Chapter 4
Corrugated Metal Pipe for Rural Levees and Culverts

4-1. General

Corrugated metal pipe may be used in rural levee systems when risk of substantial property damage and loss of life is low. Corrugated metal pipe is subject to chemical and galvanic corrosion, is not easily tapped, has a high hydraulic coefficient of friction, and is vulnerable to joint leakage and associated piping and to live load distortion. When this pipe is used, a life cycle cost analysis should be performed. The service life of a flood control project is 100 years, and corrugated metal pipe systems must be designed to meet this requirement. Typically, corrugated metal pipe may have to be replaced a minimum of once during this project life. Use 900-mm- (36-in.-) diameter pipe as a minimum for levees to facilitate installation, maintenance, and inspection.

a. Corrugated metal pipe. This pipe may be used as an option in agricultural levees where the levee embankment is less than 3.7 m (12 ft) above the pipe invert. Circular pipe must be used through levee embankments.

b. Corrosion protection. Corrugated metal pipe is susceptible to corrosion, primarily in the invert. The pipe should always be galvanized and protected with a bituminous coating and should have bituminous paving applied to the invert. Bituminous coatings and paving can add about 20 to 25 years of service life to the pipe, and a bituminous coating (AASHTO M 190) alone adds about 8 years of service life to the pipe. Polymer coatings (AASHTO M 246) can add about 10 years of service life to the pipe. If the fill or backfill materials contain chemically active elements, it may be necessary to protect the outside of the pipe with a coating of coal tar epoxy. The life of galvanized conduits can be estimated by using information from the American Iron and Steel Institute's (AISI) *Handbook of Steel Drainage and Highway Construction Products* (1993). When considering other coatings, the designer should review applicable test data for similar installations.

(1) Metallic-coated corrugated steel pipe. Metallic-coated corrugated steel pipe should conform to American Association of State Highway and Transportation Officials (AASHTO) M 36, M 218, M 246, and M 274. When spiral rib steel pipe is used, the material should conform to AASHTO M 36 and M 245. When bituminous coatings are required, the material should conform to AASHTO M 190. For installations involving only fresh water, the Type C coating should be used except when the pH value of the soil or the water at the installation site is below 5 or above 9. In this case, the coating should be ASTM A 885, Aramid Fiber Composite, and AASHTO M 190. For all seawater installations, the coating should be ASTM A 885 and AASHTO M 190. Both the loading conditions and the corrosion characteristics (soil and water) at the installation site should be considered when specifying metal thickness (steel). Metal thickness should be selected to meet the corrosion condition and should not allow the pipe to perforate during the life of the project. The soil resistivity and pH can be determined by a geotechnical engineer. This type of pipe should not be used to conduct strong industrial wastes or raw sewage. In general the environmental conditions for corrugated metal pipe require pH limits of 6 to 8 for galvanized steel, and 5 to 9 for aluminized steel. Soil resistivity should be greater than or equal to 2,500 ohm-cm for galvanized steel and 1,500 ohm-cm for aluminized steel. Long-term field test data suggest that aluminum alloy coatings (Aluminized Type 2, AASHTO M 274) lasts longer than plain galvanized coatings (Zinc, AASHTO M 218). Before selecting aluminized coatings, the designer should verify local experience with such pipe, and these coatings should not be used for sanitary or industrial sewage, salt water or when heavy metals are present.

(2) Corrugated aluminum alloy culvert pipe. This pipe is generally used for culverts and underdrain systems, and should conform to ASTM B 745M. When spiral rib pipe is used, the materials should conform to ASTM B 745M and should be included in the specifications for culverts, storm drains, and other applications on relocations and similar works which will be used on Civil Works Projects or turned over to others. Engineering standards and requirements of the affected authority should be followed. Corrugated aluminum alloy pipe should not be used through dams, levees, or other water retention embankments.

(3) Perforation life. Corrugated metal pipe should be designed by the method and equations given in the *Handbook of Steel Drainage and Highway Construction Products*, except that Figure 4-1 is to be used to calculate the perforation life of the pipe. This figure is applicable to civil works projects. The AISI approach is applicable to gravity flow systems on nonerodible granular beddings, not on silty and clayey sands which are highly erodible. Most civil works projects around spillways and through levees structures are on silty and clayey sands and under pressure.

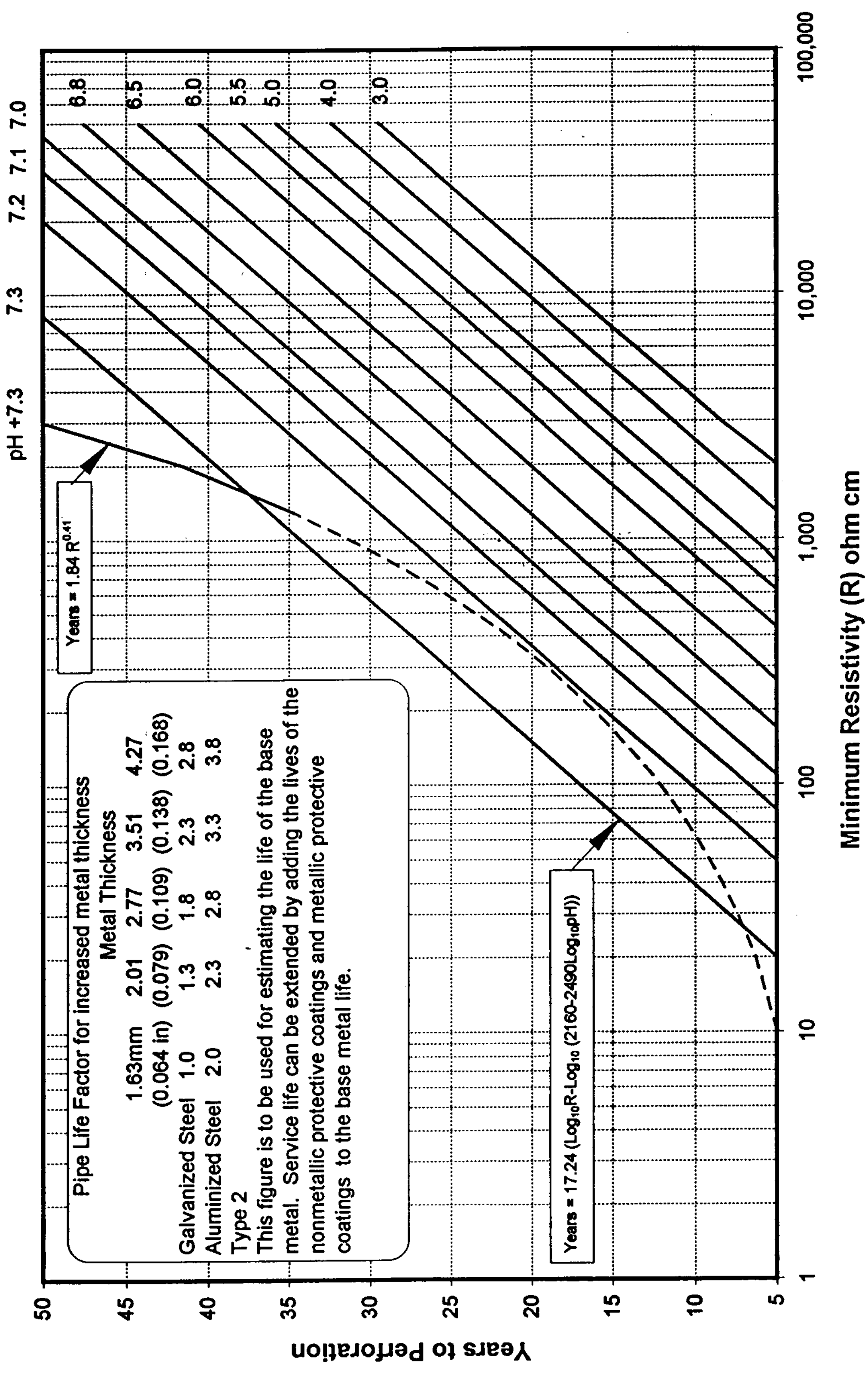


Figure 4-1. Galvanized steel pipe perforation life: metal thickness 1.63 mm (0.064 in.)

4-2. Materials

Table 4-1 lists the applicable ASTM standards for the materials used in the design of corrugated metal pipe systems.

a. Corrugated metal gate wells. Corrugated metal gate wells may be used in lieu of cast-in-place concrete where corrugated metal pipes are permitted, if designed and detailed to satisfy the same requirements as precast gate wells. These gate wells need to be designed and detailed to satisfy the loading and functional requirements. The loading requirements must include the maximum loads that can be applied through the gate lifting and closing mechanism. These mechanisms are usually designed with a factor of safety of five. This will usually require mechanical connections between pipe segments. The top, bottom, and gate frame must be securely anchored to resist all loading conditions. The joints for the gate well should should be the same type as used for the pipe conduit. The installed gate wells should be hydrostatic tested prior to backfilling.

Table 4-1
Materials for Corrugated Metal Pipe Systems

Materials	ASTM Standard	Description
* Polymer-Coated Sheets	ASTM A 742M - Steel Sheet, Metallic Coated and Polymer Precoated for Corrugated Steel Pipe	Polymer-coated galvanized sheets or aluminum-zinc alloy sheets. Used in environments when metallic-coated pipes cannot be used. *
Fully Lined Steel	ASTM A 760M Type 1A - Corrugated Steel Pipe, Metallic-Coated for Sewers and Drains	This standard is for corrugated metal pipe being used as storm-water drainage, underdrains, and culverts. Included in the standard are requirements for rivets, bolts and nuts, lock seam strengths, coupling bands, and gaskets.
Sewer and Drainage	ASTM A 762M - Corrugated Steel Pipe, Polymer Precoated for Sewers and Drains	This pipe is not intended to be used for sanitary or industrial wastes. It is a standard for polymer-coated zinc or aluminum-zinc-alloy-coated sheet steel. Additional polymer coating may be applied after fabrication of the pipe. Included in the standard are requirements for rivets, bolts and nuts, lock seam strengths, coupling bands, and gaskets.
Asphalt-Coated or Paved Invert Steel	ASTM A 849M - Post-Applied Coatings, Pavings and Linings for Corrugated Steel Sewer and Drainage Pipe	This standard covers the post-applied coatings for steel structure plate pipe; pipe arches; and arches with paved, lined or polymer coatings. Coatings include bituminous materials, concrete, mastic, or polymer. Conduits can be fully coated exterior or interior, paved invert, or fully lined.
Fiber Bonded Sheets	ASTM A 885M - Steel Sheet, Zinc and Aramid Fiber Composite Coated for Corrugated Steel Sewer, Culvert and Underdrain Pipe	This is a composite coating of zinc, aramid nonwoven fabric, and asphalt coatings used for enhanced corrosion resistance.
Aluminum Sheets	ASTM B 744M - Aluminum Alloy Sheet for Corrugated Aluminum Pipe	This standard covers the aluminum sheet used for corrugated aluminum pipe that is used for storm-water drains, underdrains, and culverts.
Aluminum Alloy Pipe	ASTM B 745M - Corrugated Aluminum Pipe for Sewers and Drains	This standard covers the aluminum pipe to be used for storm water drains, underdrains, and culverts. Included in the standard are requirements for rivets, bolts and nuts, lock seam strengths, coupling bands, and gaskets.
* Zinc-Coated, Aluminum-Coated, and Aluminum-Zinc Coated Sheet Steel	ASTM A 929M-Steel Sheet, Metallic Coated by the Hot-Dip Process for Corrugated Steel Pipe	This standard includes steel sheet with Zinc-5% Aluminum-Mischmetal (Zn-5Al-MM), 55% Aluminum-Zinc Alloy-coated (55Al-Zn), and Aluminized (Type 1 and 2) coatings. *

b. Inlet structures. Corrugated metal inlets may be used where corrugated metal pipes are permitted, if designed and detailed to satisfy the loading and functional requirements.

c. Outlet structures. Outlet structures are normally cast-in-place reinforced concrete U-wall structures.

d. Pile bents. When pile bents are used to support a length of pipe, pipe lengths should be limited to 4.9 m (16 ft). Two pile bents, as shown in Figure 3-6, are required for each pipe section when using 2.4-m (8-ft) lengths of pipe, and three pile bents are required when pipe lengths are 4.9 m (16 ft). The two upstream sections of pipe beyond the pile bents should be two half lengths of pipe to develop joint flexibility. Corrugated bands should be used on pipe joints when the pipe is supported on pile bents.

4-3. Installation

Corrugated metal pipe for levees and culverts, and structural plate for culverts should be installed in accordance with the requirements set forth in ASTM A 798 for steel pipe or ASTM A 807 for steel plate pipe or ASTM B 788 for aluminum pipe or ASTM B 789 for aluminum plate pipe.

a. Foundation. When soft soils or rock are encountered, they should be removed and replaced with approved materials as specified herein. The excavation depth below the pipe invert shall be equal to 42 mm (0.5 in.) per meter (foot) of fill above the crown of the pipe, not to exceed 600 mm (24 in.) maximum. The minimum width of material removed in a trench will be three diameters in soft soil, and one and one-half diameters in rock.

b. Backfill. Structural backfill for pipe in trenches is the material placed around the pipe from invert up to an elevation of 305 mm (12 in.) or one-eighth the diameter, whichever is more, above the pipe. For pipe in embankment conditions, structural backfill is the material within one diameter of the sides of the pipe from invert to an elevation of 305 mm (12 in.), or one-eighth the diameter, whichever is more, over the pipe. Acceptable backfill material for corrugated metal pipe includes silty and clayey gravels and sands (SM and SC, Unified Soil Classification System) as approved by the geotechnical engineer. Gravels and sands (GW, GP, GM, GC, SW, and SP) are not acceptable backfill materials in levees. Plastic clays and silts, organic soils, and peat are not acceptable materials (OL, MH, CH, OH, and PT). This backfill material is installed in 152- to 305-mm (6-to 12-in.) layers compacted per EM 1110-2-1913 and is brought up evenly on both sides of the pipe to a minimum cover of 305 mm (12 in) over the top of the pipe.

c. Minimum cover and spacing.

(1) Cover. Use the method for calculating the minimum cover as defined in ASTM A 796 and ASTM B 790 for steel and aluminum, respectively. However, a minimum cover of 610 mm (2 ft) from the top of the pipe to the bottom of the slab or crosstie is recommended for railroads, highways, and airfield pavements. For construction loads, a minimum cover of 1,220 mm (4 ft) is recommended.

(2) Spacing. When multiple lines of pipe are installed in the same excavation, a minimum spacing between pipes of one-half the pipe diameter or 900 mm (3 ft), whichever is less, should be used for adequate compaction of the backfill material. These minimum spacings are for compacted backfill and may be less when using slurry or flowable backfills.

4-4. Loadings

Earth loads and live loads (highway, railways, runways, and impact) for corrugated metal pipe are defined in ASTM A 796 and ASTM B 790 for steel and aluminum, respectively, as vertical pressures. Horizontal pressures are controlled by backfill requirements. The applications of these pressures are similar to those presented in Figure 5-2.

4-5. Methods of Analysis

The design of corrugated steel pipe is covered in ASTM A 796, and the design of corrugated aluminum pipe is covered in ASTM B 790. The designer should consider the design criteria for ring buckling strength, wall crushing strength, handling stiffness, and joint integrity. The section properties for corrugated metal pipe and seam strength requirements are provided in ASTM A 796 for steel and ASTM B 790 for aluminum. When corrugated metal pipe is used, an analysis of seam separation should be performed, except when helical lock seam pipe is used.

a. Thrust in pipe wall. Thrust in pipe walls must satisfy three criteria: required wall area as determined from ring compression or thrust, critical buckling stress, and required seam strength.

(1) Wall thickness. The minimum wall thickness is based on the yield stress of the pipe material, and

assumes a factor of safety of 2. This design is defined in ASTM A 796 or ASTM B 790 for steel and aluminum, respectively.

(2) Allowable wall stress. The critical buckling wall stress can be determined by using formulas presented in ASTM A 796 and ASTM B 790, for steel and aluminum, respectively. If the critical buckling stress is less than the yield stress of the wall material, recalculate the required wall thickness using the calculated buckling stress.

(3) Longitudinal seam stress. Because there are no seams in helical lock seam and welded seam pipe, these criteria do not apply. For pipe fabricated with longitudinal seams (riveted, spot-welded, or bolted), seam strength should be sufficient to develop the thrust in the pipe wall. The factor of safety for longitudinal seams is 3. Also, these joints must be hydrostatically tested for acceptance. Seam strengths for various seam connections are given in ASTM A 796 and B 790 for steel and aluminum pipe, respectively.

b. Handling stiffness. The handling stiffness of corrugated metal pipe should be checked to ensure that the pipe can be handled without damage during construction. The required flexibility factors for steel and aluminum pipe are given in ASTM A 796 and ASTM B 790, respectively.

4-6. Joints

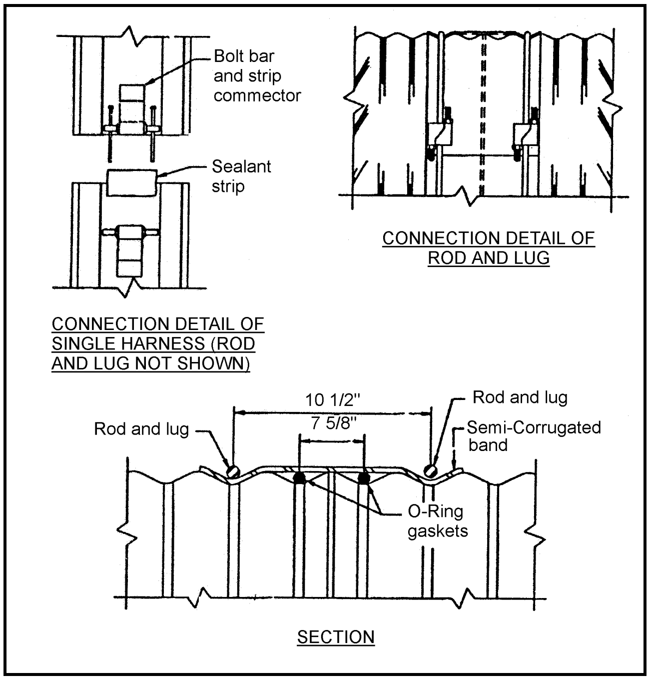
Special attention should be given to the joint between a corrugated metal pipe and any concrete structure. The gaskets and bands discussed below are used to develop leak-resistant joints in corrugated metal pipe. A typical hugger band installation is shown in Figure 4-2, and a typical corrugated band joint is shown in Figure 4-3. Joints through levees must be tested for watertightness, and require the use of corrugated bands.

a. Gaskets. For sleeve type gaskets, use ASTM D 1056, Grade 2C2. Sleeve type gaskets should be one-piece construction, closed-cell neoprene, skin on all four sides. The thickness should be 9.53 mm (3/8 in.) and 13 mm (1/2 in.) less than the width of the connection band required. O-ring gaskets should meet the requirements of ASTM C 361.

b. Coupling bands. Corrugated bands and sleeve type gasket are required when watertightness is a concern. For helical pipe, the ends should be reformed so the pipes can be coupled. Flat bands with sleeve or O-ring type gaskets, or hat-channels with mastic bands are not acceptable for watertight joints as they are susceptible to pulling apart. Bands with annular corrugations and rod and lug
* connectors, semi-corrugated bands and bands with angular corrugations, and angle iron bolt connectors are acceptable connectors.

4-7. Camber

Where considerable foundation settlement is likely to occur, camber should be used to ensure positive drainage and to accommodate the extension of the pipe due to settlement.



* **Figure 4-2. Semi-corrugated band**

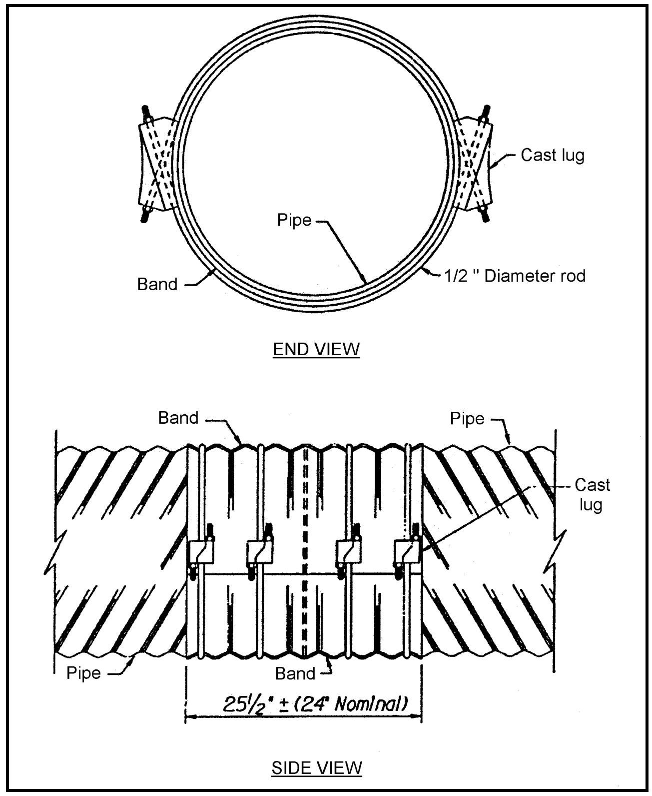


Figure 4-3. Corrugated band