition, the piling is a complex subject for treatment with a chemical compound, as it is simultaneously exposed to the atmosphere, the splash zone and water immersion. Furthermore, the application of a protective coating is subject to conditions of very high relative humidity and often low, or relatively low, temperatures. The preparation of the surface has to be completed carefully as even invisible impurities, e.g. salt- and iron++-ions, have to be removed to avoid osmotic blistering of a coating. A suitable coating compound cannot contain either caustic or heavy metals for ecological reasons.

Many other factors in connection with corrosion, exposure to different climates, impacts, surface preparation and application, viscosity and thixotropy, chemical, bacterial and mechanical resistance, ecology and economy, will have to be taken into account when the protective system is designed.

The only chemical compound which has been developed specially to protect steel sheet piling for a very long term is HUMIDUR®. This has been proven in use on more than 100,000 sq.m. of steel sheet piling over 13 years.

THE HUMIDUR® SYSTEM

The coating is a two-component, caustic and solvent-free epoxy system. This system has been developed to guarantee an unparalleled protection of steel sheet piling against corrosion.

Figure 1
Typical corrosion profile of steel sheet piling

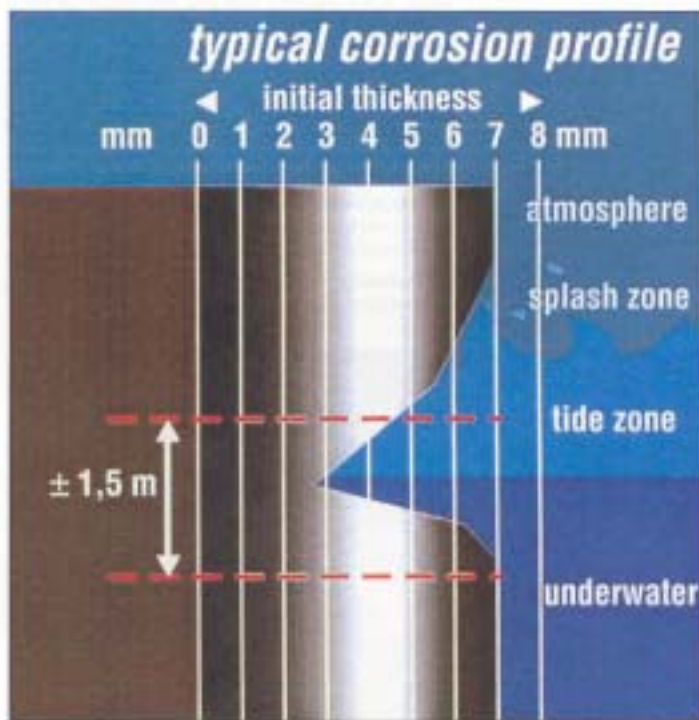


Figure 2
Underwater corrosion is covered
by a multitude of mutually
inertive processes



HUMIDUR®'s features include: extremely high adhesion, porefree, the ability to combine with a cathodic protection system and its impermeability to water, water vapour, chlorides and other ions. A one-layer application, of 400 microns is sufficient, with application being possible under conditions of high relative humidity and low temperature and does not add weight nor volume to the structure. The coating can be exposed to water immediately. The thixotropy has been designed so that on a vertical surface one layer of 400 to 600 microns thickness may be airless sprayed without problem.

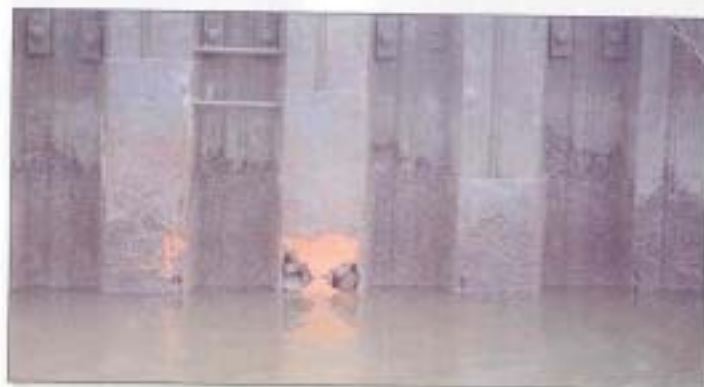
The corrosion protection is mainly achieved by its barrier resistance. Properties which influence this resistance include a high degree of cross-linking, impermeability against water vapour ions and the degree of adhesion as well as the film thickness:

- Adhesion above and below the water is excellent, even after 15 years of exposure on steel sheet piling.

- Impermeability is measured by the water vapour permeability test, chloride ion resistance, the salt spray test and the high dielectrical resistance.
- Because the HUMIDUR® composition has been formulated, and is applied, solventfree, one application on a reasonably good prepared surface will achieve the 400 microns thick film in one single layer. The application, without any solvent evaporation, favours the film continuity as well as the impermeability.

The excess of binders resulting in a low pigment-volume concentration, the selection of pigments and extenders each with their specific oil absorption and particle-size, the relative proportion of lamellar pigments known for their corrosion protecting properties as well as the water-impermeability of the different components, each contribute to the effectiveness of the barrier. In case of mechanical damage to a coating, the protective barrier activity of a system would normally collapse. With the HUMIDUR® coating, the incorporation of a corrosion-inhibitor against creeping rust in the formulation continues to protect steel surfaces.

Figure 3
Corrosion of steel piling, showing
that an attempt to prevent steel
pile corrosion with additional
steel is not a solution



APPLICATION OF THE HUMIDUR® SYSTEM

Using a mobile cofferdam (DZI) installation, water is drained from the affected area below the waterline. This allows easy, thorough and quick inspection of the sheet piling. All marine growth and rust deposits are removed from the surface (Figure 4). After the abrasive cleaning is finished, the structural stability is restored where necessary and perforations are filled. The DZI allows every operation, such as welding reinforcements, to be performed in dry conditions with little or no disruption to shipping. The DZI is normally put to work from a pontoon, although the DZI can also be used from the landside.

Conditions below the water line, in the splash zone and in the atmospheric zone are so extreme and liable to ocean impacts, that the long-term protection of the pile requires particular conditions for its application. The technique used by ACOTEC n.v. ensures that all factors are under control.

The ideal situation is to work in dry conditions using the DZI system. However, the simple application of the HUMIDUR® coating system does not guarantee effective result. Many tests need to be conducted and actions taken to ensure effectiveness, e.g. checking types of the grit, the presence of often invisible traces of sulphate, determining the degree of grit blasting, using as a chemical investigation to detect soluble iron in solution, and measuring surface dust and roughness.

Neglecting or misjudging one single parameter can diminish quality or may mean that the set quality cannot be met. Some of the above-mentioned processes weaken the initial adhesion, whilst others, such as chloride ions, cause the adhesion to wane rapidly (though very high initially). Cathodic disbonding due to overprotection or stray currents is a destructive phenomenon to which many coatings are unable to resist and increases the creation of osmotic blisters and the retraction of the protective coating.

RESULTS

Descriptive features of the HUMIDUR® system prolong the effective lifetime of maritime installations significantly. Regular investigations of treated sheet piles up to 15 years old have shown that the behaviour of the HUMIDUR® coating was still as effective as when it was first applied. The steel pile did not show any traces of further corrosion and film thickness, adhesion and film cohesion strength have maintained their initial level. The total lifetime of a treatment according to the above procedure is still unknown, but is estimated to be 20 years or longer.

THE CONSIDERED SOLUTION

Success of this treatment method is the result of an integrated approach including the proprietary construction of patented DZI installations, the high quality of the proprietary HUMIDUR® system and the employment of our own staff for on-site work.

Deposition of the anti-corrosion coating and the erection of the works ensures Acotec n.v. will assume full responsibility for the supplied quality. The work is carried out with no or little disruption to shipping, using an economical alternative to new investment or reconstruction.

Moreover, environmental requirements are met. The DZI is the ideal process to collect corrosive agents, dust and particles of grit, rust and paint and contribute to environmental conservation.



Figure 4
Removal of marine growth and rust deposits, along with thorough abrasive cleaning, is necessary to avoid the damage done by underwater corrosion. The steel piling has then to be restored and perforations filled and welded prior to applying the HUMIDUR® system.

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