

Montana Department of Transportation
Research Programs
October 2008

Experimental Project Construction Report

HIGHWAYS FOR LIFE (HFL) CULVERT REHABILITATION PROJECT

Project Name: NH-HFL 8-1(30)23 MacDonald Pass Guardrail/Erosion

FHWA Project Number: MT 00-17

Project Location: MacDonald Pass; Powell and Lewis & Clark Counties –
The eleven mile project is located approximately 15 miles west of Helena on US 12 (N-8) between RP 23.2 and RP 34.2: The section of the project which contains the experimental portion is located approximately between RP 26.0 and RP 27.0 on the west side of MacDonald Pass

Description: The relining of 10 (ten) 24” (610 mm) corrugated steel pipe (CSP) culverts with two type of lining applications; Cure In-place Pipe (CIPP) and seam welded High-density Polyethylene Pipe (HDPE). The ten culverts were split evenly for each treatment.

Date of Installation: September 2008

Principal Investigator: Craig Abernathy
Experimental Program Manager

Prime: Helena Sand & Gravel (Subcontractor germane to this report was PEC Inc.)

Objective

This project was nominated by the Montana Department of Transportation (MDT) through the Federal Highway Administration (FHWA) Highways for LIFE (HfL) pilot program to promote the adoption of innovations and new technologies, thereby improving safety and highway quality while reducing congestion caused by construction.

The qualification for the HfL requirement was the use of CIPP and HDPE application to reline the existing CSP which required no excavation or lane closures during those procedures. This in turn eliminated congestion, traffic delay, and potential safety issues which would normally occur during a conventional culvert replacement project.

Documentation

The purpose of this report is to document the processes involved in the installation of the two stated procedures. Information collected will include visual representation of the installations to denote the specific application, applicable anecdotal support, and any

construction issues that may affect performance of the treatments during the ongoing analysis and determination of performance. This report is for the needs of the experimental evaluation and not meant to replace any other project related documentation. Images contained in this report represent the practice per application and examples of procedure may be taken from different locations on the project.

Climatic conditions during installations ranged from snow and cold to warm and sunny.

CIPP and HDPE site locations are physically marked on the eastbound outside lane (approximately RP 26-27) as follows:

<u>Field Mark</u>	<u>Stationing</u>
1-HDP	184+18
2-HDP	189+47
3-CIP	194+99
4-CIP	199+97
¹ 5-CIP	206+44
6-HDP	209+71
7-CIP	213+29
8-HDP	216+98
9-CIP	221+61
10-HDP	230+58

¹This site of the CSP culvert had a broken cleaner head within the line located approximately 30' from the culvert inlet on the westbound side. The contractor initially attempted to remove the head. Eventually, the contractor was forced to excavate the roadway to the CSP and had to cut the CSP to remove the broken cleaner head. The CSP was replaced, back fill restored, and the area paved in preparation for the CIPP installation.

Project Summary to Date

All installations of the CIPP and HDPE sections were reported with no construction issues that may affect ongoing performance.

Future documentation of project performance will entail two site visits per year (early spring/late fall) to detail each application through visual representation, to be followed up with an annual report. A final report assessing both culvert rehabilitation practices will be available in 2013.

All current information available regarding this project can be found at:

http://www.mdt.mt.gov/research/projects/macpass_culvert.shtml

CURE IN-PLACE PIPE (CIPP)

CIPP is a liner that can structurally renew aging collection systems. This process involves the resin-impregnation of a polyester felt lining manufactured to whatever desired interior diameter of pipe required, up to 120", (3 meters). This resin impregnation is done off-site at the installer's facility. It is then placed in a refrigerated truck for delivery to the construction site. Since curing begins once the resin has been mixed it is imperative that the product remains below 20° F (-9° C), this will retard the setting process until it is ready for insertion and final cure.



View of CSP inlet prior to insertion of CIPP liner. During insertion the installer does angle the incoming liner towards the opening as best as can be managed. The liner under pressure does follow the path of least resistance.



View of outlet end of a typical CSP on project.



In addition to using a refrigerated truck, ice is layered several bags thick on the truck bed to insure the liners temperature is low enough to impede setting until the steam cure phase.



The CIPP liner is being pulled out of the refrigerated truck in preparation for insertion into the CSP. Normally the resin is clear in color. A dye has been added to better aid in the final inspection once the cure is complete.



Close-up view of the polyester (non-impregnated) liner. It has three separate layers with the outer (thinner) layer having a tighter (or denser) weave than the two inner layers. Once cured, all layers will be bonded as one. The denser layer will be the new interior of the culvert.



Here the installers have cut each layer of the felt which allows the liner material to be inverted (or peeled back against itself) for placement into the CIPP inversion shooter.



Next a propane heated corer removes a three inch circular portion of the felt liner. This hole will be for the placement of the air line which will be used to pressurize the liner to push (or shoot) the liner through the CSP. A board is placed between the CIPP liners to prevent an accidental burn-through to the other side.



Close-up of the hole through all three felt layers created for the air pressure line.



A compression bracket is attached on either side of the liner layers to allow the air line to be connected to the inverted liner for the pressure flow.

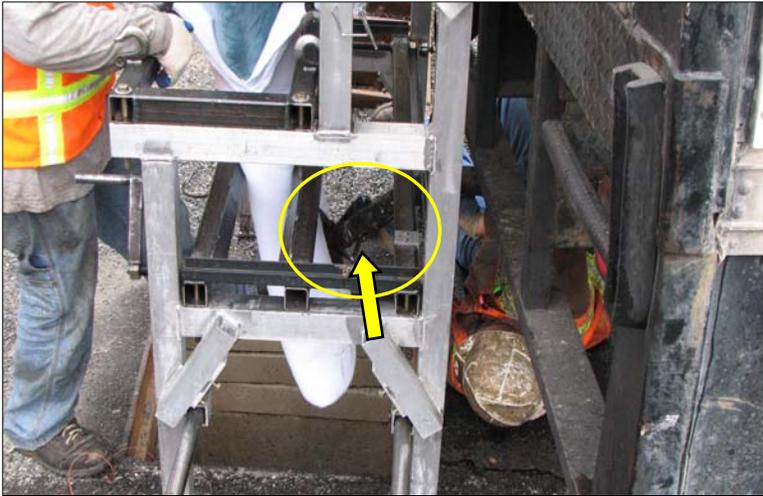


The inverted CIPP liner is then placed within the inversion shooter which is directly over the opening of the CSP culvert (inlet). All of the CIPP applications (five in total) were located at the intake flow of the culverts. The inversion shooter is designed to hold the exterior of the liner in place while the liner is pressurized for its travel through the CSP.

Note the rows of hooks on each side of the pressure bracket (red arrows).

In the image below, the contractor cuts a slot in the liner layers which allows the felt material to be secured in place by the hooks on both sides of the split liner (red arrows).

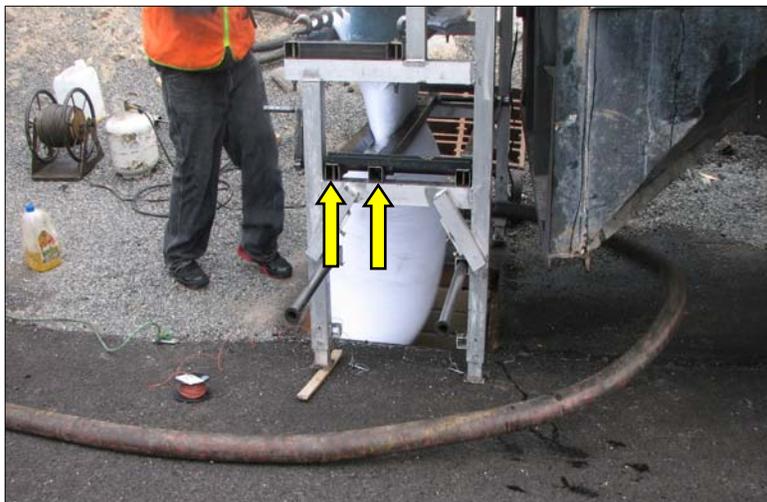




The contractor now connects the air hose to the air bracket previously attached to the liner (yellow arrow).



Air is now being pumped into the inverted liner at an average pressure of 12 pounds per square inch (PSI).



The CIPP is now fully expanded and beginning to be pushed (or flow) towards the entrance of the CSP. Note that the liner has been compressed by a vice (yellow arrows), that allows the installer to control the flow of the liner and to insure adequate air pressure to maintain the flow.



In the above image the inverted CIPP is just beginning to exit the outlet of the CSP. On average with the MacDonald pass installations (based on an average 130' CSP length); the time for complete liner insertion phase was at thirty minutes. Below, the liner is almost fully extended.





The CIPP has fully exited the outlet end of the CSP and released the air pressure which had forced it through the culvert (yellow arrow). Since the liner was initially inverted it retained a natural plug until it reached the end of the cut length of the CIPP. Now fully deflated, the liner is ready for the curing phase as seen below.





The installer places a large rubber plug on the inside discharge end of the CIPP (outlet). It is sewn in by the inner layers with rope. The plug has two connections at the end which allow the attachment of the smaller air line (red arrow) and the larger steam line (yellow arrow). The air line will be used to expand the CIPP to conform to the interior of the existing CSP. The steam line is for the actual curing of the liner.



Air is now inflating the CIPP liner. Once fully inflated, steam will be injected into the liner at an average of 5 PSI and an average temperature of 235° F (113° C). Note that air (under pressure) alone can complete the cure, however by using steam heat it decreases the cure time down from 2-3 weeks to 1.5 hours.



Image showing the CIPP on the outlet side under steam load for cure.



Steam exiting at the inlet end of the inversion shooter.



The CIPP has been allowed to cool for 1.5 hours after the completion of the steam phase. The plug has been removed and the CIPP is trimmed flush to the CSP.



View at complete cure at the inlet of the CIPP with the inversion shooter removed, ready for trimming.



The excess CIPP is cut away using a conventional knife (for the uncured felt) and a sawzall for the cured CIPP.



A close-up image of the fully cured CIPP. Note how all three polyester felt layers are bonded as one rigid composite. Average thickness of cured liner is at 5/8" (16 MM).



The contractor performs an interior inspection with a tractor mounted, remote-controlled closed circuit camera (CCTV) to insure proper placement of the CIPP.



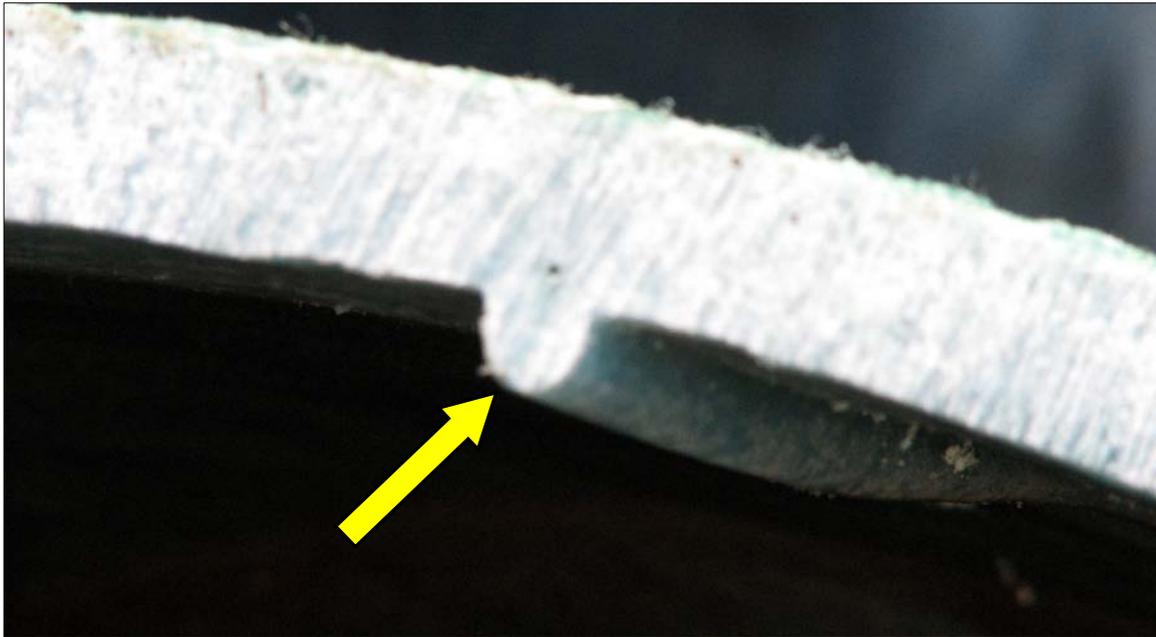
Completed CIPP at inlet



Completed CIPP at outlet. Fiber-meshed grout was used to seal the end treatments. Note that this type of culvert rehabilitation retains almost full capacity of the original culvert. Due to the reduced roughness of the liner (height loss of corrugation of the CSP due to the CIPP) may improve the hydraulic characteristics of the culvert; but that is speculation.

CIPP Supplemental: Finning

A condition called 'finning' may occur to the CIPP liner during insertion into the existing culvert. Finning is where the liner(s) may bunch up prior to curing and create a ripple in the polyester fabric or fin as seen in the below image (a cured section of excess liner). A severe fin may indicate a thinning or tear in the membrane of the liner which may affect performance of the CIPP. This condition is more of an issue with larger diameter liners than what was used on the MacDonald Pass project. Finning with less than 1 inch (25 mm) on the 24" lined CIPP is not considered a performance issue. No detrimental finning was found on any of the CIPP installations.



High Density Polyethylene Pipe (HDPE) Liner

This application involves the insertion of an HDPE 18" (46 MM) outside diameter, pipe wall thickness approximately 3/4", (19 MM), smooth exterior/interior. With a delivered length of 25' (7.6 meters). Pipe sections were prepared on site for the length required and insertion into the existing 24" CSP. The following images describe the processes for this particular procedure.



Using the excavator stick the HDPE is placed and locked into the McElroy Plastic Pipe Fuser.



The pipe fuser is then adjusted to align each ends of the pipe on center for the welding procedure. Note the device as shown by the red arrow. This trims the ends.



Prior to the fusing phase, the ends of the pipes must be trimmed to not only insure good alignment but to remove any imperfections, dirt or grease that may inhibit the quality of the weld.



The cutting tool has three razor sharp blades on both sides (refer to yellow arrows). As it rotates, the fusing device slowly pushes the ends of the pipe against the cutter as it evenly carves plastic off the ends equally until the technician is certain both ends are clean, uniform, and free of defects.

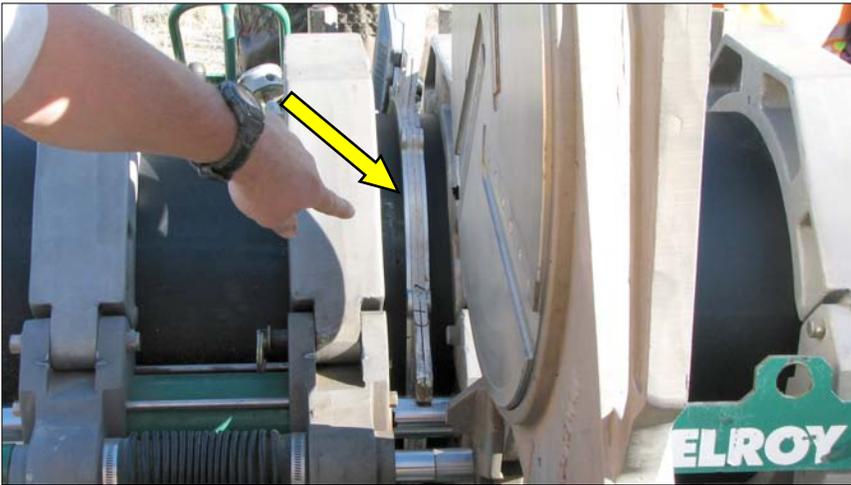


In this image the cutting device is in use. You can see shavings exiting from the bottom of the cutter (red arrow). Up to a 1/4" per side may be removed.



This image shows the electric iron (being stored in a heatproof holder) that will be used to heat each end of the HDPE sections.

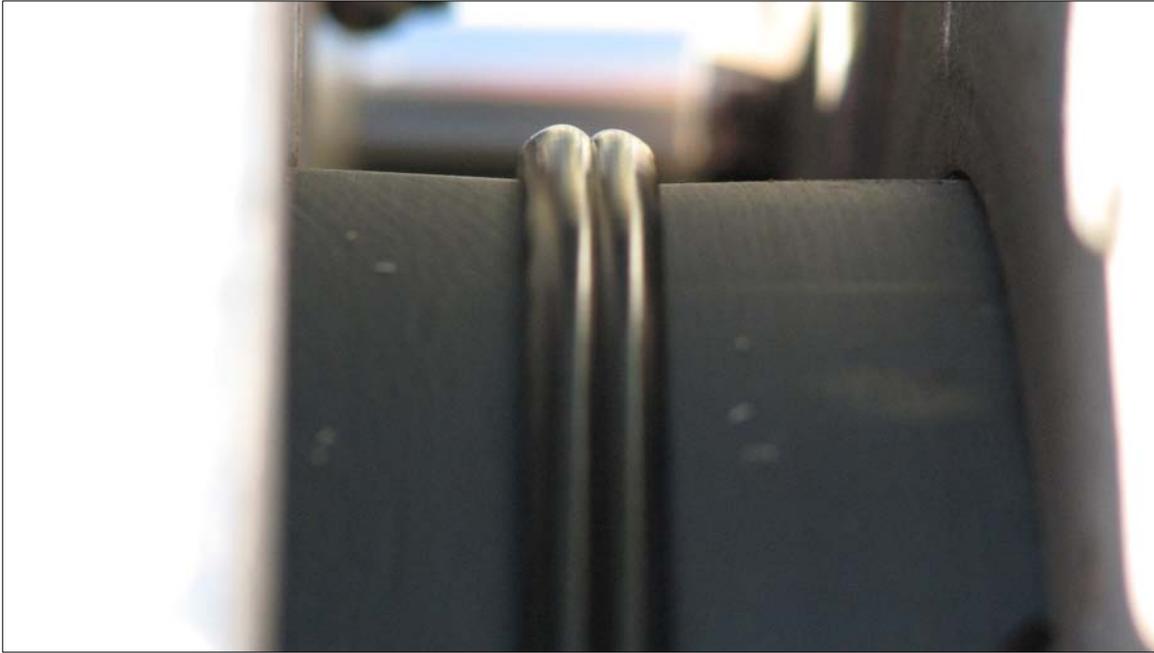
The iron is round in shape slightly larger in diameter than the pipe.



The pre-heated iron is now placed between the pipe sections. The pipe is then compressed against the iron. The contractor is pointing to the edge of the iron where the plastic is beginning to melt and form a bead.



As you can see a bead is beginning to form at the edge of the HDPE as it is being pressed against the iron plate. The size of the bead is an indication of when the HDPE is at the temperature required to fuse the pipe sections. The duration of the heated iron to pipe ranges from 2-3 minutes with average temperature of 425° F (218° C).



The HDPE is now heated to a temperature where the pipe ends can now be pressed together to complete the fusing. The above image shows the iron has been removed to allow the pipe welder to apply adequate pressure on the section ends to perform the fuse. The plastic continues to bead during the process. The ends are allowed to cool in place. Based on ambient air temperature, the average time to complete the weld can range from 15-20 minutes. Manufacturer's specifications state that a competent fused seam is structurally stronger than the pipe body itself. The exposed bead is not part of the structural bond.

Below is an interior view of the completed fuse.





Attaching the spacers.

The purpose of the spacers is to allow better placement of the grout (which is pumped between the HDPE liner and the CSP) to minimize voids.



A secondary function of the spacer allows for a more efficient insertion of HDPE liner into the CSP.

On average spacers are placed at an interval of 8'-10' along the liner.

Below is an example of a completed spacer and fused HDPE section.





The completed HDPE culvert liner is attached to a pick-up truck and dragged to the installation site. For this particular installation, the assembly site to the culvert location was over $\frac{1}{4}$ (0.25) miles away. The HDPE liner incurred no damage by this method of transportation.



The excavator is used to begin moving the liner into the culvert ditch.



The liner is snaked beyond the ditch and down the slope. Due to the apparent flexibility of the HDPE, this process went smoothly.



The liner is now at the outlet of the CSP culvert ready for insertion as soon as the grout tube is attached to the HDPE liner.



The grout tube will now be affixed to the end of the HDPE. The grout tube will follow the entire length of the liner up to the culvert inlet.



The grout tube is initially connected by nylon ties.



The tube is then firmly duct taped to the HDPE. Although difficult to see in this image, the grout tube is bent back on itself and inserted into the HDPE liner about three feet (yellow arrow). This will allow enough lead at the inlet to be attached to the grout pump line.



The excavator will incrementally move the HDPE liner and the attached grout tube through the existing CSP to the culvert inlet.



With the HDPE liner fully inserted into the CSP culvert, the excess liner is trimmed by a saw.



The HDPE outlet is now ready for the bulkhead application.

The grouting tube will be cut and positioned at the backside of the bulkhead.



Completed bulkhead.

The purpose of the bulkhead, which basically is a grouted partition, is a barrier for the grout application. The tube will be slowly pulled back as grout is pumped to fill the void between the HDPE liner and the existing CSP.



The culvert inlet received the same bulkhead treatment as the outlet. With exception of leaving a gap (see red circle) near the top to allow the tube to be pulled back during the grouting phase. Once completed, the tube is removed and the hole capped; the installation is complete.



Sample image of the device used to apply the grout. The grout is entered through the hopper on top (yellow arrow) and by piston is pumped through to the attached hose (red arrow) which connects to the grout tube adjacent to the HDPE liner.

Work zone and traffic control

No lane closure or work zone traffic control staff were needed to complete the installation of the CIPP and HDPE liners even given the geometric and geographical constraints of the project location. In most cases, the traveling public may not have been aware that active construction work was taking place. The following are representative images from both liner applications.



↑ Typical CIPP installation



↑ Typical HDPE installation

Culvert Cleaning

Prior to the installation of the liners, the contractor was required to clean the culverts of all accumulated debris. Initially a directional borer with an auger head began the cleaning phase but proved to be ineffective. The procedure was switched to high pressure jet wash which adequately cleaned the culverts for the insertion of the CIPP and HDPE liners. Below sample images of a few of the culverts prior to cleaning.



Sample image of directional borer on site.



Sample image of auger head