Increase Steel Service Life Using Hot-Dip Galvanizing

By Laura Hanson

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A 120-year service life is achievable in buried galvanized structures. Hot-dip galvanizing (HDG) is the process of immersing fabricated steel or iron into a kettle (bath) of molten zinc. While in the kettle, iron in the steel metallurgically reacts with the zinc to form a tightly-bonded alloy coating. Hot-dip galvanizing resists corrosion by providing barrier and cathodic protection, as well as through the development of the zinc patina. These three levels of corrosion protection provide galvanized steel with maintenance-free longevity for decades.

One common exposure for HDG steel is partially or fully buried in soil. Structural integrity of these items below grade is very important, but it is difficult, if not impossible, to inspect buried structures for corrosion. Furthermore, the corrosive forces experienced underground are quite unlike atmospheric conditions, and the performance of steel in these conditions is not as well understood as in above-ground applications.

Many factors affect the corrosion rate of galvanized steel in soil, and understanding them takes some measure of effort. Chloride content, pH, and moisture content of the soil all affect the performance of galvanized steel. Having an understanding of and value for these characteristics provides the input necessary to estimate the service life of the galvanized steel based on the type of soil it is buried in

Corrosion Rate in Soil

There are countless soil types in North America, which makes predicting the performance of galvanized steel in soil difficult. A number of soil characteristics affect the corrosion rate of galvanized steel, and soil content conditions can vary significantly. These variances can lead to vastly different corrosion rates for zinc, ranging from 0.2 microns per year in very favorable conditions to 20 microns annually in very aggressive soils.

Magnum Piering, Inc.'s helical pilings in Westchester, Ohio rely on hot-dip galvanizing for corrosion protection.

Hot-dip galvanizing protects the buried steel supports of the Discovery Light Solar Project in Beaverton, Ontario, Canada.

Therefore, the key to understanding how long galvanized steel will last in buried applications is through classification of the soil.

As a general rule of thumb, galvanizing tends to perform well in brown, sandy soils, and not very well in gray, clay-like soils. The reason for this difference is sandy soils with larger particles wick moisture more rapidly, limiting the galvanized piece's exposure to wet conditions, while clay-like soils hold moisture for longer periods. Similar to atmospheric exposure, galvanized steel performs best when it is exposed to both wet and dry cycles. However, there is more to the corrosion story when it comes to buried galvanized structures.

The four variables with the most profound impact on the corrosion rate of hot-dip galvanized steel in soil include chloride concentration, moisture content, pH, and resistivity. The presence of chloride ions causes resistivity to be lower, making the zinc coating more susceptible to corrosion. Along with high moisture levels in the soil, high chlorides will increase the rate of the corrosion of the zinc coating. For hot-dip galvanized steel, the soil moisture content primarily affects the activity of the chloride ions. If the moisture content of the soil is below 17.5%, the chloride ion concentration does not significantly affect the corrosion rate of the zinc. For soils with moisture content above 17.5%, the chloride ion concentration has a significant effect on the corrosion rate of zinc. Soils with pH values less than 7.0 have a higher corrosion rate on zinc coatings. If the pH of the soil is above 7.0, then the corrosion rate of the soil yields a longer service life of the zinc coating. The resistivity parameter follows the chloride ion concentration in that higher resistivity means lower chloride ion content and a lower corrosion rate of the zinc coating.

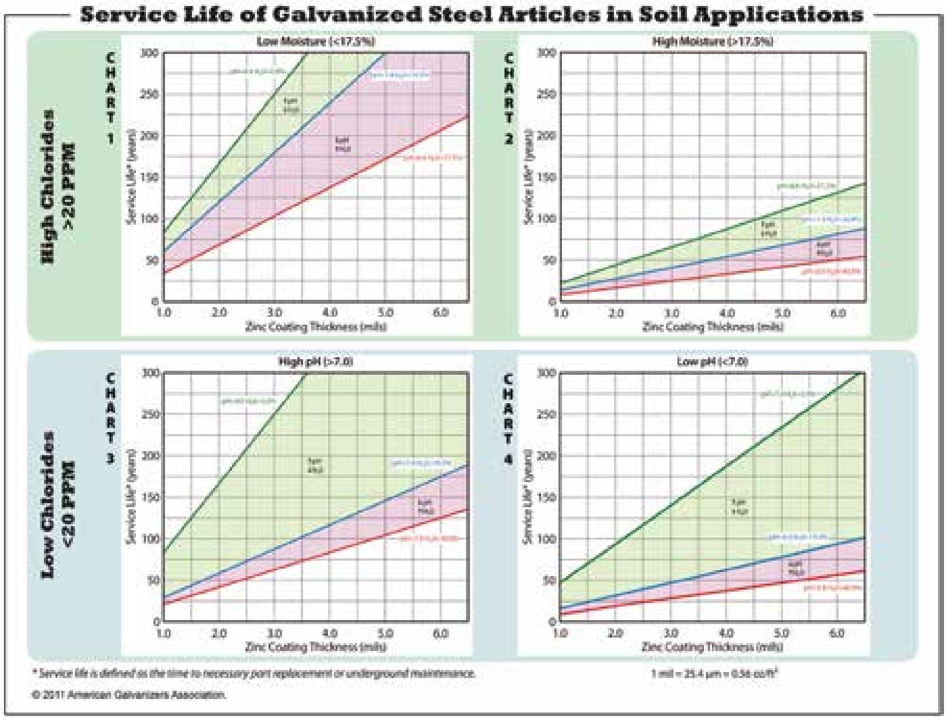
Because predicting the service life of HDG steel in soil applications is dependent on the type of soil it is buried in, the American Galvanizers Association (AGA) has developed the *Service Life of Galvanized Steel Articles in Soil Applications* chart for estimating HDG steel's performance The chart uses a combination of the three most critical environmental parameters to estimate the service life of HDG steel buried in soil. In this instance, the service life is defined as time to complete consumption of the zinc coating plus 25% loss of steel thickness. At this point, the buried structure has reached full service life and it would be time to replace it.

This chart is based on real world corrosion data from two major studies. First, the Corrpro Companies study for the National Corrugated Steel Pipe Association (NCSPA) in conjunction with the American Iron and Steel Institute (AISI), which examined soils from 122 US sites with varying pH conditions. The second study was conducted in the 1970s by Dr. Warren Rogers. With this study, Dr. Rogers developed a model to predict Mean Time to Corrosion Failure from a number of factors that were measured at Underground Storage Tank sites. Ultimately, this study helped to determine the four variables mentioned previously (chlorides, moisture content, pH, and resistivity) that have the most profound effect on the corrosion rates in soils.

Corrosion Rate Variables	
Chlorides	The presence of chloride ions causes the resistivity to be lower and makes the zinc coating more susceptible to corrosion. Along with high moisture levels in the soil, high chlorides will increase the rate of the corrosion of the zinc coating.
Moisture Content	For hot-dip galvanized steel, the soil moisture content primarily affects the activity of the chloride ions. If the moisture content is below 17.5%, the chloride ion concentration does not significantly affect the corrosion rate of the zinc. If the moisture content is above 17.5%, the chloride ion concentration has a significant effect on the corrosion rate of zinc.
pH	The lower pH (< 7.0) values of soil have a higher corrosion rate on zinc coatings. If the pH is above 7.0, then the corrosion rate of the soil yields a longer service life of the zinc coating.
Resistivity	This parameter follows the chloride ion concentration in that higher resistivity means lower chloride ion content and a lower corrosion rate of the zinc coating.

The *Service Life of Galvanized Steel Articles in Soil Applications* table has four different graphs based on the classification of the soil, including chloride content, moisture, and pH. Using the chart, the first classification is by chloride content – Charts 1 and 2 (top row) are used for soils with high chlorides (>20 PPM) and Charts 3 and 4 (bottom row) are used for soils with low chlorides (<20 PPM). Soils with high chlorides are then classified based on their moisture content. Soils with low moisture levels of less than 17.5% are shown on Chart 1, while soils with high moisture, i.e. greater than 17.5% are shown on Chart 2. Soils with low chlorides are classified by their pH levels. Soils with pH levels greater than 7.0 are shown on Chart 3, while soils with pH levels less than 7.0 are shown on Chart 4.

The blue line on all four charts represents the average for soils surveyed in that characteristic group. The green line then represents the best soil in the category sampled, while the red line represents the worst soil sampled. The shaded areas show how the changes in pH and moisture content affect the estimated service life. Assuming 3.5 mils as a minimum thickness for HDG steel buried in soil, the chart shows the average life in the harshest soils (uncommon) would be approximately thirty years and in the best soils would exceed 120 years.



Summary

By utilizing the *Service Life of Galvanized Steel Articles in Soil Applications* chart and having an understanding of the factors affecting the performance of galvanized steel in soil, predicting the service life becomes slightly easier. Although soil types vary based on location and the factors mentioned above, hot-dip galvanizing's superior corrosion protection will help lengthen the life of the buried steel by decades. The durability and relatively maintenance-free performance of hot-dip galvanized steel make it a high quality corrosion protection system for steel applications in soil.▪