INVERT REHABILITATION

Metal Culvert Overview Flowchart
Structural Defects Flowchart (Metal)
Bedding Deficiencies Flowchart (Metal)
Hydraulic Capacity Flowchart (Metal)

1. INVERT PAVING WITH CONCRETE

One of the most effective ways to rehabilitate corroded and severely deteriorated inverts in corrugated metal pipes is paving them with concrete. With certain modifications, the method can be used in concrete culverts. The method consists of pouring a concrete lining in the culvert invert, which increases surface roughness and thus decreases flow velocity and protects the culvert against abrasion. The method is usually limited to large diameter culverts (120 in. or more), and is generally applied on steep slopes that operate under inlet control (Caltrans, 2003). Portland cement based concretes including conventional concrete, high-strength concrete, or steel fiber reinforced concrete can be used (Ballinger and Drake, 1995).

Ballinger and Drake (1995) abstracted procedures for invert paving with concrete, which have been originally provided in NCSPA (1988). In metal culverts, the following are their guidelines:

- Before paving, a flow diversion (bypass) is conducted and the culvert surface to which the concrete will be applied is prepared (must be clean and dry). Any debris, dirt and other material is removed from the culvert pipe. Any void areas are filled with concrete (portions of the culvert's invert are removed as necessary to enable filling of the voids).
- Class C concrete can be used using the following mixture: 1,440 lbs/cu.yd. fine aggregate; 1,410 lbs/cu.yd. coarse aggregate (#8 max stone); cement 600 lbs/cu.yd.; water/cement ratio 0.5.
- The bottom portion of the pipe is paved as follows:
    - In round pipes, the bottom 25% of the inside pipe circumference,
    - In pipe arches with spans of up to 10 ft 3 in., the bottom 30% of the inside periphery
    - In pipe arches with spans over 10 ft 3 in., the bottom 35% of the inside periphery
- The minimum coverage is 4 in. over corrugations.
- The pavement is reinforced with steel fabric reinforcement meeting specifications in FHWA's Standard Specifications (FHWA, 2003: Section 709 Reinforcing Steel and Wire Rope). The reinforcement can be installed in the following alternate methods:
    - A wire, No. 6 gauge, on 6 in. centers longitudinally and transversally, is placed 2 in. above the corrugations. The wire is attached to the pipe by welding to the crest of corrugations or tied to studs or angles previously welded to the pipe (spaced 2 ft apart longitudinally and transversally).
    - A wire mesh, 6×6×8×8 (6 in.×6 in.×2.1 mm×2.1 mm), is positioned so that transverse wires lie in the groves of the multi-plate corrugated sheets. The wire mesh is tack welded to invert every 30 in. longitudinally and every 2 in. transversally.
- The concrete surface is protected within 18 hours after completion or, if exposed to sunlight, immediately after completion. For protection, approved curing cover or membrane curing compound applied at a min rate of 1 gallon per 150 sq. ft. can be used.
- The concrete is left to cure for a minimum of 48 hours before the water is permitted to flow inside the culvert.

Ballinger and Drake (1995) also referenced a specification by the US Army Corps of Engineers for invert paving in a concrete culvert with severe abrasion problem. Two types of concrete were specified as alternatives, and a method of bonding the new invert concrete with the existing concrete culvert pipe:

- Steel fiber reinforced concrete can used, composed of 3/8 in. coarse aggregate, fine aggregate, Portland cement, wire fibers, water and admixtures (batched and mixed in accordance with ASTM C94). Ferrous wire fibers can be round, flat or deformed, 1 in. long.
- High strength concrete can also be used as an alternative for fibrous reinforced concrete.
- Steel reinforcing bars are used to anchor the fibrous concrete to the invert of the pipe. The bars are straight and hooked on one end. Holes for anchor bars are drilled at specified angle in the culvert invert (hole diameter no less than 1.5 times the diameter or greatest transverse dimension of the anchor bar). The holes are filled with grout the anchor bars forced into place and vibrated, and the grout left to cure for at least 36 hours before applying the fibrous concrete.

Moll (1993) reported ten corrugated metal culvers rehabilitated with invert paving by the Oklahoma DOT. Two different concrete design mixes were used and both provided “very good, no cracking” performance ratings. The cement grout was manually trowelled to create 3 in. thick layer above the corrugations. The width of the paving was 75% of the pipe diameter.

2. INVERT LINING WITH STEEL ARMOR PLATES

The method consists of installing steel plates in the culvert invert area, which provides a smooth surface and reduced impediment to the flow compared to the corrugated surface, thus ultimately reducing the effect of abrasion. Steel plates are between 0.37 in. and 1 in. thick (Caltrans, 2003).

Figure 1. Invert steel armor plating (Caltrans, 2003)

Figure 2. Finished steel plated invert (Caltrans, 2003)

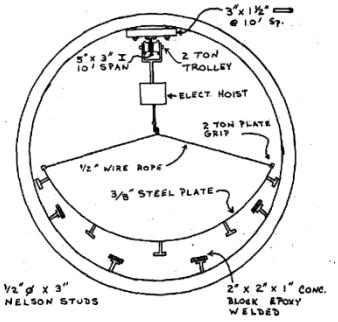

Figure 3. Installation of steel plates (Ikerd, 1984)

Ikerd (1984) reported the use of steel armor plates by Alabama DOT to repair corrugated metal inverts severely deteriorated by abrasion. The project, completed in 1974, repaired the inverts of a triple barrel culvert. Each barrel was 84 in. in diameter and 517 ft long.

Ikerd (1984) provided construction details about this method. Anchors are welded to the existing pipe inverts and a concrete mortar bed placed along the pipes. Next, the steel plates are lowered vertically into the mortar bed. An overhead monorail system attached to the crown of the pipe was used for transporting the steel plates (Figure 3).

3. REFERENCES

Caltrans, 2003. *Caltrans Supplement to FHWA Culvert Repair Practices Manual*, Design Information Bulletin (DIB) No. 83-01, June 2003, 136p.

FHWA, 2003. The Standard Specifications for the Construction of Roads and Bridges on Federal Highway Projects (FP), US DOT, Federal Highway Administration, 718p

Ikerd, S R, 1984. "Invert Replacement of Corrugated Metal. Structural Plate Pipe," *Transportation Research Record 1001*, Symposium on Durability of Culverts and Storm Drains, pp.102-103

Moll, J. 1993. “Paving of Corrugated Metal Pipe Inverts for Repair and Fish Passage,” USDA Forest Service, Technology and Development Program, July 1993, 4p --- 27881.pdf

NCSPA, 1988. Rehabilitation of Steel Pipe and Pipe Lines of Other Materials, Drainage Technology Bulletin, Sep 1988, National Corrugated Steel Pipe Association, Washington, D.C.

ASTM C94 / C94M - 09a Standard Specification for Ready-Mixed Concrete

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