exposed to de-icing salts and freeze-thaw conditions. To do otherwise may cause problems because Nature rejects imperfect work.

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Innovated Repair of a Large Failing Structural Steel Plate Pipe Arch Culvert

CHARLES R. DUNCAN

ABSTRACT

A value-engineering team studied alternatives to replacing a failing structural steel plate pipe arch culvert 14 ft x 9 ft 8 in. x 260 ft long. Their proposal consisted of rolling a slightly smaller asbestos-bonded asphalt-coated pipe through the existing culvert and grouting between them. The cost was $169,957, which represented a savings of $92,000, or 54 percent of the cost to replace the culvert. The contractor's procedures, the problems encountered, and recommendations for future projects of this kind are discussed herein.

A structural steel plate pipe (SSPP) arch culvert 14 ft x 9 ft 8 in. x 260 ft long constructed in 1969 under I-90 in southeastern Montana 7 miles west of Hardin was failing because of severe corrosion. The material hauled in from an adjacent cut was extremely hot; the pH varied between 5.8 and 8.9 with a resistivity range of 125 to 222 ohm-cm. Because of this material, the 12-gauge culvert had an estimated average life of less than 10 years. The native material around the bottom half of the pipe was not corrosive. Typical corrosion in this culvert is shown in Figure 1. The perforations varied in size from that of a fist and smaller.

The initial proposal was to replace the culvert and the surrounding corrosive backfill material. However, the construction procedures would have required temporary shoring and heavy investment in equipment to remove and replace the 20 ft of fill and to replace the pipe. Furthermore, extensive traffic control would have exposed the motorist to unnecessary safety risks. The estimated cost was $262,000.

In light of a then-recent National Highway Institute value-engineering (VE) course, the Montana Department of Highways established a VE team to study the problem. This multidisciplinary team consisted of a hydraulic engineer, a chemist, a district construction supervisor, a roadway designer supervisor, and an FHWA bridge engineer. Based on the VE con-

FIGURE 1 Typical corrosion in culvert.

FIGURE 2 Removing muck with small loader.

cept, the basic functions of the culvert replacement scheme and the associated costs were as follows: traffic maintenance, $93,700; corrosion prevention, $83,300; and water conveyance, $67,000. The team recommendation was to insert a pipe through the existing culvert and grout between them. The pipe was to be an asbestos-bonded asphalt-dipped 10-ft-round corrugated steel pipe arched 11 ft 10 in. x 7 ft 7 in. The estimated savings was 24 percent, or $60,000. (Hydraulically, by considering storage and flood routing, the smaller pipe would still pass the 100-year storm without overtopping the Interstate or causing backwater damages.)

The VE team recommendation was accepted with the exception that the pipe was changed to 10-gauge, 3 x 1-in. corrugated 11 ft 10 in. x 7 ft 3 in. structural plate arch. The corner radii were shop rolled to 31 in. to match the culvert.

There were two major concerns expressed about this concept. First, could the pipe be inserted without the protective coating being scraped off? Because of this concern, the asbestos-bonded asphalt-coated pipe was specified.

Second, for a pipe this large, the insert concept had been largely untested nationally and never had been tested on any scale in Montana. Therefore, concern was expressed that the contractors might shy away from the job or might increase the bid prices to reflect uncertainties. There were 18 bidders with bids ranging from $169,957 to $235,847.36. The engineer's estimate was $246,610. The three low bidders were less than $3,000 (1.6 percent) apart.

CONTRACTOR'S PROCEDURES

The method of installation is best described through a series of steps:

1. The contractor used a small loader and hand labor to remove the 1.5 ft of muck (Figure 2).
2. The contractor rolled the pipe in place on a guide constructed from a 1.5 x 8-ft channel iron. The guide was set to grade every 10 ft and then anchored to the culvert every 3.5 ft (Figure 3). A pit just in front of the cut-off wall provided workmen with access to coat underneath the pipe (Figure 4). To assure that the insert would fit, the contractor assembled a short section of pipe and rolled it through the culvert. It had some ±2 ft of clearance in the tightest spot. Rollers were bolted to the pipe every 12 ft (Figure 5).

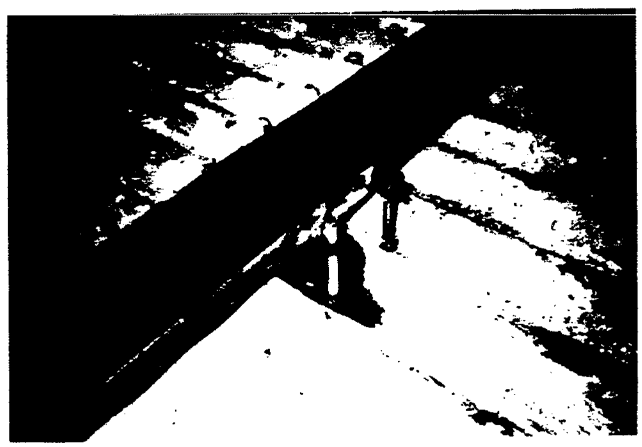

FIGURE 3 Guide for rolling pipe in place.

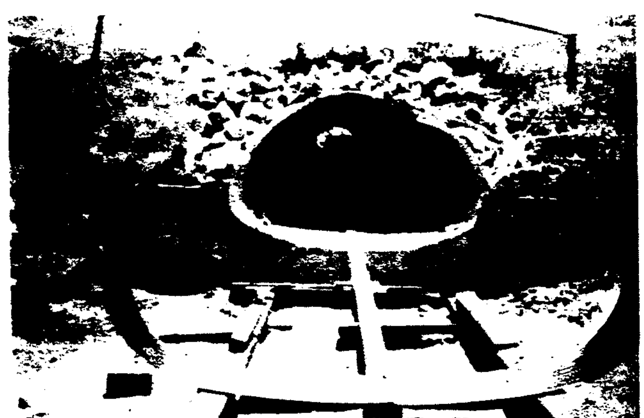

FIGURE 4 Assembly area and channel guide in place.

3. To prevent the pipe from tipping out of the guide, angle iron rub rails 4 in. x 3 in. x 3 ft long were installed every 12 ft at the 5 and 7 o'clock positions on the pipe (Figure 6).
4. The pipe was assembled by bolting together the bottom plates one at a time. Three top plates

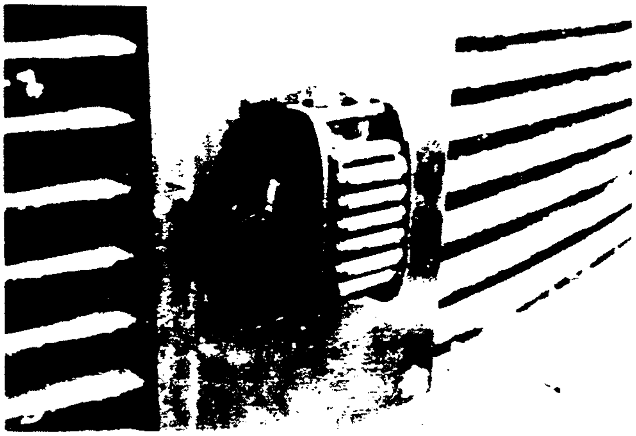

FIGURE 5 Roller system.

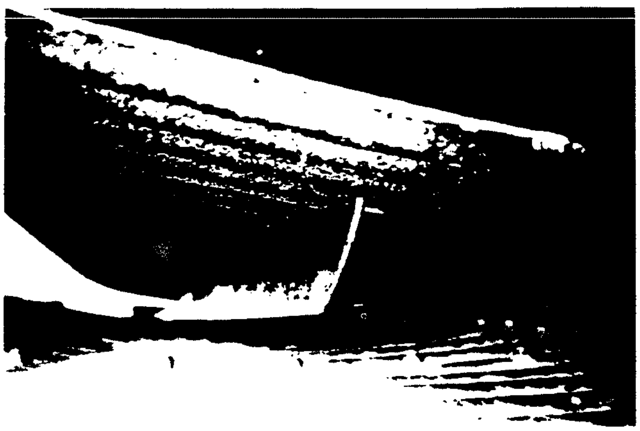

FIGURE 6 Angle iron rub rails to prevent pipe from tipping out of guide.

were assembled on the ground and positioned with the backhoe for bolting to the bottom half (Figure 7).

5. Brackets were installed in the pipe floor (Figure 8) and in the walls of the culvert (Figure 9). The pipe was pulled through the culvert with a 20-ton come-a-long. A view of the partly completed pipe assembly is shown in Figure 10.

6. To prevent the pipe from lifting during the grouting operation, it was anchored to the culvert at the 3, 6, 9, and 12 o'clock positions at 10-ft intervals. The anchor system used a nut welded to a 0.25 x 4 x 9-in. strap iron that was bolted to the pipe during the erection process. After the pipe was in place, a long bolt was threaded up through the pipe and the nut until it contacted the culvert.

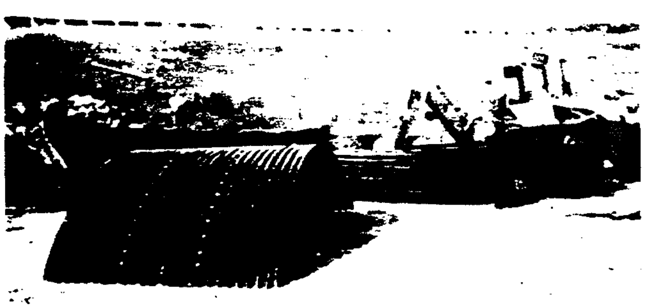

FIGURE 7 Assembly of pipe.

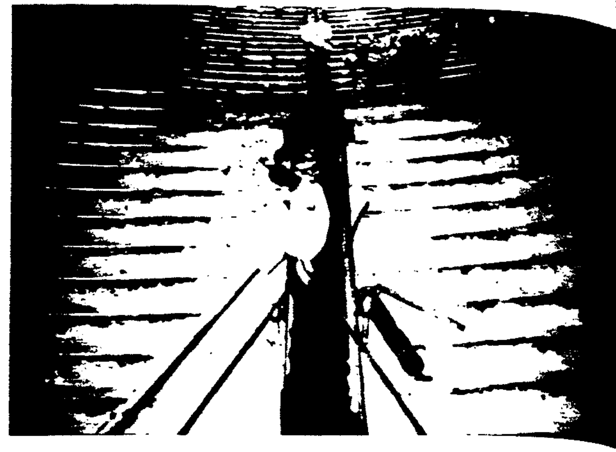

FIGURE 8 Bracket installed in pipe floor.

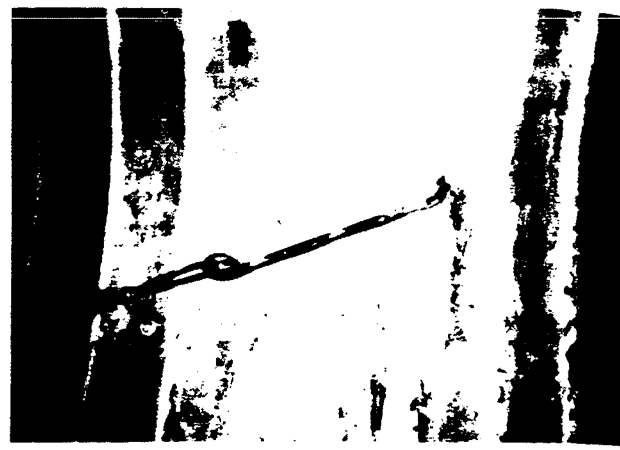

FIGURE 9 Bracket in wall of culvert.

FIGURE 10 Partly completed pipe assembly.

The finished job is shown in Figure 11.

FIGURE 11 Finished SSPP arch culvert.

PROBLEMS ENCOUNTERED AND RECOMMENDATIONS

The following problems were experienced with the insert procedure:

1. The 3 x 1-in. corrugated sheets are fabricated only in plates 2 ft wide. This resulted in there being many bolts to stuff and torque. If three or four plates could be riveted together at the fabrication plant, the field assembly would be closer to multiplate erection with plates 6 or 8 ft wide and bolting will be reduced accordingly.

2. The bolt torque was inconsistent on the first few plates. Further examination revealed that the bolt heads were being pulled through the punched holes. This problem was corrected by using a washer on each side of the plate.

3. Asbestos-bonded asphalt-coated pipe was specified to ensure that the protective coating would not be completely scraped off during the installation process. For the procedure used, the pipe did not touch the existing pipe, so a cheaper coating could have been specified. Furthermore, a standard multiplate arch could have been specified.

The following problems were experienced with the grouting procedure:

1. Three 2-in. holes were provided every 4 ft at the 4, 8, and 12 o'clock positions on the pipe. With the grout holes at the 12 o'clock position, it was difficult to keep the grout flowing evenly to each side. With a large void to be filled, this became a critical element. To overcome this problem, a deflector shield was welded to the inside of the grout hose nozzle that allowed the workers to direct the grout to either side. It is recommended on future projects that grout holes be placed at the 3 and 9 o'clock positions at 8-ft intervals and at the 11:45 and 12:15 o'clock positions at 4-ft intervals, alternating along the centerline.

2. A few small voids were found under the pipe when several bolts were removed for inspection. The voids were filled. To facilitate filling under the bottom of the arch culvert, grout holes should be placed at the 5:45 and 6:15 o'clock positions at 4-ft intervals alternately on either side of the centerline.

3. The grout was pumped through a 3-in. line and the line pressure varied between 1,000 and 1,400 psi. If the grout was stiff, it had a tendency to slightly deform the pipe or float the pipe up. However, when the grout maintained 9 to 10-in. slump, no problems were experienced.

CONCLUSION

The inserted arch was installed with a minimum of difficulty. The contractor used 47 of the 60 working days allowed. No claims or change orders were processed. The final cost was $169,957, which represented a $92,000 savings, or 54 percent of the cost to replace the culvert.

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