

Soil-Side Service Life

Protective Coatings

93% Total Recycled Content (EAF)

$5.0 < \text{pH} < 9.0$
 $r > 1500 \text{ ohm-cm}$

FHWA Abrasion Level

pipe selection guide

INTRODUCTION

Corrugated steel pipe (CSP) has been used successfully for more than 100 years in storm sewer and culvert applications throughout North America and around the world. Over the past 50 years, CSP has gone through an evolutionary process resulting in better materials, with a longer service life in challenging environments.

This Pipe Selection and Service Life Guide provides information and methods for the selection of the appropriate corrugated steel pipe product using estimated material service life for given environmental ranges. When estimating the average invert service life, engineers and designers can refer to either the service life prediction section of this Guide, the Durability chapter of the Corrugated Steel Pipe Design Manual, or the Corrugated Steel Pipe Institute's (CSPI) Canadian Durability Guideline.

ENVIRONMENTAL CONSIDERATIONS

Water-Side Durability

When determining which CSP product is best suited for an installation, one must first determine the site's water-side environmental conditions for pH and resistivity. Normal environmental conditions have a pH range of 5.8 to 8.0 with a resistivity, $R > 2000$ ohm-cm. Mildly corrosive conditions have a pH range of 5.0 to 5.8 with a resistivity, $1500 \leq R \leq 2000$ ohm-cm. Corrosive conditions have a $pH < 5.0$ and a resistivity of $R < 1500$ ohm-cm.

An additional condition which must be taken into account is presence of soluble salts. Soft water has a significant effect on galvanized coatings but does not impact the longevity of aluminized or polymer coated CSP. Natural water contains calcium carbonate ($CaCO_3$) in varying concentrations. Hard water has an excess of this dissolved salt which is deposited on the pipe wall in the form of scale. This scale protects the underlying coating and extends the pipe's service life. In situations where the calcium carbonate concentration in the effluent drops below 50 parts per million (ppm), the water is considered soft. At this concentration level there is no excess $CaCO_3$ to deposit on the galvanized pipe, which prevents buildup of the protective scale layer.

There is a correlation between water softness and resistivity. A high resistivity level will be an indicator of a lower calcium carbonate concentration. Therefore, if a site has a resistivity $\geq 10,000$ ohm-cm, this could be an indicator that soft water is present. The designer should then consider using aluminum coated type 2 or polymer coated corrugated steel pipe.

Abrasion velocities should also be evaluated on the basis of frequency and duration. The Federal Highway Administration (FHWA) established a classification system of abrasion levels based on flow velocity and bed load that can be seen in figure 1.

FHWA Abrasion Levels		
Level 1	Non-Abrasion	No bed load regardless of velocity; or storm sewer applications.
Level 2	Low Abrasion	Minor bed loads of sand and gravel and velocities of 5ft./sec or less.
Level 3	Moderate Abrasion	Bed loads of sand and small stone or gravel with velocities between 5 and 15ft./sec.
Level 4	Severe Abrasion	Heavy bed loads of gravel and rock with velocities exceeding 15ft./sec.

Note:
Consideration of velocities should be based on a frequent storm event, such as a 2-year storm.

FIGURE 1

ENVIRONMENTAL CONSIDERATIONS

Soil-Side Durability

A study performed by Corpro Companies in 2002 found that soil-side durability is generally not the limiting factor in designing CSP systems. Survey results indicate that 93.2 percent of the plain galvanized installations have a soil-side service life in excess of 75 years, while 81.5 percent have a soil-side service life in excess of 100 years.

The study also found that soil moisture contents below 17.5 percent did not exhibit any accelerated corrosion. Under most circumstances, corrosion rates are directly related to soil moisture content. However, for galvanized steel storm sewer and culvert pipe, the soil moisture content primarily affects the activity of any chloride ions present and the chloride's acceleration of the corrosion. Where the soil moisture content was below 17.5 percent, the chloride ion concentration did not have a significant effect on the corrosion rate of the zinc coating.

All corrugated steel pipes have a metallic coating for corrosion protection. When the coating selected does not provide the required service life or is outside the appropriate environmental conditions, an alternate coatings system can be selected. Often the required service life can also be achieved by increasing the sheet thickness; this alternative should be weighed against the cost of supplemental coatings.

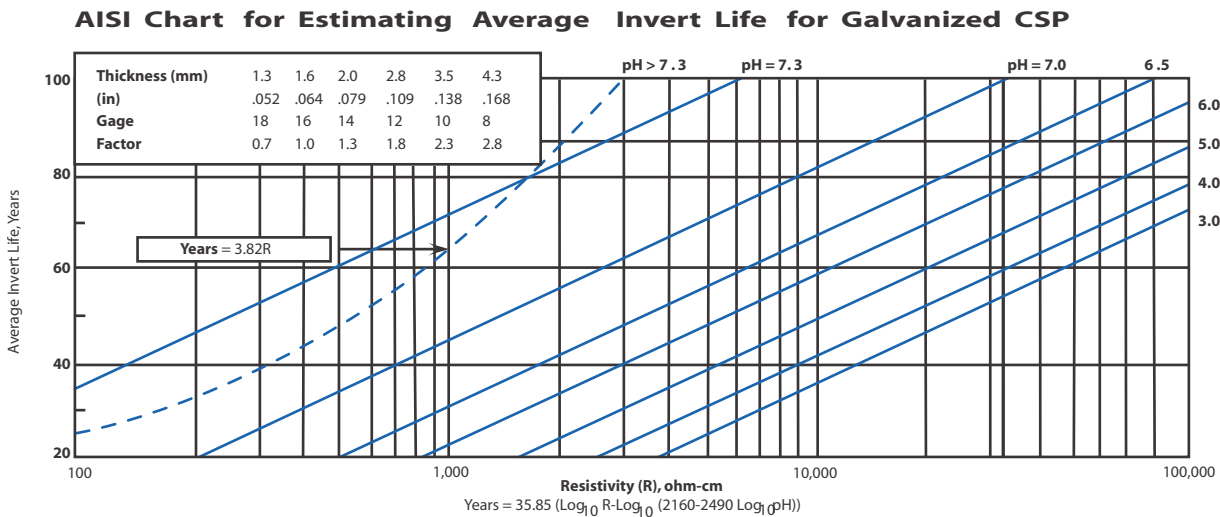


FIGURE 2

Steps in Using the AISI Chart

The durability design chart can be used to predict the service life of galvanized CSP and to select the minimum thickness for any desired service life. Add-on service life values are provided in figure 4 for additional coatings.

- 1) Locate on the horizontal axis the soil resistivity(R) representative of the site.
- 2) Move vertically to the intersection of the sloping line for the soil pH. If pH exceeds 7.3, use the dashed line instead.
- 3) Move horizontally to the vertical axis and read the service life years for a pipe with 1.6 mm (0.064 in.) wall thickness.
- 4) Repeat the procedure using the resistivity and pH of the water; then use whichever service life is lower.
- 5) To determine the service life for a greater wall thickness, multiply the service life by the factor given in the inset on the chart.

SERVICE LIFE FOR CORRUGATED STEEL PIPE

Zinc-Coated (Galvanized)

Zinc-coated (Galvanized) Steel (AASHTO M36, ASTM A929) is produced with a coating weight of 610 g/m² (2 oz/ft²) of surface (total both sides) to provide zinc coating thickness of 43 μm (0.0017in.) on each surface.

The zinc's excellent resistance to corrosion is due to the galvanizing, which provides a barrier coating, and through its cathodic protection or the formation of protective films on zinc during exposure. High corrosion rates in strongly acidic and strongly alkaline solutions can be attributed to the absence of film on the metal surface (stable films are present on the surface when the corrosion rates are low).

The service life of zinc-coated galvanized is determined using the American Iron and Steel Institute (AISI) Chart for Estimating Average Invert Life for Galvanized CSP, in figure 2. This chart predicts a variable service life based on pH and resistivity of water and soil and has been an industry standard for many years. The service life of CSP can be reasonably predicted based on the environmental conditions discussed above. This chart is based on 16 gage galvanized CSP with a 610 g/m²(2 oz/ft²) coating and can be applied to other thicknesses with the appropriate factor. See discussion below for estimating the service life of aluminum coated type 2, polymer coated and other coating materials.

How AISI Determines Service Life

The AISI chart, which gives service life in terms of resistivity and pH, was developed from a chart originally prepared by the California Department of Transportation (Caltrans). The Caltrans study of durability was based on life to first perforation in culverts that had not received any special maintenance treatment. The results included the combined effects of soil-side and interior corrosion, as well as the average effects of abrasion. For pipes where the pH was greater than 7.3, soil-side corrosion controlled and life could be predicted by resistivity. For pipes where the pH was less than 7.3, the interior invert corrosion generally controlled and both resistivity and pH were important. A majority of the pipes were expected to last longer than the chart prediction.

The consequences of small perforations are minimal in a gravity flow pipe, such as most storm sewers and culverts, and do not accurately reflect the actual service life. Because of this fact, the original curves were converted to average service life curves using data on weight loss and pitting in bare steel developed by the National Institute of Standards and Technology. Since storm sewers and culverts are usually designed with a structural safety factor of at least 2.0, a significant safety factor of 1.5 remains at the end of the service life predicted by the chart. Thus, use of the chart is considered reasonably conservative. Where service life is controlled by invert performance, rehabilitation of the invert at the end of the predicted life can extend service life significantly.

SERVICE LIFE FOR CORRUGATED STEEL PIPE

Polymer Coated CSP

Polymer coated (AASHTO M245, ASTM A742) is a laminate film that is applied over protective metallic coatings, typically galvanized. The 10/10 grade (10 mils thickness, each side) is the primary product used. Polymer coating provides excellent adhesion to the base steel and extended corrosion and abrasion resistance. The service life recommendations are based on extensive lab and field tests. While polymer coated CSP has not been in use quite as long as the galvanized or aluminized coatings, polymer CSP installations still go back to nearly 40 years ago.

The performance of polymer CSP has been monitored by Corrpro and found to have essentially no deterioration despite installation in some extreme environments. NCSA and The Dow Chemical Company, the manufacturer of TRENCHCOAT™ Protective Film, have conducted laboratory tests to provide additional data related to the service life of polymer coated CSP. Sites contained environmental conditions with resistivity as low as 100 ohm-cm and pH as low as 2.1.

Recent testing indicates polymer coated CSP can withstand abrasion level three conditions. Since polymer is a barrier coating, it exhibits uniformly predictable durability performance within defined environmental ranges. These criteria and the defined ranges for polymer coated pipe are shown in figure 3. Polymer coated pipe operating within these ranges can achieve a 100-year service life based on the current evaluations of installations in the recommended ranges of adverse conditions for nearly 40 years.

Note: Corrosion conditions at the extreme limits of the environmental ranges may require adjusting service life values.

ESTIMATED MATERIAL SERVICE LIFE FOR CSP			
ESTIMATED SERVICE LIFE	SITE ENVIRONMENTAL CONDITIONS	MAXIMUM FHWA ABRASION LEVEL	MATERIAL
Minimum 100 Years	5.0 < pH < 9.0 r > 1500 ohm-cm	Level 3	Polymer Coated
		Level 2	Aluminized Type 2*
Minimum 75 Years	4.0 < pH < 9.0 r > 750 ohm-cm	Level 3	Polymer Coated
	5.0 < pH < 9.0 r > 1500 ohm-cm	Level 2	Aluminized Type 2
Minimum 50 Years	3.0 < pH < 12.0 r > 250 ohm-cm	Level 3	Polymer Coated
Average 50 Years	6.0 < pH < 10.0 2000 < r < 10,000 ohm-cm > 50 ppm CaCO ₃	Level 2	Galvanized

FIGURE 3

* 14 gauge minimum.

SERVICE LIFE FOR CORRUGATED STEEL PIPE

Aluminum Coated Type 2

Aluminum Coated Type 2 (AASHTO M274, ASTM A929) is a pure aluminum coating (no more than 0.35 percent silicon). It is produced with a coating weight of 305 g/m² (1 oz/ft²) of surface (total both sides) to provide a coating thickness of 48 µm (0.0019 in.) on each surface. The aluminum coated type 2 (ALT2) is the most widely used supplemental coating for CSP. “Aluminum is a reactive metal, but it develops a passive aluminum oxide coating or film that protects it from corrosion in many environments.” This film is quite stable in neutral and many acid solutions but is attacked by alkalis greater than a pH of 9. From a corrosion standpoint, aluminum has an advantage over galvanized in lower pH and in soft water conditions due to the formation of the oxide film. The coatings are essentially equal under abrasion and in waters where the zinc oxide film forms rapidly.

Aluminum coated type 2 CSP has been installed at thousands of sites over the past 50 years and many of these sites have been and are still being monitored for performance. Recent AK Steel research has indicated that 14 gage ALT2 CSP can achieve a 100-year service life when the environmental conditions have a pH of 5 to 9 and a resistivity greater than 1500 ohm-cm.

Additional Coatings

Additional service life can be provided by increasing the thickness of the base steel in accordance with the factors shown in the Chart for Estimating Average Invert Service Life or with the use of additional coating systems. Add-on service life values are provided in figure 4, titled Service Life Add-ons for Supplemental Pavings and Coatings. These coatings offer advantages over metallic coatings in the form of increased abrasion resistance, wider environmental ranges and longer service life. Inherent in these coatings is less variability in performance which is why specific add-on service life values are recommended under various abrasion levels.

SERVICE LIFE ADD-ONS FOR SUPPLEMENTAL PAVINGS AND COATINGS				
COATING MATERIAL	FHWA ABRASION LEVEL			
	1	2	3	4
	Add-on Service Life (Years)			
Asphalt Coated	10	10	N/R	N/R
Asphalt Lined and Paved	30	30	30	30
Polymerized Asphalt Invert Coated	45	45	35	N/R
Polymer Coated and Paved	80+	80+	80+	30
Polymer Coated with Polymerized Asphalt Invert Coated	80+	80+	80+	30
High Strength Concrete Lined	75	75	50	N/R
Concrete Paved	80+	80+	80+	50
Concrete Paved	80+	80+	80+	50

FIGURE 4

N/R - Not Recommended

SERVICE LIFE FOR CORRUGATED STEEL PIPE

Asphalt Coated (AASHTO M190, ASTM A849)

An asphalt coating is applied to the interior and exterior surface of the pipe with a minimum thickness of 1.3 mm (0.05 in.) in both fully coated and half coated. Asphalt coatings are generally used for soil-side protection but also provide additional waterside protection. Numerous studies have concluded that asphalt coating typically provides 10 years additional service life to the inside of the pipe. Asphalt coatings provide much higher service life on the soil-side and inherently extend the environmental ranges for soil conditions. According to Corpro, “study results indicate that the addition of an asphalt coating may have provided a soil side service life in excess of 100 years.”

Fully Lined with Asphalt Material (ASTM A849)

An asphalt material is used to fill the corrugations and provide a minimum thickness of 3.2 mm (1/8 in.) above the crest of the corrugations, providing a smooth surface over the entire pipe interior. Asphalt linings are typically used for improved hydraulic performance but also provide additional abrasion protection and extended service life. The use of asphalt material and metallic-coated steel provide higher service life values.

Invert Paved with Asphalt Material (AASHTO M190, ASTM A849)

An asphalt material is used to fill the corrugations and provide a minimum thickness of 3.2 mm (1/8 in.) above the crest of the corrugations for at least 25 percent of the circumference of round pipe and 40 percent of the circumference for pipe arch. Asphalt paved CSP provides both additional service life and added abrasion protection on the water side of the pipe. Based on several studies, coated and paved is considered to provide an additional 30 years service life under most abrasion levels. This is considered a very conservative estimate for non abrasive and low abrasion (levels 1 and 2).

Invert Coated with Polymerized Asphalt Material (ASTM A849)

A polymer modified asphalt material is used to fill the corrugations and provide a minimum thickness of 1.3 mm (0.05 in.) above the crest of the corrugations for at least 25 percent of the circumference of round pipe and 40 percent of the circumference for pipe arch. Generally used for invert treatments only, polymerized asphalt provides improved adhesion and abrasion resistance over standard asphalt products. Full scale abrasion tests conducted by Ocean City Research indicate no deterioration of the coating under moderate abrasion (level 3). Based on independent test lab results using test method ASTM A926, results indicate that the commercially available polymerized asphalt coating lasts at least 10 times longer than standard asphalt coating and at least three times longer than standard culvert coated and paved.

SERVICE LIFE FOR CORRUGATED STEEL PIPE

Polymer Coated and Asphalt Paved

Polymer coated and asphalt paved benefits from the excellent adhesion of the polymer coated to the base steel and the subsequent adhesion of the paving to the precoat. According to laboratory and field tests the combination of the three coatings results in a pipe which is highly resistant to acidic effluent. The bituminous material has much better adhesion to the polymeric coating than it does to the galvanized coating.

Polymer Coated with Polymerized Asphalt Invert Coated

Full scale abrasion tests conducted by OCR show equal performance of the polymerized asphalt over polymer coated when compared to standard asphalt paved. This system has the same bonding characteristics as the polymer coating and asphalt paving. Field sites also indicate improved adhesion.

Invert Paved with Concrete Material (ASTM A849, ASTM A979)

A 75 mm (3 in.) thick concrete layer is placed in the installed pipe for at least 25 percent of the circumference of round pipe and 40 percent of the circumference for pipe arch. Concrete inverts provide extreme abrasion protection and extended service life. According to Stratfull, "metal pipe with an invert paved with concrete should provide an indefinite service life if it is of sufficient width, thickness and quality. By calculation, a 4-inch thick coating over the invert steel could be expected to postpone its initial time to corrosion by approximately 7.7 times greater than a 3/4 inch coating."

Fully Lined with Concrete Material (ASTM A849, ASTM A979)

A high strength concrete material is used to fill the corrugations and provide a minimum thickness of 3.2 mm (1/8 in.) above the crest of the corrugations providing a smooth surface over the entire pipe interior. Concrete linings are typically used for improved hydraulic performance but also provide additional abrasion protection and extended service life. The use of high strength concrete and metallic coated steel provide high service life values.

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