Galvanized Steel in Water and Wastewater Infrastructure

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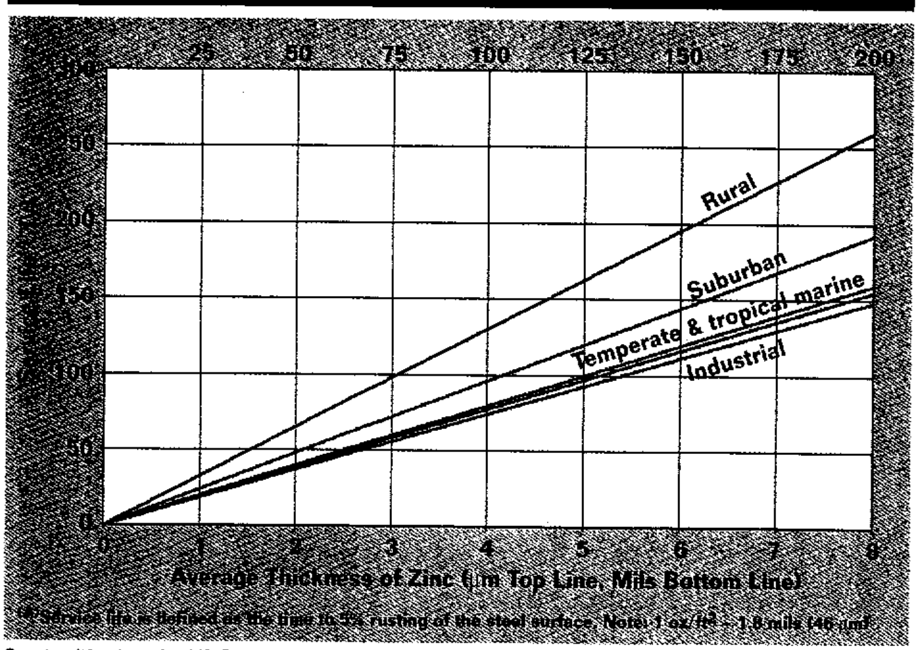
Hot-dip galvanizing is an economical way to protect steel in atmospheric and submerged exposures. This article outlines the strengths and limitations of hot-dip galvanized (HDG) steel in water and wastewater service. It also describes the use of HDG steel in a wastewater plant.

FIGURE 1



Service life chart for HDG coatings in various environments.

Whether directly above water, submerged in water, or exposed to moisture-laden air, steel is acutely susceptible to corrosion. This article discusses the performance of steel protected by hot-dip galvanizing in submerged and above-water applications in water and wastewater facilities.

Performance in Atmospheric Conditions

Galvanized steel performs best when the zinc coating is permitted to react naturally with oxygen, hydrogen, and carbon dioxide (CO_2) in the air to form a stable zinc carbonate ($ZnCO_3$) patina film. In atmospheric exposure, this film is inert—not water-soluble—and generally is slowly removed over long periods of time only by the physical forces of abrasion and erosion (wind, water) or chemical reactions. In the case of atmospheric corrosion, thousands of galvanized structures have been tested over many decades. The life expectancy of hot-dip galvanized (HDG) steel can be accurately predicted in various atmospheric exposures (Figure 1). Factors affecting performance include sulfides and chlorides in the air. Figure 1 indicates that galvanizing can easily provide nearly maintenance-free corrosion prevention for 35 to 40 years in moist atmospheres.

VARIABLES AFFECTING THE CORROSION RATE OF ZINC IN WATER

Predicting the length of corrosion prevention of galvanized steel in water is much more difficult than in the atmosphere because of the many variables associated with aquatic exposure, including pH level, oxygen content, water temperature, water condition (hard or soft), water type (deionized, fresh, salt), and agitation.

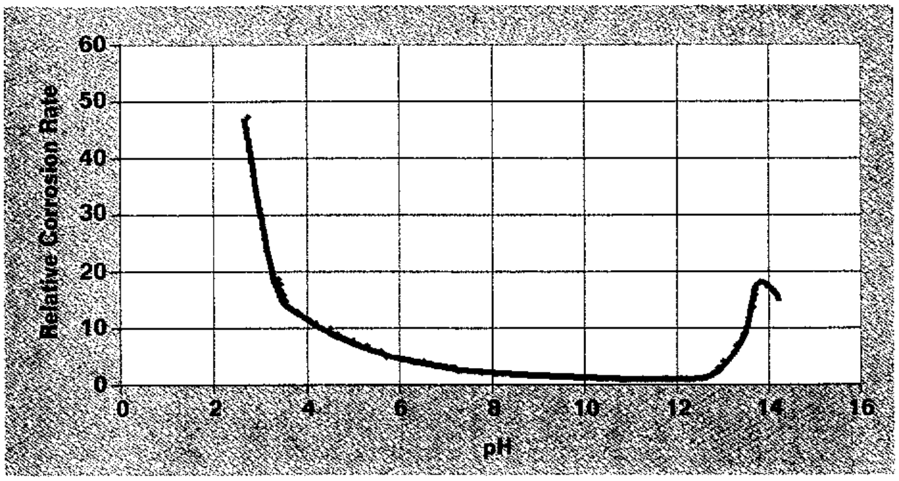
Deionized (pure) water has a corrosive effect on HDG steel—and even more so when the water is aerated. As oxygen content increases, the corrosion rate of zinc increases as well. In fact, oxygen is five to 10 times more corrosive to zinc than carbonic acid (H_2CO_3).

Freshwater environments have two major constituents for categorizing zinc corrosion potential: hard and soft water. Carbonates and bicarbonates, present in some concentration in fresh water, tend to deposit protective films on the zinc surface, stifling corrosion. Carbonates subdue the corrosion effects of anions, the most corrosive to zinc being chloride in concentrations of 50 mg/L or more. The softer the water, the lower it is in carbonate and thus has a more pronounced chloride content and higher corrosion rate. Conversely, the harder the water, the greater the carbonate level (the corrosiveness of chlorides is minimized). Therefore, the general rule is that soft water is more aggressive to HDG steel and hard water is passive.

The pH of the water is important too. Because zinc is amphoteric, it is soluble in both basic and acidic solutions. In the broad range of pH from 5 to 13, however, zinc is most stable and has a very low corrosion rate (Figure 2).

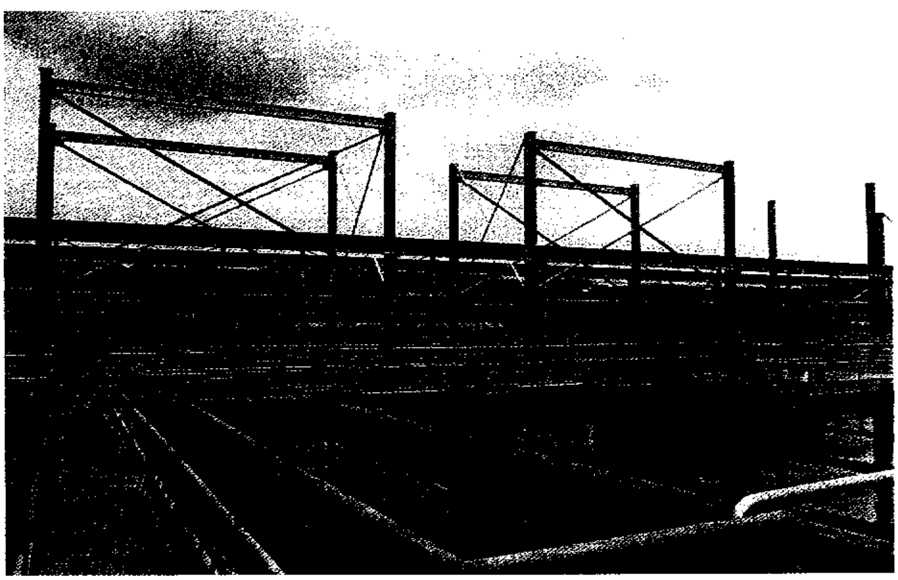
Temperature also affects the corrosion rate of zinc. The higher the temperature, the greater the dissolution of zinc in water. Fluid agitation also is important in determining the corrosion protection delivered by HDG steel. Often, this motion of "washing" the carbonates off the zinc surface and not allowing them to form a protective film, along with zinc erosion, is the cause for base steel corrosion.

FIGURE 2



Corrosion rate of zinc vs pH.

FIGURE 3



Aspinwall Water Treatment Plant under construction in 1989. HDG steel columns support the steel roof truss in the clarifier building.

Case Histories

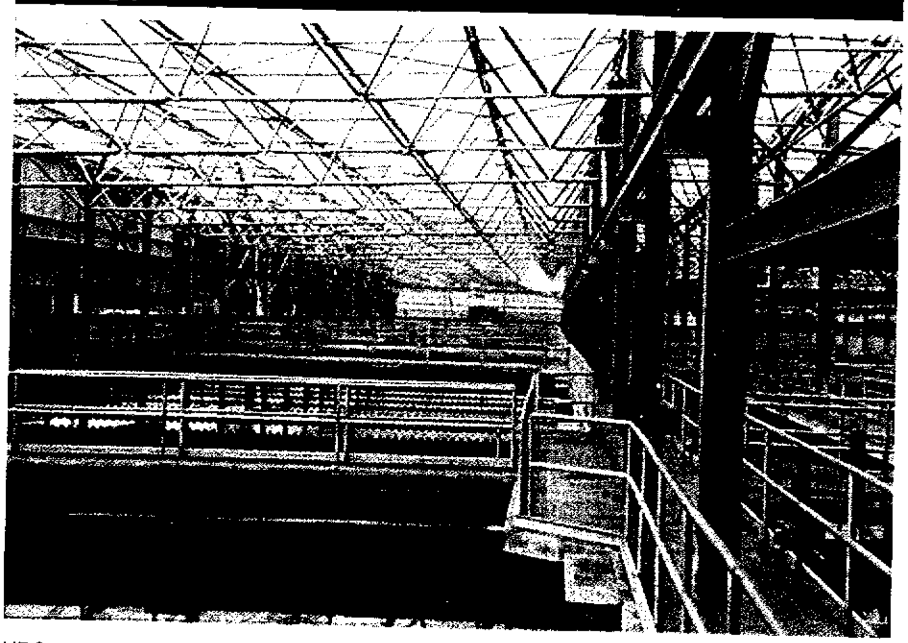
WATER TREATMENT PLANT

In 1989, more than 250 tons (226,800 kg) of HDG steel were used in the columns and truss network covering the four-basin clarifier at the Aspinwall Water Treatment Plant (Pittsburgh, Pennsylvania) (Figure 3). Harsh chemicals added to the clarifier (chlorine, alum, lime, and permanganate) accelerate corrosion of unprotected steel. A 1997 inspection of the galvanized steel measured 5 mils (127 μm) of zinc—enough to last at least 50 more years (Figure 4).

WASTEWATER TREATMENT PLANT

The Back River Wastewater Treatment Plant (Baltimore, Maryland) (Figure 5), built in 1938 and designed to treat corrosive sludge and industrial wastes, has experienced more than 40 years of virtually maintenance-free service from HDG steel. Galvanized weirs in the settling tanks have seen continuous service since the day the plant opened. In the final settling tanks, weirs, brackets, and guide rails have remained in excellent condition for 30 years. In the trickling filter system, galvanized steel rotary distributors have been maintenance-free for more than

FIGURE 4



HDG steel roof trusses in the Aspinwall Water Treatment Plant were built to withstand the harsh flocculation environment of the clarifier building. Inspection after 8 years of service revealed 5 mils of zinc remaining on the steel—sufficient for 50 additional years.

FIGURE 5

Backwater Wastewater Treatment Plant. HDG wiers in the settling tanks have been in constant service for 30 years.

30 years as well. Moreover, the galvanized grit-removal gratings served 40 years before they required removal, regalvanizing, and reinstallation.

Summary

The performance of HDG steel in abovewater and close-proximity conditions is well-documented and predictable. A nearly maintenance-free service life of 50 years or more is common. The life expectancy of HDG steel in water, however, is not as easily determined or predictable. Soft water is a harsher environment to zinc than is hard water. High oxygen content and warm waters also accelerate the corrosion rate of zinc as well. Corrosion of zinc is lowest in the pH range from 5 to 12. Most natural potable waters have a pH range from 5 to 8.5. The corrosion of zinc in such waters is accelerated largely by the impurities present in the water, and rarely is natural water pure.

Anything that disturbs the formation of a protective film ($ZnCO_3$) on the zinc surface will inhibit the HDG coating from delivering superior corrosion protection. In addition, other factors—including pH, time of exposure, temperature, and fluid agitation—influence the corrosion of zinc in water. Having identified the variables that adversely affect the galvanized coating, it is important to note that applying galvanized coatings to steel that will be submerged is a reliable method of corrosion prevention. It is not uncommon for HDG steel to perform flawlessly in water for 10 years or more.

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