Conduits, Culverts, and Pipes Part I

Course Number: CE-02-101

PDH: 4

Approved for: AK, AL, AR, DE, FL, GA, IA, ID, IL, IN, KS, KY, LA, MD, ME, MI, MN, MO, MS, MT, NC, ND, NE, NH, NJ, NM, NV, NY, OH, OK, OR, PA, SC, SD, TN, TX, UT, VA, VT, WI, WV, and WY

State Board Approvals

Florida Provider # 0009553 License #868
Indiana Continuing Education Provider #CE21800088
Maryland Approved Provider of Continuing Professional Competency
New Jersey Professional Competency Approval #24GP00025600
North Carolina Approved Sponsor #S-0695
NYSED Sponsor #274

How Our Written Courses Work

This document is the course text. You may review this material at your leisure before or after you purchase the course.
After the course has been purchased, review the technical material and then complete the quiz at your convenience.
A Certificate of Completion is available once you pass the exam (70% or greater). If a passing grade is not obtained, you may take the quiz as many times as necessary until a passing grade is obtained).
If you have any questions or technical difficulties, please call (508) 298-4787 or email us at admin@PDH Pro.com.

Module 1: Introduction and Life Cycle Design

Learning Objectives

By the end of this section, you will be able to:

- **Evaluate** conduit materials and coatings based on environmental factors and required project service life.
- **Select** appropriate pipe types (rigid vs. flexible) for specific applications such as dams, urban levees, and agricultural levees.
- **Implement** critical design features for seepage control, including drainage fills and watertight joints, to prevent piping failure.

*Executive Summary***:** For major infrastructure projects, you must design for a minimum project service life of **100 years**. While reinforced concrete typically supports this longevity, flexible materials like steel, aluminum, and plastic often have shorter product lives (approx. 50 years) and may require replacement during the project's operation. Consequently, avoiding piping failure through robust joint design and the installation of a 450-mm (18-in.) drainage filter ring is critical for long-term safety.

Design Fundamentals

Purpose and Applicability

This module provides design guidance for conduits, culverts, and pipes used in civil works. It covers structural design procedures for various loading conditions, including trench/embankment loads, highway and railroad live loads, and internal/external fluid pressures.

While broadly applicable to civil engineering, these standards specifically govern USACE facilities. You must differentiate between high-risk structures (dams, urban levees) and lower-risk applications (agricultural levees) when selecting materials.

Life Cycle Design Strategy

Engineering requirements must balance initial construction costs with long-term performance and maintenance.

1. Project Service Life vs. Product Service Life

- **Project Service Life:** Major infrastructure projects are designed to remain in service indefinitely. Use a minimum service life of **100 years** for design purposes.

- **Product Service Life:** Many materials will not last 100 years. You must account for replacement costs (including cofferdams and operational disruptions) in your life cycle cost analysis if the product life is shorter than the project life.

2. Material Durability Estimates Environmental factors such as soil pH, resistivity, and flow velocity dictate the actual life of a material. However, general baselines include:

- **Concrete:** Estimated life is **70 to 100 years**. It generally provides a service life two times that of metal pipes.
- **Steel (Corrugated):** Failure usually occurs via corrosion of the invert or exterior. With proper coatings, expect a life of at least **50 years**.
- **Aluminum:** Susceptible to soil-side corrosion. Performance is difficult to predict; do not expect more than **50 years**.
- **Plastic:** Limited performance history. Do not expect more than **50 years**.

⚠️ **Safety Constraint:** Corrugated Metal Pipes (CMP) are **only** acceptable in agricultural levees where the conduit diameter is 900 mm (36 in.) or less and the embankment height is no higher than 4 m (12 ft) above the invert.

System Selection and Installation

Material Behavior: Rigid vs. Flexible

- **Rigid Conduits (Concrete):** Support loads primarily through wall strength. Used for dams and urban levees where public safety is at risk.
- **Flexible Conduits (Steel, Aluminum, Plastic):** Rely on soil-structure interaction. Vertical loads deflect the pipe walls, mobilizing the passive resistance of the surrounding soil. **Control of backfill compaction is critical** to prevent excessive deflection and failure.

Structural Shapes and Loads

- **Shapes:** Circular sections are most common. Rectangular (box) shapes are preferred for large conduits through levees or under railroads. Oblong and horseshoe shapes are used for specific hydraulic or installation conditions.
- **Loadings:** You must account for earth loads, surface surcharges (including reservoir pool height), vehicle loads, and fluid pressures. Internal pressure becomes a governing concern when it exceeds external pressure.

Critical Protection Features

Joint Integrity

Leaking joints are a primary cause of **piping** (erosion of soil particles) and embankment failure.

- Joints must be watertight and flexible to accommodate longitudinal/lateral movement.
- Improper installation leads to soil fines entering the conduit or water tracking along the pipe exterior.

Seepage and Piping Control

To prevent water piping along the outside of the conduit or soil migration into the trench, you must install specific drainage features.

Mandatory Drainage Detail: Regardless of the conduit type, you should provide a **450-mm (18-in.) annular thickness of drainage fill** around the landside third of the conduit.

- This layer intercepts seepage and prevents piping.
- It must have an outlet (blind drain or connection to other collection features) to the ground surface at the levee toe.

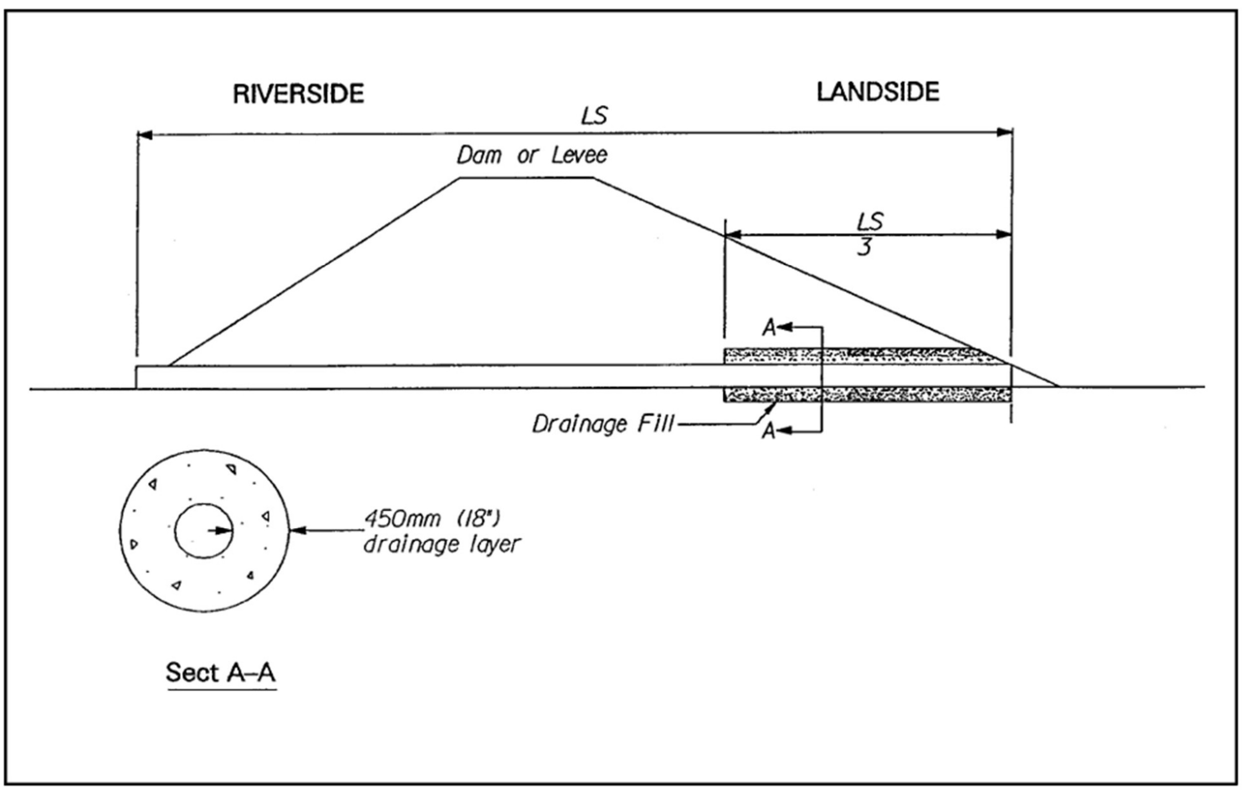

Figure 1-1: Drainage fill along conduit

💡 **Design Tip:** Concrete pipe is generally preferred for inlet structures, intake towers, and gate wells. Corrugated metal structures are restricted to agricultural or rural levee applications.

Checkpoint Quiz

1. **For a major infrastructure project (e.g., a large dam), what is the minimum project service life you must use for design?**
   a) 50 years
   b) 75 years
   c) 100 years
   d) Indefinite

Answer: (c) 100 years. While economic analyses often use 50-75 years, major infrastructure is expected to remain in service indefinitely, requiring a 100-year design life for planning.

2. **Which of the following conditions permits the use of Corrugated Metal Pipe (CMP) in a levee?**
   a) An urban levee protecting a residential area.
   b) An agricultural levee with a conduit diameter of 1200 mm.
   c) An agricultural levee where the embankment is 3 m (10 ft) high.
   d) Any levee, provided a life cycle cost study is performed.

Answer: (c) An agricultural levee where the embankment is 3 m (10 ft) high. CMP is restricted to agricultural levees with diameters ≤ 900 mm (36 in.) and embankment heights ≤ 4 m (12 ft).

3. **What is the primary function of the 450-mm (18-in.) drainage fill required around the landside third of a conduit?**
   a) To provide structural support for flexible conduits.
   b) To prevent piping and control seepage along the conduit exterior.
   c) To reduce the vertical earth load on the pipe.
   d) To allow for easier replacement of the pipe in the future.

Answer: (b) To prevent piping and control seepage along the conduit exterior. This drainage layer intercepts water tracking along the conduit and prevents the migration of soil fines (piping).