CULVERT RENEWAL

Final Report
March 1992

Prepared By

Dave Johnson
Research Operations Engineer

and

John Zollars
Research Assistant

Physical Research Section
Office of Materials and Research
Minnesota Department of Transportation

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the views or policies of the Minnesota Department of Transportation at the time of publication. This report does not constitute a standard, specification, or regulation.

The authors and the Minnesota Department of Transportation do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the objective of this report.
TABLE OF CONTENTS

I. BACKGROUND .................................................. 1

II. PURPOSE .......................................................... 1

III. APPROACH ....................................................... 2

IV. RESULTS .......................................................... 7
   A. OVERVIEW ....................................................... 7
   B. CULVERT REMOVAL AND REPLACEMENT ....................... 8
   C. CULVERT RELINERS ............................................. 10
      1. Smooth Polyethylene with Mechanical Joints
      2. Smooth Polyethylene with Fused Joints
      3. Corrugated Polyethylene
      4. Spiral Ribbed Polyvinyl Chloride
      5. Fiberglass
      6. Spiral Ribbed Coated Steel Arch
      7. Cured Resin Impregnated Felt Tube
   D. CULVERT JOINT REPAIR ....................................... 26
      1. Joint Void Sealing and Filling
      2. Joint Sealing

V. RECOMMENDATIONS ............................................... 31

VI. ACKNOWLEDGEMENTS ............................................. 33

VII. APPENDICES:
   A. PRELIMINARY CULVERT INSPECTION
   B. DRAINAGE CHART FROM PLANS
   C. SAMPLE CULVERT RELINING DATA SHEET
   D. ALTERNATIVE COST TABULATION
   E. ALTERNATIVE TIME REQUIREMENT TABULATION
   F. DISTRICT 8 RELINER INSPECTION NOTES
I. BACKGROUND

The replacement of a deteriorated culvert under a roadway is an expensive proposition. The work required to remove and replace (r & r) such a structure is both disruptive to the driving public and to the structural integrity of the existing pavement. Finding an inexpensive and less disruptive alternative would be very desirable.

Minnesota Department of Transportation (Mn/DOT) Maintenance Area 1A based in Duluth was particularly interested in this problem since their area of operations included soil and moisture conditions conducive to the deterioration of corrugated metal culverts. This situation was not identified until 1969 in the Final Report of Minnesota Department of Highways Investigation Number 116, "Serviceability of Corrugated Metal Culverts". Area roadways designed before 1969 included corrugated metal culverts that are now experiencing high deterioration rates.

II. PURPOSE

The objectives of this research project was to investigate alternative means of culvert renewal in lieu of total replacement, to apply several state of the art renewal techniques, and to collect and evaluate the experiences of performing alternative methods of correcting culvert deterioration problems. These alternatives were to be compared using the following criteria:

Cost
Skills and resources required
Time required
Old culvert preparation
Traffic disruption
Work area requirements
Placement problems
Grouting procedures

Also we wanted to review the field performance of the alternatives after one year in place to evaluate the short term effects of climate.

It was hoped that this research project would lead the department to accept one or more of the alternatives as a less expensive and less disruptive method than culvert replacement, whether done by contract or Mn/DOT maintenance forces. This project should also serve as a basis for evaluating any future culvert renewal products.
III. APPROACH

The following steps outline the approach taken by Mn/DOT in this research project:

1. Evaluate various culvert repair and relining methods and select some viable renewal alternatives.

2. Inspect and identify deteriorated culverts as possible candidates for repair, relining, or replacement.

3. Match the candidate deteriorated culverts to the selected renewal alternatives.

4. Develop plans and special provisions for a culvert renewal project.

5. Observe and evaluate the execution of the culvert renewal contract.

6. Perform post construction evaluation of renewal methods and materials.

7. Write a research report.

A task force met in 1988 and 1989 to identify, evaluate, and specify various proprietary products that would be used in a demonstration culvert renewal project. This Mn/DOT task force represented:

- Central and District Maintenance
- Central and District Hydraulics
- Central and District Design
- District Construction
- District Materials
- Research Administration and Development
- Physical Research
- Standards
- FHWA

Relining pipe materials that were considered included polyethylene, fiberglass, steel, polyvinyl chloride, and a cured resin impregnated felt tube. Since no long term historical experience with relining was available, the task force felt that the reliners should meet the strength requirements of a new installation, if possible. The task force considered methods of repairing concrete pipe joints and of overlaying the deteriorated bottom of a culvert with a concrete overlay. The intent was that these renewal methods would keep traffic disruption to a minimum. In addition, the task force wanted to include a culvert removal and replacement site on the project to provide a basis for comparisons.
On October 18th, 1988 Mn/DOT staff from the Hydraulics Section, Physical Research Section, and District 1A inspected 59 culverts between Reference Posts 165 and 235 on Interstate 35 between Duluth and the Twin Cities. This stretch of I-35 was constructed between 1962 and 1967, thus predating a recommendation not to use corrugated metal culverts in this area. The purpose of this inspection was to identify deteriorated culverts that might be considered for joint repair, relining, or replacement. A summary of that inspection are in Appendix A. The following photographs show examples of deterioration encountered during the inspection:

Joint separation in a concrete culvert.
Extreme deterioration of metal culvert bottom.

Typical deterioration at end of metal culvert.
On January 17th, 1989 the initial recommendations matching specific deteriorated culverts with specific renewal methods were listed. As this original list was modified and refined it became the basis of hydraulic analysis, cost estimates, plans, and special provisions.

One major design concern was hydraulic capacity. Any reliner reduces the cross sectional area of flow of a culvert, although some reliners have a smooth interior which may compensate for the reduction in area. Careful analysis was done to insure that relining was only recommended for culverts that could function adequately with a modified hydraulic capacity. It was determined that relined culverts should have their aprons replaced since they were generally in poor shape as well.

Methods of grouting were evaluated. Two methods of pipe joint repair were developed with modifications. The planned concrete overlays of the deteriorated bottoms of large corrugated steel arch culverts were eliminated when it was discovered that these culverts were more structurally deficient than previously thought.

State Project 0980-122 was let on July 28, 1989. The contract was awarded to the low bidder, Duluth Superior Erection. The contract called for culvert work at 35 sites including 2 replacements, 24 reliners, and 9 joint repairs. Appendix B, the Drainage Chart plan sheet summarizes the planned work. All reliners were to be grouted except for the cured resin impregnated felt tube. Two unique features were included in this contract because of the research element. Video tapes were taken of the interior length of deteriorated culverts after cleaning and again after relining. Also the contractor was asked to participate in a post construction evaluation meeting and to provide time and cost breakdowns for the purpose of comparing alternatives.

Construction began September 23, 1989. In 1989 the contractor completed all relinings, all joint repairs, and some grouting. In the spring of 1990 the contractor completed all culvert replacements and the remainder of the grouting. Contract work was reduced to 25 sites including 2 replacements, 18 reliners, and 5 joint repairs. The major reason for reducing the number of reliners was a difficulty in correctly sizing reliner pipes that would push into deteriorated culverts whose original cross section and profile had changed. This also led to changing the planned reliner at some sites. The reason for reducing the number of joint repair sites was a decision to restrict the use of planned quantity of repairs to the sites and joints most in need of repair. In addition to normal inspection practices this work was monitored by research personnel, was photographed or recorded on video tape, and was documented on "Culvert Relining Data Sheets". See Appendix C.
On April 11, 1991 District 1 Construction and Physical Research personnel conducted a post construction visual inspection of all culvert sites where work was completed under S.P. 0980-122. The air temperature was around 32 degrees Fahrenheit. Some photographs were taken. This inspection revealed that in general all renewal work was performing well approximately 1 year after contract completion. Only a few minor concerns were raised.
IV. RESULTS

A. OVERVIEW

The contents of the result section come from Culvert Relining Data Sheets, Alternative Cost Tabulations (Appendix D), Alternative Time Requirement Tabulations (Appendix E), visual observations, photograph and video tape review, conversations with Mn/DOT construction staff, and conversations with contractor staff. Except for the remove and replace sites traffic control was minimal, that is, mostly restricted to shoulder signing. In a typical relining operation the reliners were chained to a backhoe mounted on a tractor. The reliner was then pushed into the old culvert using movement of the backhoe and tractor. Besides the tractor/backhoe operator, this operation normally included 2 laborers.

Grouting of reliners was generally performed in 3 steps. First the opening between the old culvert and the reliner was mortared shut at both ends, leaving a small opening at the top for inserting the grout pipe and for observation. After the mortar cured, approximately half the required grout was pumped in and cured. This prevented the reliner from floating in the plastic grout. Finally, the remainder of the grout was placed. Typically a 3 person crew was used along with a grout pump. Initially grout was delivered to the site in ready mix trucks, but later the contractor started mixing the grout on site.

The original specification called for a grout mix with course aggregate but was changed to a mix without course aggregate to accommodate pumping. The grout mix used was a Mn/DOT specification 3A grout mix design with cement = 864 pounds per cubic yard, water = 380 pounds per cubic yard, and sand = 2261 pounds per cubic yard. The target air voids was 10% and no fly ash was added to the mix.

It should be noted that for the most part results are from a single project. It is felt that time and cost figures from this project are reasonably representative but may not be reflected in other similar contracts.
B. CULVERT REMOVAL AND REPLACEMENT (R&R)

An existing culvert was removed and replaced at 2 sites. These 2 sites were both at Reference Point 186+0.82, one on the north bound roadway and the other on the south bound. Not only were the culverts at these locations deteriorated but they were also undersized. Relining was not an option because the flow capacity could not be reduced. To increase the flow each existing 36" corrugated metal arch pipe was replaced with 2 new 44" reinforced concrete arch pipes. Because 2 new pipes were placed at each site direct cost comparisons were difficult, but the summary in Appendix D shows an adjusted comparison.

Obviously, this is a very expensive alternative. It was over 4 times more costly than relining a similar sized pipe with a new steel pipe. Most of the cost difference was in labor and equipment costs. Experienced district personnel indicate that culvert R&R under traffic is 5 to 6 times more costly than placing new culvert with no traffic. Culvert R&R can also be costly to the driving public. Each R&R site was reduced from 2 lanes to 1 lane of traffic for about 2 weeks. This delay included concrete cure time, so this delay would be slightly less had they been asphalt pavement sections.

When the culvert R&R sites were revisited about 1 year after their placement they appeared to be in excellent shape. The ride over the replaced concrete panels was very smooth. District inspection staff attributed the smooth ride to the proficient concrete finishers that the contractor had on the project. Experience shows that this is not always the case.

Excavation of old culverts.
Installation of new pipes.

Completed R&R.
C. CULVERT RELINERS

1. Smooth Polyethylene with Mechanical Joints (PEM)

Three 15" PEM reliners were placed in 18" existing culverts at NB 165+0.90 (67'), at NB 166+0.30 (65'), and at SB 175+0.30 (54'). Except for the cost of the pipe these installations were similar to other reliners of similar size. The pipe cost was more because mechanical joints had to be purchased and fused to the pipes. These joints were fused to the pipe at a central site before being hauled to installation sites. These installations required only a tractor backhoe for equipment and very little time. These smooth liners pushed easily and a bullet end improved pushing even more. If work space were a problem these could be pushed one section of pipe at a time, but the contractor preferred to snap all sections together and pushed all at once. In fact the contractor did some minor excavation of the back slope so reliner sections could be pushed all at once.

Grout overruns averaged about 40%. At one site the grout oozed from the shoulder, apparently above a separated joint in the old concrete culvert. When these sites were revisited after one year it was noted that these liners were debonded from the grout, probably because of differences in coefficients of thermal expansion. On the cool day that we reviewed the sites, the polyethylene pipe had shrunk relative to the surrounding grout. This debonding was probably facilitated by the relative smooth surface of this reliner. There is concern that in the long term water will seep between the liner and grout and that freeze/thaw cycling will cause deterioration. Similar liners were installed in the Willmar district in 1988. Twenty of these sites were inspected on May 13, 1991. See summary in Appendix F for inspection notes. Debonding was observed but appears to be restricted to the ends of the 18 inch reliners. All twenty reliners seemed to be in good shape and fully functional after three winters in place. At this point in time there is no observable problem related to this debonding phenomenon. It was noted that these reliners were grouted in one step and therefore reliner floating was observed.
Closeup view showing mechanical joint.

PEM being installed.
Completed PEM installation, showing pipe/grout debonding.
2. Smooth Polyethylene with Fused Joints (PEF)

Two 15" PEF's were installed in the NB lane at 231+0.85 (148') and 234+0.91 (87'). Two 15" PEF's were installed in the SB lane at 171+0.48 (60') and 234+0.98 (134'). The cost of the PEF pipe was slightly less than PEM's, but the fusion of these pipes necessarily had to take place at each site. Where there was sufficient work space, all sections were fused and then pushed at one time. Where work space was limited, part of pipe was pushed, then space was excavated for the fusion machine, more pipe was added, then pushed, and so on. The 2 longer (100'+) culverts contained 30 degree elbows. By dovetailing the lead end of the pipes, they were successfully pushed right through the elbow sections. Generally PEF's pushed easily with a tractor backhoe.

Grout overruns averaged about 25%. When these sites were revisited after one year, the debonding between the grout and the pipe similar to the PEM's was noted.

Dovetailing of lead end of pipes.
Fusion machine in operation.

Inside reliner at elbow.
3. Corrugated Polyethylene (PEC)

Because of liner sizing problems and the necessity of changing liner types for some sites, no PEC's were placed under this contract.

4. Spiral Ribbed Polyvinyl Chloride (PVC)

Two 24" PVC reliners were placed in 30" corrugated metal pipes at Reference Point 185+0.75. One was under the north bound roadway (95') and the other under the south bound (86'). A planned installation on the entrance ramp at NB 195+0.71 was cancelled due to a sizing problem. The material cost of PVC's was relatively inexpensive, but pushing the ribbed reliner a section at a time through a corrugated pipe was somewhat difficult. The ribs tended to catch on the rivets of the existing corrugated metal pipe. The spigot end was the lead end of the pipes when they were pushed, but the ribs on the bell end of these pipes were knocked off to ease pushing. The grout under runs for PVC pipes averaged 7 percent.

One major difficulty with PVC pipe in Minnesota's climate is its brittleness in cold weather. On November 2, 1989 when a PVC pipe was dropped from a truck it came apart at its spiral seams. Obviously pipe can be handled more carefully, but it is difficult to avoid point impact loadings on pipes in real world construction environments. The post construction inspection revealed a small "pop out" near the end of one reliner. Otherwise the installations appeared to be in excellent condition.
Closeup of PVC pipe.

Installation process of PVC reliner.
Unwound PVC pipe.

PVC reliner in place after 1 year.
5. Fiberglass (FG)

Two 21" FG reliners were placed in 24" reinforced concrete culverts at NB 168+0.89 (56') and at SB 168+0.91 (60'). A 21' FG reliner was placed in a 35" span corrugated metal arch culvert on an entrance at NB 191+0.45 (60'). Installation went relatively smoothly, although pushing was a little tougher through corrugated pipe. Pipes were pushed a section at a time with the spigot end leading. Bid prices on FG reliners were generally quite high, probably reflecting a relatively high material cost. As a result total installation costs were quite high for this size of pipe. Also, FG reliners are quite heavy and thus more difficult to handle than other reliners.

Grouting at the 2 sites where concrete culverts were relined over ran an average of 26 percent. At the site where a metal arch culvert was relined the grout under run was 11 percent. The post construction inspection revealed small cracking at the push end of one reliner. Otherwise their condition appeared excellent.
Installation process of FG reliner.

FG reliner in place after 1 year.
6. Spiral Ribbed Coated Steel Arch (ST)

Two ST reliners were installed in corrugated metal arch culverts in exit ramps at NB 191+0.22 (42" span X 58') and at NB 195+0.45 (35" span X 47'). Relining was accomplished by pushing a section at a time. Individual reliner sections were joined by wrapping a steel band around the joint and securing both sides with self tapping sheet metal screws. Although these 2 sites were successfully relined, the pushing of the reliners was very difficult. The ribbing on the reliner caught on the rivets and corrugations of the old culvert. In fact the end section of an old culvert was pushed out of the ground by a reliner that got caught on it during the pushing operation. The contractor found that ST reliners were the most difficult and time consuming to push on the project.

One site had an over run and the other an under run on grout quantities. Both were within 8% of the estimated grout quantity. At both sites there was leakage of grout into the interior of the reliner at joints. The inspection one year after the contract revealed that some of the coating had debonded from the end of the reliner and that some grout remained inside the reliner. Otherwise the reliners were functioning well.

It should be noted that in spite of the difficulties with this reliner option it does allow existing arch culverts to be relined with a minimum of capacity loss.
View of installation operation.

Old culvert end pushed out of ground.
Debonding of coating at end of reliner.
7. Cured Resin Impregnated Felt Tube (RIT)

A total of 4 RIT reliners were installed in existing culverts at NB 166+0.09 (18" diameter X 63'), at NB 185+0.00 (35" span X 184'), at SB entrance ramp 191+0.24 (43" span X 46'), and at SB exit ramp 191+0.52 (35" span X 50'). This relining technique is considerably different than other techniques, requiring a specialized crew to do the installation.

The RIT was initially flexible, similar to an "inside out sock". The open end of the "sock" was fed down into a vertical pipe the bottom of which ended in an elbow near the end of the culvert to be relined. The open end of the "sock" was attached to the elbow end. Then as hot water was pumped into the vertical pipe, the sock was forced into the old culvert and was turned "right side out" in the process. Enough heated water was pumped in to push the "sock" through the entire existing culvert and to cure the resins impregnated in the "sock". All 4 installations on this project were basically completed in 3 days. Three RIT reliners were installed in existing arch pipe. These reliners conformed to the arch shape closely so very little hydraulic capacity was lost.

Because some old culverts were considerably out of shape some minor grouting was required on RIT reliners. However, one reliner was not sized correctly and required 24 cubic feet of grout. The post construction inspection revealed small end cracking in the reliner at the NB 166+0.09 site. All other sites appeared in excellent condition. This method of relining is quite expensive, comparable to the remove and replace option. It is probably better suited to urban rather than rural environments where space and disruption considerations are critical, or to locations that cannot withstand a reduction in hydraulic capacity.
RIT "sock" before installation.

Installation setup for RIT.
End of RIT "sock" reaching end of culvert.

Completed installation.
D. CULVERT JOINT REPAIR

1. Joint Void Sealing and Filling (Seal & Fill)

The Seal & Fill option was planned for 6 sites but was executed at only the 4 sites with the worst joints because of quantity over runs. This repair method was performed on 30" and 36" diameter reinforced concrete culverts at NB 187+0.92 (4 joints), at SB 192+0.70 (6 joints), at NB 192+0.70 (12 joints), and at NB 199+0.50 (17 joints). After cleaning, the work consisted of sealing open joints with a rubber seal held in place with expandable steel bands then pumping a two component chemical grout into the void behind the seal. Voids behind joints received from 1.1 to 12.8 gallons of chemical grout. Once placed behind the joint seal this chemical grout expanded into the void and solidified. Two to four people worked at sealing joints. A pump operator and two laborers performed the sealing.

The fitting that combined the two grout components and directed them through the seal tended to clog up as the operation moved from one seal to another. A considerable amount of time was lost keeping these fittings clean. Samples of the combined chemical grout were taken by the Mn/DOT field inspector. As these samples were left exposed to air they continued to shrink. This raises a concern about the long term void filling performance of the chemical grout. The Seal & Fill operation cost $1500 per joint plus $17.50 per gallon of grout placed. The post construction inspection of the treated joints was inconclusive because of the inability to inspect the voids and the fact that water was flowing through the culverts. From the culvert ends it appeared that the seals were remaining in place.
Chemical grout pumping operation.

Interior of sealed and filled culvert.
2. Joint Sealing (Seal Only)

The Seal Only option was originally planned for 3 sites but was eliminated at two sites because the planned quantity of work was reached at the one site (NB 194+0.40) with the worst joints. After the joints were cleaned the following 4 joint sealing methods were used on 6 joints each in the 84" reinforced concrete culvert:

a. A silicone joint sealant over a backer rod.

b. An activated oakum process distributed by Avanti International.

c. An open celled backer rod treated with a 3M chemical.

d. Metal ties were placed across 3 joints on each end of the culvert.

From the construction inspector's notes: Method a. was the easiest and appeared to give the best seal. Method b. seemed to work alright but required more work. Method c. proved somewhat difficult because the backer rod would not stay in place at the top of the culvert joint. Method d. is not really comparable because it is meant to hold the joints together, not seal them.

Water was flowing through this culvert during the post construction inspection so results are inconclusive at this time.
Activated oakum sealant.

Open celled backer rod treated with a 3M chemical.
Metal ties to hold joints together.
V. RECOMMENDATIONS

A. Culvert relining can be a viable, inexpensive, and minimally disruptive alternative for culvert repair when cross sectional area reduction is allowable. Mn/DOT should use it more often. Some of the following recommendations and previous text further define how to best accomplish relining.

B. Reliners with smooth exteriors should be used whenever possible. Grout debonding is not considered a serious problem. Smooth reliners push through old culverts better than reliners with rough (corrugated or ribbed) exteriors and perform better hydraulically. The most difficult push was a rough reliner going through an old corrugated culvert.

C. Both smooth exterior polyethylene reliners proved to be relatively inexpensive, flexible, and easy to install. The use of larger size and arch shaped polyethylene reliners should be explored. Methods of maintaining the grout/reliner bond must be explored further with this option.

D. This project showed that arch shaped reliners could be pushed into existing arch shaped culverts, thus maintaining considerable hydraulic capacity. Because old and new pipes were rough this proved to be one of the most difficult pushes, but other lessons learned on this project could reduce future difficulties.

E. One of the biggest difficulties of the project was to correctly measure the size and shape of old culverts so a proper size reliner could be selected. Perhaps pipe deflection gauges or sized cleaning balls are tools that can be used to improve pre-design inspection. At any rate pipe cleaning needs to take place before the pre-design inspection.

F. This project demonstrated that most reliners can be installed without specialized equipment or large manpower requirements. Cost savings realized by relining, as compared to replacing, could certainly justify the purchase of a department polyethylene fusion machine or pipe cleaning equipment. Mn/DOT maintenance forces are certainly capable of doing this type of work and should be encouraged to do so starting with easier relining projects.
G. Further post construction inspection is needed. The joint repair culverts need to be inspected during the next low water season and all project culverts should be reinspected periodically.

H. Grouting should be done in two stages to avoid reliner floating. This makes for better culvert geometry.

I. The inlet geometry can be improved by placing mortar in a taper at the entrance to the culvert, thus eliminating the abrupt vertical end of the reliner.
VI. ACKNOWLEDGEMENTS

The efforts of all the members of the task force made the development of this project possible. Their work is greatly appreciated. Special thanks is extended to the maintenance, design, and construction personnel from Mn/DOT District 1 in Duluth who turned ideas into reality.
APPENDIX A

PRELIMINARY CULVERT INSPECTION
APPENDIX B

DRAINAGE CHART FROM PLANS
**DRAINAGE CHART**

<table>
<thead>
<tr>
<th>STATION</th>
<th>REF.PT.</th>
<th>RAS</th>
<th>EXISTING STRUCTURE</th>
<th>APFGD</th>
<th>REMOVE</th>
<th>PIPE</th>
<th>PROPOSED CONSTRUCTION</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>27+00</td>
<td>139.92</td>
<td>R.B.</td>
<td>48' x 18' CHP + 2 APRONS</td>
<td>3.7</td>
<td>-</td>
<td>Initi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26+40</td>
<td>139.51</td>
<td>R.B.</td>
<td>48' x 18' CHP + 2 APRONS</td>
<td>3.7</td>
<td>-</td>
<td>Initi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25+00</td>
<td>126.52</td>
<td>R.B.</td>
<td>36' x 18' CHP + 2 APRONS</td>
<td>3.2</td>
<td>-</td>
<td>Initi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21+00</td>
<td>105.87</td>
<td>R.B.</td>
<td>56' x 26' CHP + 2 APRONS</td>
<td>3.5</td>
<td>-</td>
<td>Initi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19+70</td>
<td>101.36</td>
<td>R.B.</td>
<td>42' x 26' CHP + 2 APRONS</td>
<td>2.7</td>
<td>-</td>
<td>Initi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18+00</td>
<td>99.82</td>
<td>R.B.</td>
<td>48' x 36' CHP + 2 APRONS</td>
<td>3.2</td>
<td>-</td>
<td>Initi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17+50</td>
<td>96.97</td>
<td>R.B.</td>
<td>48' x 36' CHP + 2 APRONS</td>
<td>7.3</td>
<td>2</td>
<td>Initi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17+00</td>
<td>96.42</td>
<td>R.B.</td>
<td>48' x 36' CHP + 2 APRONS</td>
<td>3.4</td>
<td>2</td>
<td>Initi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16+00</td>
<td>95.97</td>
<td>R.B.</td>
<td>48' x 36' CHP + 2 APRONS</td>
<td>10.2</td>
<td>2</td>
<td>Initi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15+00</td>
<td>94.97</td>
<td>R.B.</td>
<td>48' x 36' CHP + 2 APRONS</td>
<td>13.3</td>
<td>2</td>
<td>Initi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14+00</td>
<td>93.97</td>
<td>R.B.</td>
<td>48' x 36' CHP + 2 APRONS</td>
<td>16.2</td>
<td>2</td>
<td>Initi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13+00</td>
<td>92.97</td>
<td>R.B.</td>
<td>48' x 36' CHP + 2 APRONS</td>
<td>19.2</td>
<td>2</td>
<td>Initi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12+00</td>
<td>91.97</td>
<td>R.B.</td>
<td>48' x 36' CHP + 2 APRONS</td>
<td>21.7</td>
<td>2</td>
<td>Initi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11+00</td>
<td>90.97</td>
<td>R.B.</td>
<td>48' x 36' CHP + 2 APRONS</td>
<td>23.7</td>
<td>2</td>
<td>Initi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10+00</td>
<td>90.04</td>
<td>R.B.</td>
<td>48' x 36' CHP + 2 APRONS</td>
<td>24.4</td>
<td>2</td>
<td>Initi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9+00</td>
<td>89.04</td>
<td>R.B.</td>
<td>48' x 36' CHP + 2 APRONS</td>
<td>24.4</td>
<td>2</td>
<td>Initi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8+00</td>
<td>88.04</td>
<td>R.B.</td>
<td>48' x 36' CHP + 2 APRONS</td>
<td>24.4</td>
<td>2</td>
<td>Initi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7+00</td>
<td>87.04</td>
<td>R.B.</td>
<td>48' x 36' CHP + 2 APRONS</td>
<td>24.4</td>
<td>2</td>
<td>Initi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6+00</td>
<td>86.04</td>
<td>R.B.</td>
<td>48' x 36' CHP + 2 APRONS</td>
<td>24.4</td>
<td>2</td>
<td>Initi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5+00</td>
<td>85.04</td>
<td>R.B.</td>
<td>48' x 36' CHP + 2 APRONS</td>
<td>24.4</td>
<td>2</td>
<td>Initi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4+00</td>
<td>84.04</td>
<td>R.B.</td>
<td>48' x 36' CHP + 2 APRONS</td>
<td>24.4</td>
<td>2</td>
<td>Initi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3+00</td>
<td>83.04</td>
<td>R.B.</td>
<td>48' x 36' CHP + 2 APRONS</td>
<td>24.4</td>
<td>2</td>
<td>Initi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2+00</td>
<td>82.04</td>
<td>R.B.</td>
<td>48' x 36' CHP + 2 APRONS</td>
<td>24.4</td>
<td>2</td>
<td>Initi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1+00</td>
<td>81.04</td>
<td>R.B.</td>
<td>48' x 36' CHP + 2 APRONS</td>
<td>24.4</td>
<td>2</td>
<td>Initi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0+00</td>
<td>80.04</td>
<td>R.B.</td>
<td>48' x 36' CHP + 2 APRONS</td>
<td>24.4</td>
<td>2</td>
<td>Initi</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**LEGEND**

- **CMP** = CORRUGATED METAL PIPE
- **RCP** = REINFORCED CONCRETE PIPE
- **CMPA** = CORRUGATED METAL PIPE ARCH
- **IPPLFJ** = INSERT PE PIPE LINER, BUTT FUSION JOINTS
- **IFPL** = INSERT FIBERGLASS PIPE LINER
- **ICPPLS** = INSERT CP PIPE LINER, SMOOTH INTERIOR
- **IPVCPLR** = INSERT PVC PIPE LINER, RIBBED
- **IRR** = INVERT RESIN IMPREGNATED TUBE
- **IPORPRL** = INSERT PC-XRS PIPE LINER
- **IPJSS** = INTERNAL PIPE JOINT SEALING SYSTEM
- **SPJTS** = SEAL PIPE JOINTS
- **IPPLJI** = INSERT PE PIPE LINER, MECHANICAL JOINTS
- **RCPA** = REINFORCED CONCRETE PIPE ARCH

---

(1) REMOVE 18" THICK
(2) EXCISE 12" THICK
APPENDIX C

SAMPLE CULVERT RELINING DATA SHEET
CULVERT RELINING DATA SHEET

Location:
Reference Post (i.e., 185.66) = NB SB (Circle One)

Type of Pipe (Choose one of the following.)
CMPA Span = Rise = (inches)
CMP Diameter =
RCP Diameter =
RCPA Span = Rise =

OTHER: Please be specific and include dimensions.

Type of Liner (Indicate Number)
1) Polyethylene Butt Fusion 2) Polyethylene Mechanical Joints
3) Corrugated Polyethylene 4) Spiral Ribbed Steel Liner
5) Fiberglass Liner 6) Corrugated Poly, Smooth Interior
7) Ribbed PVC Liner 8) Insituform Liner
9) Internal Joint Sealing 10) Seal Pipe Joints

Other Information:
Please indicate the date, the skill level and number of people in the crew, and the time required to complete the following operations.

Clean the Pipe:
Video Tape:
Relining:
Grouting:
Joint Repair (if applicable)
Video Tape (2nd take)

Was traffic control necessary? Yes No (Circle One)
If yes, what type?

General Comments: (i.e., condition of the pipe, was it necessary to dig the backslope, was this a particularly difficult relining or grouting operation? Please indicate any unique environmental conditions and the date they occurred (i.e., cold weather, under water, etc.). Use backside of this sheet if necessary.)
APPENDIX D

ALTERNATIVE COST TABULATION
<table>
<thead>
<tr>
<th></th>
<th>CONVENTIONAL</th>
<th>RELINING</th>
<th></th>
<th>TOTAL</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traffic control</td>
<td>Clean pipe</td>
<td>Cost of pipe</td>
<td>Labor &amp; Equipment</td>
<td>Cement grout</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>44&quot; Concrete</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>arch pipe</td>
<td>$5900</td>
<td></td>
<td>$7500</td>
<td>$42720</td>
<td></td>
<td>$56120</td>
</tr>
</tbody>
</table>

**RELINING**

<table>
<thead>
<tr>
<th></th>
<th>Traffic control</th>
<th>Clean pipe</th>
<th>Bid cost of pipe</th>
<th>Cement grout</th>
<th>TOTAL Labor &amp; Equipment</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyethylene</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>with butt fusion joints</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15&quot;</td>
<td>$263</td>
<td>$637</td>
<td>$1500</td>
<td>$1058</td>
<td>$3,458</td>
<td>$514</td>
</tr>
<tr>
<td>with mech. joints</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15&quot;</td>
<td>$263</td>
<td>$637</td>
<td>$1875</td>
<td>$1058</td>
<td>$3833</td>
<td>$425</td>
</tr>
<tr>
<td>Fiberglass</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21&quot;</td>
<td>$263</td>
<td>$637</td>
<td>$5625</td>
<td>$2565</td>
<td>$9090</td>
<td>$825</td>
</tr>
<tr>
<td>Polyethylene</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>corrugated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15&quot;</td>
<td>$263</td>
<td>$637</td>
<td>$1125</td>
<td>$1058</td>
<td>$2025*</td>
<td></td>
</tr>
<tr>
<td>20&quot;</td>
<td>$263</td>
<td>$637</td>
<td>$1500</td>
<td>$1058</td>
<td>$2400*</td>
<td></td>
</tr>
<tr>
<td>PVC RIBBED</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17&quot;</td>
<td>$263</td>
<td>$637</td>
<td>$1500</td>
<td>$3238</td>
<td>$6163</td>
<td>$542</td>
</tr>
<tr>
<td>24&quot;</td>
<td>$263</td>
<td>$637</td>
<td>$2025</td>
<td>$3238</td>
<td>$6163</td>
<td>$542</td>
</tr>
<tr>
<td>Coated steel</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35&quot;</td>
<td>$263</td>
<td>$637</td>
<td>$5625</td>
<td>$5137</td>
<td>$11662</td>
<td>$1500</td>
</tr>
<tr>
<td>42&quot;</td>
<td>$263</td>
<td>$637</td>
<td>$6375</td>
<td>$4856</td>
<td>$12131</td>
<td>$938</td>
</tr>
<tr>
<td>Insituform</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17&quot; span 22&quot; rise</td>
<td>$263</td>
<td>$637</td>
<td>$16500</td>
<td>$17400</td>
<td>**</td>
<td></td>
</tr>
<tr>
<td>35&quot; span 27&quot; rise</td>
<td>$263</td>
<td>$637</td>
<td>$22500</td>
<td>$23400</td>
<td>**</td>
<td></td>
</tr>
<tr>
<td>43&quot; span 27&quot; rise</td>
<td>$263</td>
<td>$637</td>
<td>$37500</td>
<td>$38400</td>
<td>**</td>
<td></td>
</tr>
</tbody>
</table>

* were not installed
** Labor & equipment cost on relining was part of bid price
APPENDIX E

ALTERNATIVE TIME REQUIREMENT TABULATION
<table>
<thead>
<tr>
<th>Material</th>
<th>First Lane &amp; Shoulder</th>
<th>Second Lane &amp; Shoulder</th>
<th>Relining</th>
<th>Grouting</th>
<th>Total Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>44&quot; Concrete Arch Pipe</td>
<td>8 hr</td>
<td>8 hr</td>
<td>8 hr</td>
<td>8 hr</td>
<td>8 hr</td>
</tr>
<tr>
<td></td>
<td>4 hr</td>
<td>8 hr</td>
<td>8 hr</td>
<td>8 hr</td>
<td>8 hr</td>
</tr>
</tbody>
</table>

**RELINING**

<table>
<thead>
<tr>
<th>Material</th>
<th>Cleaning</th>
<th>Relining</th>
<th>Grouting</th>
<th>Total Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyethylene</td>
<td>1.0 hr</td>
<td>2.30 hr</td>
<td>2.10 hr</td>
<td>5.40 hr</td>
</tr>
<tr>
<td>with butt fusion joints</td>
<td>1.0 hr</td>
<td>0.75 hr</td>
<td>1.30 hr</td>
<td>3.05 hr</td>
</tr>
<tr>
<td>with mech. joints</td>
<td>1.0 hr</td>
<td>0.75 hr</td>
<td>1.30 hr</td>
<td>3.05 hr</td>
</tr>
<tr>
<td>PVC Ribbed</td>
<td>1.0 hr</td>
<td>3.75 hr</td>
<td>1.88 hr</td>
<td>6.63 hr</td>
</tr>
<tr>
<td>Coated Steel</td>
<td>1.0 hr</td>
<td>2.00 hr</td>
<td>3.17 hr</td>
<td>6.17 hr</td>
</tr>
<tr>
<td>Fiberglass</td>
<td>1.0 hr</td>
<td>1.75 hr</td>
<td>2.70 hr</td>
<td>5.45 hr</td>
</tr>
<tr>
<td>Insituform</td>
<td>1.0 hr</td>
<td>5.50 hr</td>
<td>5.50 hr</td>
<td>6.50 hr</td>
</tr>
<tr>
<td>35&quot; span 22&quot; rise</td>
<td>1.0 hr</td>
<td>7.25 hr</td>
<td>7.25 hr</td>
<td>8.25 hr</td>
</tr>
<tr>
<td>43&quot; span 27&quot; rise</td>
<td>1.0 hr</td>
<td>7.25 hr</td>
<td>7.25 hr</td>
<td>8.25 hr</td>
</tr>
</tbody>
</table>
John Zollars, Art Bolland, and I inspected 20 culvert relining sites constructed in 1988 in District 8. All sites included smooth wall butt fused polyethylene (PE) reliners with grout placed between the reliner and the old culvert. The purpose of this inspection was to further investigate a concern raised by a 4/11/91 inspection of the 1989 relining research project on I-35 in the Hinkley area. The concern was that smooth wall PE reliners on I-35 exhibited a debonding from the mortar headwall. We wanted to see if a similar debonding or any related problems were visible on older, but otherwise similar, installations.

The air temperature was around 70 to 80 degrees F. Ten sites on TH 71 between TH 14 East and TH 68 West were visited. All sites had 18" reliners in 24" circular concrete culverts. Each exhibited longitudinal (typically 1.5" total) and radial shrinkage (typically less than 1/4") with debonding. The inside of the reliners were tapped with a wrench and it sounded like debonding was present only at the ends, at the mortar headwalls. However, this conclusion was very subjective and could not be verified. Each reliner was grouted completely at one time rather than in two stages, so some floating of the reliners was observed. These ten sites were roughly at the following reference points (RP): 55.7, 59.4, 59.8, 60.2, 61.2, 61.5, 61.7, 62.2, 64.7, and 65.5.

Ten sites on TH 59 from North of Slayton to TH 30 were also visited. Nine of these sites were 18" reliners in arch or circular concrete culverts. Each exhibited longitudinal (typically 1.5" total) and radial shrinkage (typically less than 1/4") with debonding. Again the inside of the reliners were tapped with a wrench and it sounded like debonding was present only at the ends and some floating of the reliners was observed. These nine sites were roughly at the following RP's: 42.6, 42.8, 43.1, 43.3, 44.4, 45.6, 45.9, 46.8, and 46.9. In addition at roughly RP 45.4 a 30" reliner was placed in a 36" circular concrete culvert. More significant radial shrinkage was observed at this site and tapping seemed to indicate that debonding occurred at least as far as I could reach inside the culvert. No floating was observed at this site but the reliner did appear to be slightly out of round, perhaps due to the weight of the grout above it.

In summary, debonding was observed but may have been restricted to the ends for the 18" reliners. All twenty reliners seemed to be in good shape and fully functional after three winters in place. At this point in time there is no observable problem related to the debonding phenomenon.