CHAPTER nine

INTRODUCTION

Corrugated steel pipe (CSP) has been used successfully since the late 1800s for storm sewer and culvert applications throughout North America and around the world. CSP continues to be specified because of the variety of CSP products and their ability to provide long service life in a wide variety of site environmental conditions. Durability describes the ability of a specific material to resist degradation caused by corrosion, abrasion, applied loads, and method of installation. Throughout the long history of CSP, more than 50,000 installations have been the subject of critical evaluation to establish durability guidelines. The behavior of both the soil side and the water side of the pipe has been studied. These studies have shown that CSP can provide outstanding durability and that virtually any required service life can be attained by selecting the appropriate coating and thickness of steel for the pipe wall.

This chapter explains how the methods of evaluating pipe durability have evolved with expanded experience, new materials and knowledge of the impact of site conditions. The results of field studies, along with methods for predicting the durability of CSP in differing conditions, are addressed. Various metallic and nonmetallic coatings, various steel thicknesses, and where necessary invert pavements, can be used to enhance the durability of CSP and provide the necessary service life.

SCOPE

This chapter provides the designer with information and methods needed to evaluate the durability (service life) of corrugated steel pipe products. A vital part of this chapter is a brief review of the significant field surveys, inspections and studies that have provided the historical data needed to improve the tools and methods used to estimate the service life of CSP.

Over the past 50 years, corrugated steel pipe has gone through an evolutionary process with the result being better materials, with longer service life in challenging environments. One of these materials is Aluminized Type 2, which has been in service at thousands of sites since 1948. When installed in the recommended environmental range, Aluminized Steel Type 2 CSP will have a minimum service life of 75 years.

A coating developed in the early 1970's is a 10 mil polymer film that is laminated over galvanized steel. When installed in the recommended environmental ranges, this coating will have a service life of over 100 years. Polymer coated pipe can be installed in conditions more severe than concrete pipe and have a longer service life. Inspections of polymer coated pipe in service for over 35 years, in a range of conditions, show no deterioration.

Table 9.1

Estimated Material Service Life for CSP

CSP Material	Estimated Service Life	Site Environmental Conditions	Maximum FHWA Abrasion Level
GALVANIZED CSP	AVERAGE 50 YEARS	$6.0 \leq$ pH ≤ 10.0 $2000 \leq$ r $\leq 10{,}000$ (ohm-cm) Water Hardness (> 50 ppm $CaCo_3$)	LEVEL #2
ALUMINIZED TYPE 2 CSP	MINIMUM 100 YEARS	$4.5 \leq$ pH ≤ 5 r > 5000 ohm-cm	LEVEL #2
	MINIMUM 75 YEARS	$0.0 \leq$ pH ≤ 9.0 r > 1500 ohm-cm	
POLYMER COATED CSP*	MINIMUM 100 YEARS	$5.0 \leq$ pH ≤ 9.0 r > 1500 ohm-cm	LEVEL #3
	MINIMUM 75 YEARS	$4.0 \leq$ pH ≤ 9.0 r $\geq$ 750 ohm-cm	
	MINIMUM 50 YEARS	$3.0 \leq$ pH ≤ 12.0 r $\geq$ 250 ohm-cm	

NOTE: Refer to Table 9.3 for definition of FHWA abrasion levels.
* Polymer coating is 0.010 in. on each side.

The method for estimating service life is different for galvanized than for Aluminized Type 2 or polymer coated CSP. This chapter first defines and explains the method used to determine service life for galvanized CSP. Evaluating all three coatings will ensure the pipe materials specified for your project will meet service life requirements at the lowest cost.

SERVICE LIFE DEFINITIONS

Design Service Life

Many public agencies establish a design service life (DSL) for construction of infrastructure projects. The DSL for roadway projects is dependent upon the type of roadway, the traffic volumes, and future growth patterns. Depending on the agency involved, the DSL of roadways typically varies from 25 to 100 years.

Estimated Material Service Life

Estimated Material Service Life (EMSL) is defined as the years of reliable service from the time of installation until rehabilitation or replacement is required. The EMSL of a pipe is dependent on the pipe material and environmental conditions. Table 9.1 shows the EMSL of CSP with three different coating systems.

It is not necessary that the EMSL of a pipe match the DSL of the project. For example, pavements, bridge decks and other portions of a highway are typically replaced or rehabilitated several times during the life of that highway. CSP can be rehabilitated by sliplining, paving the invert or other methods. Many agencies now oversize the initial pipe installation to accommodate future rehabilitation. Most agencies routinely inspect all culverts, regardless of the pipe material, to ensure timely identification of problems.

The material selection for a culvert or storm sewer should recognize the life-cycle economics including the costs of the initial installation, routine inspection, maintenance, and possible rehabilitation (see Chapter 11). Numerous evaluations of the durability of storm sewers and culverts show that the EMSL of storm sewers can be expected to be greater than for culverts, due to lower flow velocities, intermittent flow, and reduced bed load size and quantity.

FACTORS AFFECTING THE DURABILITY OF CSP

Durability In Soil

The material in the soil envelope around the pipe or backfill, is generally controlled by the project specifications. The better suited the backfill material is for structural support of the pipe, the less corrosive it is likely to be toward the pipe. Table 9.2 compares the corrosiveness of several soil types. In corrosive soils, an envelope of properly specified backfill material around the pipe can protect the pipe from most of the corrosive elements inherent in the native soil. However, soil-side corrosion is rarely the determining factor in predicting pipe service life.

The durability of steel pipe in soil is a function of several interacting parameters including soil resistivity, acidity (pH), moisture content, soluble salts, and oxygen content (aeration). All underground corrosion processes involve the flow of current (conductivity) through the ground from one location to another (a corrosion cell). Resistance to current flow through a material is measured by the resistivity of that material. The greater the resistivity, the smaller the current flow, which tends to lower the corrosion rate. The resistivity value, expressed as ohm-cm, is inversely proportional to the conductivity value.

The pH value of a substance is a measure of the hydrogen ion concentration in the substance. Most soils fall within a pH range of 6.0 to 8.0, which is considered to be the neutral range and is favorable to the durability of steel pipe. Soils with lower pH values (acidic soils), usually found in areas of high rainfall, tend to be more corrosive and require a more careful selection of the pipe coating(s). The pH values of soil and water at a site are significant factors in selection of the right pipe product.

The moisture content in the soil can also be a significant factor affecting the durability of CSP. Granular soils that allow rapid drainage of the pipe backfill enhance durability. Soils with moisture content less than 20 percent tend to be non-corrosive to CSP on the soil-side. Soils with high clay content tend to hold water longer and therefore are more corrosive than well drained soils.

Table 9.2

Corrosiveness of Soils

Soil Type	Description	Aeration	Drainage	Color	Water Table
I. Non Corrosive	1. Clean Sands 2. Well graded gravel	Excellent	Excellent	Uniform	Very low
II. Lightly Corrosive	1. Sandy loams 2. Light textured silt loams 3. Porous loams or clay loams thoroughly oxidized to great depths.	Good	Good	Uniform color	Very low
III. Moderately Corrosive	1. Sandy loams 2. Silt loams 3. Clay loams	Fair	Fair	Slight mottling	Low
IV. Badly Corrosive	1. Clay loams 2. Clay	Poor	Poor	Heavy texture Moderate mottling	2 to 3 ft below surface
V. Unusually Corrosive	1. Muck 2. Peat 3. Tidal Marsh 4. Clays and organic soils	Very poor	Very poor	Blue, gray, green	At surface; or extreme impermeability

NOTE: Soil types III, IV and V are poor quality and are not recommended for use as backfill.

Durability In Water

The water side of the pipe is typically subjected to additional detrimental actions that are more severe than those acting on the soil side. Field studies have shown that the portion of the pipe most susceptible to corrosion is the invert. This should not be surprising since the invert is exposed to standing or flowing water more than any other part of the pipe interior. Common factors affecting durability are pH, resistivity, soluble salts, water hardness and abrasion.

Most storm or natural waters will have a pH in the range of 6.0 to 8.0. The chemistry of the water is controlled by rainfall which leaches salts from the soil on its way to the culvert or storm sewer. These chemicals are in the form of soluble and partially soluble salts. Groundwater may also contain various dissolved salts removed from the soil itself. These dissolved salts can contribute to corrosion by increasing the conductivity of the ground water and thus lowering the soil's resistivity. Conversely, many salts in the soil form layers of carbonates or hydroxides on the coating surface. These layers of chemical compounds have the effect of reducing corrosion. However, high levels of other salts, principally chlorides and sulfates will make a soil more aggressive.

In the presence of hard waters ($CaCO_3$ > 50 ppm), a process called scaling results in the deposition of a protective barrier on the pipe surface and reduces corrosion. While increasing amounts of $CaCO_3$ protect the pipe, increasing levels of dissolved oxygen and CO_2 can accelerate corrosion. The most important effect of increased levels of CO_2 in water relates to its interference with the formation of the protective $CaCO_3$ scale that develops on galvanized pipe surfaces. High resistivity levels in water (R > 10,000 ohm-cm) may indicate soft water ($CaCO_3$ < 50ppm). Soft water has a reduced ability to neutralize acid events often attributed to air pollution and acid rain. This condition in combination with minimum thickness of protective scale is conducive to accelerated corrosion rates in galvanized steel.

The Aluminized Type 2 (ALT2) coating performs well in soft water where the oxygen present in the water forms an aluminum oxide layer on the pipe wall that extends the pipe's service life. The laminated film over the galvanized steel on polymer coated pipe provides an inert protective barrier in soft water and severe environments.

The CSP involved in establishing the charts used in the earlier performance charts developed by CALTRANS, AISI, FHWA and others, was galvanized steel pipe installed 40 to 80 years ago, since this was the only CSP available during that time period. This resulted in galvanized CSP being installed in sites that likely would not be environmentally appropriate for galvanized CSP today. Water hardness, a parameter that has a significant impact on the service life of galvanized CSP, was not measured at the culvert sites. Had the impact of soft water on galvanized CSP been recognized at the time of installation of the CSP evaluated in these early studies, the current methods used to estimate the service life of CSP would result in longer service life predictions, for galvanized CSP installed within the environmental guidelines detailed in this chapter.

Durability In Abrasive Conditions

Abrasion is the removal of the coating and the deterioration of the steel from the invert of the pipe wall caused by high velocity water and abrasive material the water carries with it. Protective barrier layers or scaling will improve performance in abrasive conditions. Table 9.3 provides a classification of abrasive conditions, established by the FHWA, based on flow velocity and bed load.

Storm sewers tend to have flatter slopes, lower velocities, and are exposed to smaller, less abrasive bed load material than culverts. Hence, storm sewers typically experience few abrasion issues. Culverts generally have steeper slopes, higher velocities, continuous flow, and more significant bed loads.

Table 9.3		
FHWA Abrasion Levels		
Level 1	Non-Abrasive	No bed load regardless of velocity; or storm sewer applications
Level 2	Low Abrasion	Minor bed loads of sand and gravel and velocities of 5 ft/sec. or less
Level 3	Moderate Abrasion	Bed loads of sand and small stone or gravel with velocities between 5 and 15 ft/sec.
Level 4	Severe Abrasion	Heavy bed loads of gravel and rock with velocities exceeding 15 ft/sec.
NOTE: Consideration of velocities should be based on a frequent storm event, such as a 2-year storm.		

FIELD EVALUATION OF CSP DURABILITY

The best method for evaluation of the service life of CSP at proposed sites is evaluation of previously installed pipe. The first significant field evaluation of installed CSP was conducted by CALTRANS in the early 1960s. The data generated in the CALTRANS study of 7000 culverts was used to develop the chart for estimating average invert life of galvanized CSP (Figure 9.1). This figure predicts the EMSL of a pipe based on a loss of 25 percent of the steel in the pipe invert. This study evaluated the service life of CSP based on the values of pH and resistivity. Water hardness was not measured at the culvert sites. Since the CALTRANS field evaluation, numerous states in the US and provinces in Canada have conducted similar studies of their culverts. The results were wide spread with the variations due to a prevalence of soft water, heavy snowfall or possibly the heavy use of road salt. The results of regional studies emphasize the importance of using local information when available.

The predictive method developed by the CALTRANS evaluation depended on whether the pH exceeded 7.3. Where the pH was consistently less than 7.3, the resulting service life was controlled by the corrosion rate of the pipe invert, with the corrosion rate being dependent upon the combined influence of pH and resistivity. For sites with a pH greater than 7.3, soil-side corrosion was the controlling factor. These latter sites tended to be in the semiarid and desert areas with less than 10 inches of rainfall per year.. The CALTRANS report stated that at least 70 percent of the pipes were expected to last longer than indicated by the chart.

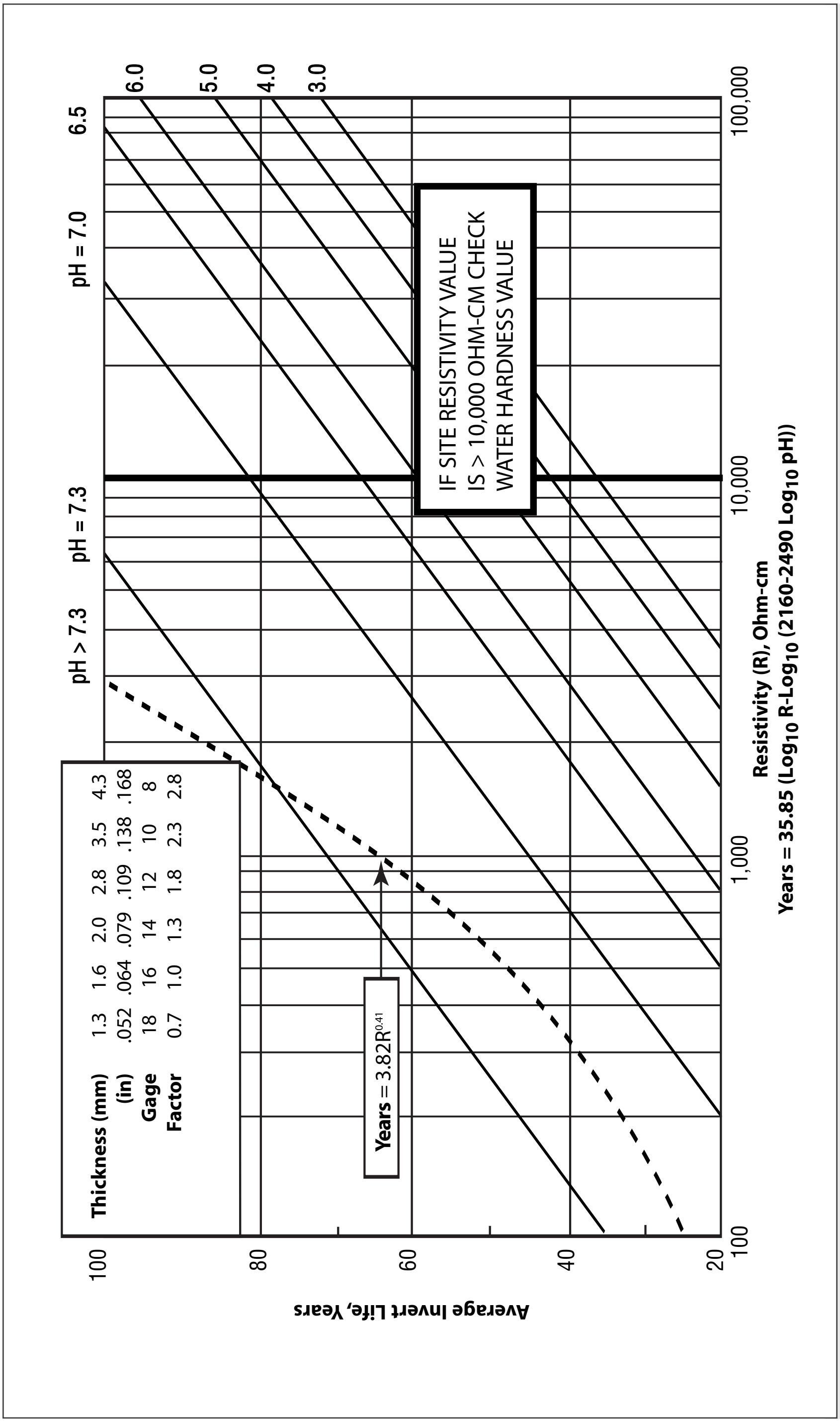

Figure 9.1 Estimated material service life of galvanized CSP.

NCSPA/AISI Study

In 1986, the NCSPA, with the cooperation of the AISI, commissioned Corrpro Companies, Inc., a corrosion consulting firm located in Medina, Ohio, to conduct a condition and corrosion survey on corrugated steel storm sewer and culvert pipe. The installations investigated were located in 22 states scattered across the United States, and had installation durations ranging from 20 to 74 years. Soil resistivities ranged from 1,326 to 77,000 ohm-cm, and the pH ranged from 5.6 to 10.3.

The study showed that the soil-side corrosion was relatively minimal on most of the pipes examined. Where significant interior corrosion was observed, it was typically limited to the pipe invert. Specific predictive guidelines were developed on a statistical basis.

Invert pavements can be provided, by either factory or field application, to provide significant additional durability (Table 9.4). The data shows that galvanized CSP systems can be specified with a paved invert to provide a service life of 100 years in a variety of soil and water conditions.

New Coatings for CSP

The steel suppliers and the fabricators of CSP continued development of better performing coatings that would allow installation of CSP in environmental conditions that exceeded the environmental ranges favorable to galvanized CSP. Two coatings, Aluminized Type 2 and Polymer Coated CSP are the result of these efforts. The performance of these coatings has been verified by field evaluations conducted by many public agencies.

Aluminized Type 2

Aluminized Type 2 (ALT2) was introduced as an alternative coating in 1948. Extensive field studies of thousands of ALT2 pipe installations by industry, federal, state and Canadian agencies have confirmed its excellent performance. This product develops an oxide barrier layer on the interior pipe surface and thus performs well in areas where the presence of soft water would require a coating other than galvanized CSP. In addition to performing well in soft water conditions, CSP with an ALT2 coating performs in wider ranges of pH and resistivity. Continuing evaluation of CSP with the aluminized coating, installed at sites with the extended ranges of environmental conditions, has provided adequate evidence of the enhanced performance of this coating. When installed in the established environmental conditions, field evaluations of CSP with the ALT2 coating, have proven this material will achieve a minimum 75-year service life.

Polymer Coated

Further development by the CSP industry resulted in the introduction of polymer coated CSP in the 1970's. This coating was developed for use in environmental conditions that exceed those in which most materials can perform. This polymer coating is applied over the galvanized coating that was the standard coating for CSP for many decades. The presence of two coatings, and the resulting strong bond between these coatings, allows polymer coated CSP to achieve performance levels not attainable by most pipe materials and coatings. Field evaluations of polymer-coated CSP have proven that when installed at sites within the defined site environmental conditions, this pipe can provide service well in excess of 100 years.

DURABILITY GUIDELINES

CSP With Only a Galvanized Coating

The CALTRANS service life estimation method referred to previously was based on life to first perforation of an unmaintained culvert. However, the consequences of small perforations in culverts are usually minimal, and have little or no effect on the pipe's hydraulic or structural performance. The CALTRANS report stated that at least 70% of the pipes were expected to last longer than the life determined by using the CALTRANS chart. Given the ultra conservative results presented by the initial CALTRANS chart, the curves on the chart were converted by R. F. Stratfull to "average service life" curves, using data developed on weight loss and pitting of bare steel samples by the National Institute of Standards and Technology (NIST).

Experience gained from further field evaluations of galvanized CSP performance, has shown that sites with high resistivity values, might be indicative of soft water. This experience has led to further modifications of the CALTRANS chart. The latest change cautions the designer about the use of galvanized CSP on sites with high resistivities. It is recommended that sites with high resistivities be evaluated for water hardness before specifying the proper CSP product. Figure 9.1 shows the resulting chart for estimating the average invert service life of galvanized CSP, when the site pH and resistivity are known.

CSP With Supplemental Pavings Or Coatings

There may be sites where the three coatings available on steel delivered to pipe fabrication facilities may not be the best match for the conditions on the site. Additional add-on life can be provided by coating or paving the invert of CSP with asphalt or concrete either after fabrication or after installation. The number of years of additional life are independent of the base coating on the pipe and are shown in Table 9.4.

Table 9.4

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 Coated and Paved	30	30	20	N/R
Concrete Paved			80	80

NOTE: N/R = Not Recommended

EXAMPLES OF DURABILITY DESIGN

The following design examples indicate the proper methodology for selecting an appropriate CSP product from among the options available. The examples assume that the pH, resistivity, and abrasion level at the sites are known or can be estimated with reasonable accuracy. Also, it is assumed that the pipe has been hydraulically sized and structurally evaluated. The pipe initially selected is a 16 gage CSP with galvanized coating, which enables us to use Figure 9.1. If the 16 gage galvanized coating does not meet the DSL, the designer should consider a heavier gage galvanized pipe and one or more of the alternative coatings. It is possible the designer will find a number of alternatives that will meet or exceed the DSL. In this case, all pipe materials that satisfy DSL should be specified and the contractor allowed to make the final decision based on installed pipe costs.

The following examples assume that the water side of the pipe controls the durability design, i.e., the backfill materials and ground water do not create corrosive conditions that determine the pipe's EMSL.

Example No. 1

Site Conditions: pH = 6.5, resistivity = 4000 ohm-cm, abrasion = level 2
Water hardness = 200 ppm ($CaCO_3$)
Design Service Life = 50 years
Initial Pipe Selection (structural calculation): 48 in. diameter, 16 gage
(2 2/3 x 1/2 in. corrugation)

With r = 4000 ohm-cm, pH = 6.5, EMSL of galvanized pipe (Fig. 9.1) = 52 years (>50 years OK)

Water hardness > 50 ppm, (Water hardness not a problem; galvanized coated CSP can be used)

Alternative Pipe Selections:

See Table 9.1 for EMSL of polymer coated and ALT2.
Site environmental conditions are suitable for galvanized, polymer coated and ALT2 (DSL = 50 years).

1. Galvanized CSP	16 gage:	EMSL = average 52 years
2. ALT2 CSP	16 gage:	EMSL = minimum 75 years
3. Polymer Coated CSP	16 gage:	EMSL = minimum 100 years

There are three CSP products suitable for this site: 16 gage galvanized, 16 gage ALT2 and 16 gage polymer coated.

Example No. 2

Site Conditions: pH = 5.0, resistivity = 2000 ohm-cm, abrasion = level 2
Water hardness = 125 ppm ($CaCO_3$)
Design Service Life = 70 years
Initial Pipe Selection (structural calculation): 60 in. diameter, 16 gage (5 x 1 in. corrugation)

With r = 2000 ohm-cm, pH = 5.0, EMSL of galvanized pipe (Fig. 91) = 25 years (16 gage)
16 ga. galvanized CSP does not meet DSL and requires a heavier gage or alternative coating.

For 12 gage: EMSL = 1.8 x 25 = 45 years (<70 years so does not satisfy the service life). Use a heavier gage.

For 8 gage: EMSL = 2.8 x 25 = 70 years (OK)

Alternative Pipe Selections:

See Table 9.1 for EMSL of polymer coated and ALT2.
Site environmental conditions are suitable for galvanized, polymer and ALT2 (DSL = 70 years)

1. Galvanized CSP	8 gage:	EMSL = average 70 years
2. ALT2 CSP	16 gage:	EMSL = minimum 75 years
3. Polymer Coated CSP	16 gage:	EMSL = minimum 100 years

Three cost-effective CSP products are suitable for this site: 8 gage galvanized, 16 gage polymer coated and 16 gage ALT2).

Example No. 3

Site Conditions: pH = 4.0, resistivity = 1000 ohm-cm, abrasion level = 3
Water hardness = 50 ppm ($CaCO_3$)
Design Service Life = 75 years
Initial Pipe Selection (structural calculation): 54 in. diameter, 14 gage (2 2/3 x 1/2 in. corrugation)

Alternative Pipe Selections:

1. Galvanized pipe is not recommended at this site because pH, resistivity, and water hardness are outside recommended environmental ranges for this coating. See Table 9.1.
2. ALT2 is not recommended at this site because the pH is below 5.0, the resistivity is below 1,500 ohm-cm and the abrasion level is greater than 2.
3. Polymer coated CSP will perform well in all the site environmental conditions with a minimum service life of 75 years.

The best pipe for installation at this site is 14 gage polymer coated. This pipe will perform well at this site, where the pH is too low even for concrete pipe.

SPECIAL PIPE AND APPLICATIONS

Spiral Rib Pipe

The previous design examples focused on traditional CSP corrugation profiles such as 2 2/3 x 1/2 inch and 5 x 1 inch corrugation. CSP fabricators offer a range of pipe wall corrugations to help the designer meet both hydraulic and structural conditions at each site. An alternative product developed over the last few decades is spiral rib pipe in which the corrugation consists of a smooth interior wall with a helical rectangular rib projecting to the pipe exterior at a spacing of 7.5 or 11.5 inches. The advantage of this wall corrugation is that it provides a CSP product with hydraulic performance equal to that of reinforced concrete pipe and HDPE pipe. This is an economic advantage because it is not necessary to use a larger sized CSP to achieve hydraulic performance equal to that of other pipe materials. Because of the smooth interior, spiral rib pipe is less susceptible to coating loss due to abrasion than traditional CSP corrugations.

Storm Sewers

Most of this chapter has dealt with culvert applications. CSP is also widely used in storm sewer applications. The durability evaluation of storm sewers differs greatly from that of culverts. The major difference is that storm sewers rarely experience high velocities or bed loads of any significance. Flow through storm sewers tend to be much more intermittent than culverts and storm sewers are usually installed at the minimum slopes required to ensure the storm sewer system remains in a self-cleaning condition. These conditions reduce the impacts of abrasion and corrosion. If the effluent through the sewer system is expected to be soft water, caution should be exercised in the use of galvanized CSP. In the absence of soft water, any CSP that satisfies hydraulic and structural requirements can be used in storm sewers without significant durability concerns. Economics will likely be the deciding factor in evaluating alternatives.

Spiral rib pipe is often used in storm sewers to minimize the size of pipe required and thereby reduce the depths at which the downstream lines must be placed. Another distinct advantage of using spiral rib pipe is that it enables the designer to specify three alternative pipe materials (CSP, HDPE and concrete), all of which will require the same size pipe. The smooth nature of the inside of the spiral rib pipe further reduces the already minimal effects of abrasion on the pipe wall. With little or no abrasion forces to damage the interior pipe wall, the EMSL of CSP, when used in storm sewer applications, can be expected to be much greater than when used in culvert applications. A study conducted by the Federal Lands Highway Division of FHWA concluded that 16 gage galvanized CSP would have a service life 25 percent longer than predicted when using the CALTRANS chart. This conclusion was based on their interpretation of the data from their study of sites where abrasion conditions were classified as FHWA Levels 1 or 2.

Given the less aggressive nature of the effluent flowing through storm sewers, the site conditions of the pipe exterior may be the determining factor in calculating pipe service life. A study of the soil side durability of sewer pipe, conducted by the Corrpro companies, and reported in 1991, concluded that where soil side conditions controlled, more than 90 percent of galvanized coated CSP installations would have a service life in excess of 75 years and more than 80 percent would have a life in excess of 100 years. These service life levels should certainly exceed the design service life for the vast majority of storm sewer installations.

Underground Stormwater Systems

CSP is the most widely used material in the construction of underground stormwater storage systems. These systems are used to capture and hold stormwater during storms and then release the stored stormwater at a controlled rate established by local regulations. These systems vary in size from 24 inch diameter to the maximum size of 144 inch diameter. An integral aspect of these systems is the use of many fittings, bulkheads, access manholes, weirs, and bypass piping. Simply stated, these are stormwater storage containers. Stormwater flows into the systems, is temporarily stored there, and is gradually discharged into the storm sewer system at a rate approved by the local regulators.

The flows into these systems are consistent with those generally encountered in storm sewer systems. This means inlet and outlet velocities are minimal and are too low to create abrasive forces within the system.. The flow rate of effluent from the systems is usually less than the inflow rate. These systems essentially operate without developing abrasive conditions. As discussed in the previous section on storm sewers, the CSP in these systems will provide an EMSL significantly greater than the DSL.

NCSPA commissioned a study to evaluate the condition of 17 stormwater storage systems that had been in place for as long as 25 years. The majority of the systems were galvanized coated pipe with no supplemental coatings. Parsons Brinkerhoff and Corrpro performed the visual inspection and evaluated coupons from the pipe walls. The conclusion of the evaluations was that the systems had experienced little or no deterioration over many years of operation, and would have a service life significantly in excess of 100 years.

Steel Structural Plate

Steel structural plate (SSP) has been in use for over 70 years and has a proven performance record. SSP is used where the site requires a structure rather than a manufactured pipe due to the size of the required opening or the depth of earth cover over the structure. SSP is used where the structure span or pipe diameter is larger than is available in CSP. To accommodate the larger sized structure, individual plates are shipped in small sizes and bolted together on site. For a number of reasons, durability is less of a concern with structural plate than with CSP. The thickness of the structural plates is greater than the typical wall thicknesses used in CSP, and the thickness of the plates that form the invert of the structure can be made with steel plates heavier than used in the balance of the structure in order to enhance durability. The maximum thickness of SSP plates is 0.380 inches, nearly 6 times the thickness of the 16 gage CSP used as the basis for Figure

9.1 (EMSL). CSP typically has a galvanized coating weight of 2 oz/sq. ft (total both sides), while SSP is coated after fabrication with a galvanized coating that is 50 percent heavier at 3 oz./sq. ft. With the increased steel thickness and the 50 percent heavier coating thickness, SSP can easily have a service life as much as 8 or 9 times that of 16 gage CSP.

Another advantage of structural plate is that some of the shapes, such as arches and box culverts, can be assembled without an invert. Having no invert eliminates the portion of the pipe or structure which is of greatest concern regarding durability. Another method used to create natural inverts in a structure or pipe is to bury the structure deeper than normal and fill the pipe interior with natural fill material up to the stream gradient. An alternate means of increasing service life of SPP at a given site is to specify an asphalt or concrete paving in the invert of the pipe.

ADDITIONAL INFORMATION

For more specific information on available coatings, linings, and pavings, consult with your local CSP fabricators. Local fabricators can be located on the NCSPA website at www.ncspa.org. Their knowledge and experience will be of great value when dealing with issues related to the service life of CSP products. As can be seen from the example designs, the evaluation of durability is not an exact science. However, over 100 years of experience provides CSP suppliers with a great deal of practical knowledge. Using this knowledge it is possible to make reasonable estimates of durability given basic information related to environmental conditions at the planned installation site. Take advantage of this experience.

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Typical CSP underground detention system.

Proper backfill and equipment are important for a successful installation.