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DATE: December 16, 2009

TO: Richard Tetreault, P.E., Program Development Director

FROM: Jason Tremblay, M.S., E.I., Research Engineer
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via Bill Ahearn, P.E., Materials and Research Engineer

SUBJECT: Insituform CIPP on I-91 in Barnet Assessment

Introduction

VTrans utilized a process called Cured-In-Place Pipe (CIPP) from Insituform Technologies, Inc., headquartered in Chesterfield, MO, for the rehabilitation of three existing culverts along the I-91 corridor. These culverts were repaired in conjunction with two projects; Barnet IM SCRP (2), which specified the repair of two culverts (54 and 60 inches in diameters), and Rockingham IM SCRP (5) which specified the repair one culvert 66 inches in diameter. Both projects were completed during the 2008 construction season with minor to no concerns documented by the Project Residents with the exception of health concerns related to curing process.

The two rehabilitated culverts in the town of Barnet were recently inspected by the VTrans' Operations Division and a private entity which sells similar liners. Several discrepancies were noted along the 60" culvert including evidence of a large amount of water and rust colored staining on the inside of the liner. This report provides a brief overview of field observations and photo documentation as well as surveillance and testing measures and associated results.

Product Overview

According to the manufacturer, Insituform Technologies, "Insituform CIPP is a jointless, seamless, pipe-within-a-pipe that renews structural integrity to the host pipe." In this process, resin-saturated, coated felt tube is inverted or pulled through the host pipe and cured with either hot water or steam to form a tight-fitting, corrosion resistant lining. The CIPP should be designed in accordance with ASTM F1216 "Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube" and should assume that no bonding to the original pipe wall will take place.

According to the specifications provided by the manufacturer, the tube should be a sewn tube consisting of at least one layer of absorbent non-woven felt fabric and should meet the requirements given in ASTM F1216, ASTM F1743 "Standard Practice for Rehabilitation of Existing Pipelines and Conduits by Pulled-in-Place Installation of Cured-in-Place Thermosetting Resin Pipe (CIPP)," or ASTM D5813 "Standard Specification for Cured-In-Place Thermosetting

Resin Sewer Piping Systems." The layers should be uniformly bonded so that it is not possible to cleanly separate any two layers with a knife blade or move a blade freely between the layers. The tube is coated with a permanently-bonded layer of polyethylene, which is resistant to hydrolysis, defined by the EPA (Environmental Protection Agency) as the decomposition of organic compounds by interaction with water, and chemical attack. The tube should be manufactured to a size that it will fit tightly to the internal circumference and the length of the existing pipe, with allowances made for circumferential stretching during installation. It should be a light reflective color to allow for examination with closed circuit television inspection equipment upon completion. The seams should be stronger than the rest of the tube material and are butt-sewn, providing maximum strength with minimum wrinkling. The tube should be marked for distance at least every 5 feet along the length of the pipe for reference during subsequent inspections by closed-circuit television following installation. The resin should be a corrosion-resistant polyester or vinyl ester system that creates a composite that satisfies the requirements of ASTM F1216, ASTM D5813 and ASTM F1743 when cured within the tube. Samples of the resulting CIPP with and without plastic coating are required to meet the chemical resistance requirements given in ASTM F1216.

Prior to installation, the pipe must be inspected using closed circuit television in order to locate breaks, obstacles, service connections, and any other potential problem areas. Obstructions in the pipe, such as a protruding service connection, dropped joint, or a collapse that would prevent installation must be repaired. Upon completion of the installation, inspection shall be performed in accordance with ASTM F1216 or ASTM F1743. According to the manufacturer, "the minimum wall thickness at any point shall not be less than 87.5% of the submitted minimum design wall thickness as calculated." The minimum physical properties must have a minimum modulus of elasticity of 250,000 psi and a minimum flexural stress of 4,500 psi in accordance with ASTM F1216, and with an enhanced resin should have a minimum modulus of elasticity of 400,000 psi and a minimum flexural stress of 4,500 psi.

Culvert Overview

The prime and subcontractor for the Barnet IM SCRP (2) project was J.A. McDonald Inc. and Insituform Technologies Inc., respectively. Brigitte Codling was the Resident Engineer (RE). The 54" culvert located at MM 117.96 along I-91 was repaired in July of 2008. The largest issues documented during the installation were safety related, most particularly the strong styrene odors that were released during the curing process. No other significant problems with the installation or immediate concerns with the culvert liner following construction were noted. However, the RE contacted Chris Benda of M&R and Shauna Clifford of Maintenance, to discuss apparent issues related to hydrology and voids on-site; both individuals visited the project. The RE requested that the lab provide ground penetrating radar to locate significant voids and perhaps determine the extent of soil loss under the interstate. A field evaluation of the interstate pavements and culvert lining showed minimal evidence of new distress or cause for geophysical methods such as GPR at the time. No further investigation was undertaken because of limitations with GPR technology and the depths associated with the culverts.

Email correspondence from the Brigitte Codling received on November 19, 2009 is as follows: "There were a few small sink holes in the embankment over an indent in the pipe near the outlet. There was also a sink hole directly over the northern pipe in the drive lane that collapsed during construction; this area had been patched repeatedly by maintenance and finally let go. This area was repaired and we patched the surface. In addition the design called for placement of flowable fill concrete under both barrels of the interstate around the pipes…we placed 20 cy of flowable fill in and around the outlet end of the northern pipe; I have attached a field sketch of the bore hole locations in this area. I went and looked yesterday (November 18, 2009) and I have a few concerns, there are new sink holes developing in the median, there is water pouring over the cradle headwall outside the pipe along with some very strange slimy material that same material is what appears to be seeping through the liner in good fashion at the end." According to the RE, the 54" liner at MM 117.96 is in poorer condition as compared to the 60" liner, as opposed to the original feedback received from the Operations Division stating that the 60" liner was in the worse condition. It was also noted in correspondence that the outlet end of the culvert liner was in worse condition, with more of the slimy material than the inlet end.

The 60" culvert incorporated in the Barnet IM SCRP (2) project is located at MM 117.72. Correspondence from the RE indicated that this culvert liner is in significantly better condition as compared to the 54" liner. A few concerns were noted during construction regarding the 60" liner. On the proposed day of installation the liner was removed from the truck, however a hard rain began. The liner was reloaded onto the truck but was ripped (about six inches) during this process and needed to be repaired. It is unclear at this point where this repair is located with respect to the culvert itself (it was not possible to locate this during installation). According to correspondence dated November 16, 2009 (which was sent before the RE visited the site and realized that it was not the 60" liner that had the issues in question) from the RE, this culvert "was certainly the most deformed of both culverts originally, prior to construction; there was a large sink hole (of which we fixed) directly above the area where there was a large indent in the roof of the pipe; the seam in this area had rusted enough to allow the pressure to cause some push through damage." Again, this culvert liner is not experiencing the same issues as the 54" liner.

Also in conjunction with these culverts, two 10" by 10" samples of the cured material were collected on-site by the RE soon after curing, taken from end sections of the 54" liner and were delivered to the Materials and Research Section on November 18, 2009 by the RE.

Site Visit and Sampling Overview

A site visit was performed on Tuesday, November 24th, 2009 to examine the current condition of the 54" liner located at **MM 117.96** in an effort to investigate the above claims and to extract samples for laboratory examination.

Visual Inspection

Once onsite, the inlet and outlet of the 54" culvert liner was visually inspected. Photographs were also collected and used later to compare the current condition of the inlet and outlet to the asbuilt condition. As stated in the "Culvert Overview" section, the outlet of the culvert liner is in much worse condition than the inlet, displaying considerable (suspected) corrosion staining. The inlet of the culvert liner also demonstrates staining as the outlet to a much lesser extent. The staining in question comes from the so-called slimy material that appears to be seeping through the liner. The material was brown in color and resembled a dirt substance, a product of metal corrosion, or both. The material has stained, as it has run down the curvature of the culvert liner due to gravity, and into the water present in the culvert. Photographs of the pre and post installation conditions, as well as current, are provided in Figures 1 and 2 below. There is no photograph of the outlet of the culvert liner immediately following construction for comparison. The staining pattern is shown below.

Figure 1. Condition of the inlet of the culvert (clockwise from top left), preconstruction, post-construction, and present.

Figure 2. Condition of the outlet of the culvert at preconstruction (top), post-construction (bottom right), and present (bottom left).

<u>Core Extraction</u>

Four locations were randomly selected for the extraction of 4 samples, two considered in ‘good’ condition (with no visible staining) and two considered in ‘poor’ condition (a large amount of visible staining and possible corrosion residue). All four locations were chosen near the outlet of the culvert to minimize any safety concerns. The exact locations of the samples are shown in Table 1. Samples were extracted with the use of a cordless drill with two inch diameter hole bit. Upon removal samples were placed in tied plastic bags and properly labeled. Samples were transported to the Materials and Research Laboratory for analysis.

Table 1. Locations of the four test samples extracted from the outlet of the culvert.

Location of Liner Test Samples			
Sample	Distance from Outlet (in)	Height from Bottom (in)	Condition Designation
1	88	21	Poor
2	101	18	Poor
3	51	38	Good
4	56	25	Good

Upon removal of samples 1, 2, and 4, a steady stream of water poured through the liner from an outside source. Conversely, following the removal of sample 3, no excess water flowed through the liner. While the source was not identified, it is interesting to consider extraction height of the samples with respect to observed water infiltration. Samples 1, 2, and 4 were extracted at a maximum distance of 25 inches from the bottom of the culvert while sample 3 was collected from a distance of 38 inches from the bottom of the culvert. This could indicate that some source of water creates a water table around the bottom of the pipe. Figures 3 and 4 below show the water ingress into the culvert at the three locations. Water at location 4 drained heavily into the culvert for a short time and subsequently stopped within an hour. Upon extraction, sample 2 was in two pieces with the outermost ¼ of an inch delaminated (separated) from the rest of the sample as shown in Figure 5.

Figure 3. Water flowing into the culvert at sample 2 (far) and sample 4 (near).

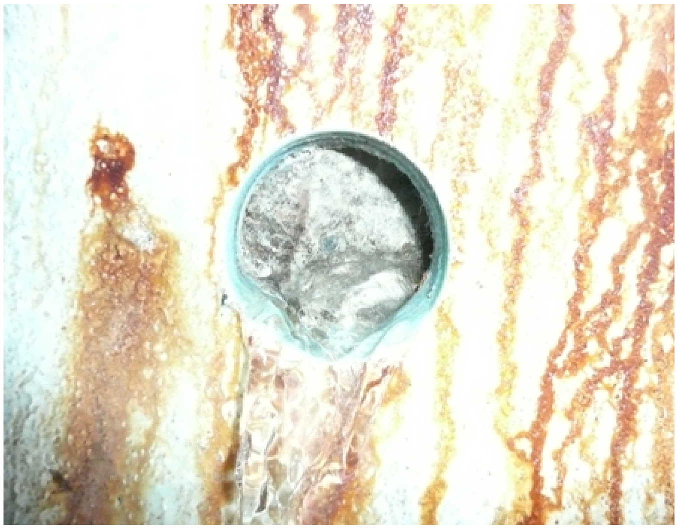

Figure 4. Water flowing into the culvert at sample 1

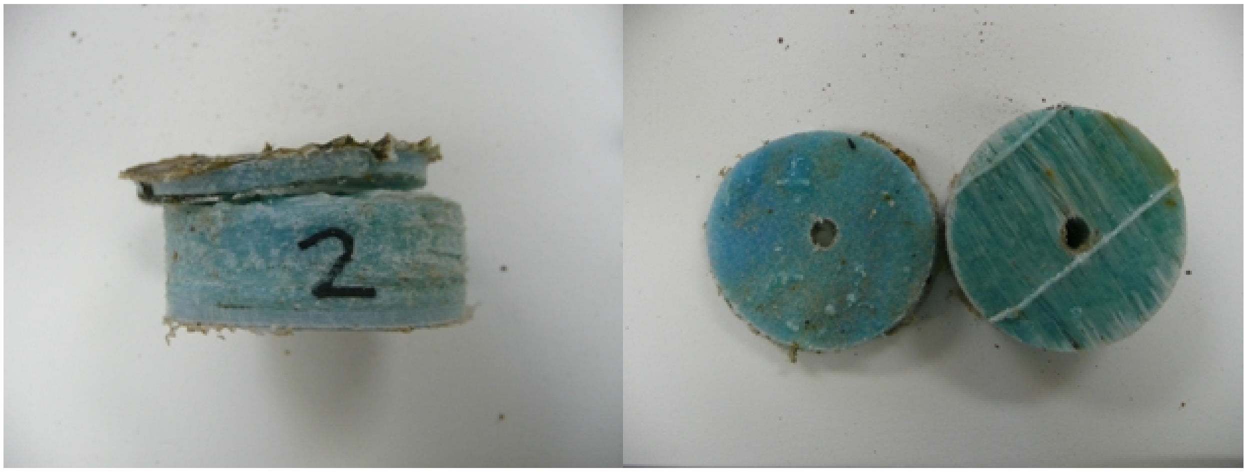

Figure 5. Photographs of sample 2, showing separated layers.

The left hand image in Figure 5 shows the cross section of sample 2, with the outermost layer (the layer closest to the original culvert) delaminated from the remainder of the sample. These two pieces have separated from one another; they appear to have not bonded during the curing process. The right hand image shows the difference in the appearance and structure of the different layers; one layer (right) being very fibrous, while the other (left) much smoother and homogenous.

Repair of the core holes was performed using a product called Tiger Hair manufactured by Evercoat. It is a long strand fiberglass reinforced body filler, and claims to have high strength and high build, as well as being waterproof and stress crack resistant. The main drawback of this repair material (and almost any other) is that the repair area must be dry in order for the material to cure properly. Holes at test sample location 3 and 4 were easily repaired as water did not infiltrate sample location 3 and water only infiltrated through sample location 4 for a short duration. Unfortunately locations 1 and 2 were not able to be repaired on the day of sampling as water continuously flowed through them for the entire duration of the site visit. Repair will be attempted on a future date, when no water is present or when another method is proposed. However the presence of these small holes does not reduce the structural integrity of the liner.

Samples of residue located inside and outside of the culvert were also collected. A sample was scraped from a particularly bad location, one with a considerable amount of residue attached to the inside of the liner, and placed into a sample bottle. A second sample was scraped from just outside of the outlet of the culvert along the concrete headwall where an abundance of this material was located, as seen in Figure 6. Both samples were sent to the Vermont Department of Environmental Conservation (DEC) for laboratory analysis and composition determination.

Figure 6. Photograph of the slimy material present on the outlet headwall.

Testing and Results

Compositional Analysis

Laboratory analysis was performed by the Vermont DEC on the residue samples taken from inside and outside of the culvert. Both samples were of mainly identical composition and described by Jerry DiVincenzo via email correspondence in the following narrative:

Personnel in DEC looked at the two samples sent to the Lab on 11/24/09. The findings were the same for both samples and are described below. Both the samples contained the same Fe bacterium.

The sample brought down earlier today was examined under high power using a compound microscope. The sample composition was primarily iron particulates attached to detritus. Detritus is the general debris of living and nonliving particulate material found in our samples. Colonies of iron bacterium were also observed. We do not have a key to speciate iron bacteria, but it is a very common type according to Hynes's "The Biology of Polluted water is Leptothrix ochracea. It looked very similar to this species by using pictures provided in Ward and Wipple's 2nd Edition of "Freshwater Biology".

Weight Change Analysis

In an effort to determine if water is penetrating into or through the culvert, all samples were weighed one day following retrieval ("wet weight") at the VTrans Central Laboratory Facility. These samples were then dried in an oven for two hours at a temperature of 110ºC and allowed to cool to room temperature. Once cooled, the samples were weighed a second time ("dry weight"). Two additional samples, or control samples, were extracted from a portion of the cured liner removed immediately following construction and allowed to soak, submerged, in water for one week and then placed in a plastic bag for one day to simulate surveillance and testing performed during the field investigation. Once again wet and dry weights were documented. Calculations were performed to determine the weight loss percentage following the drying procedure. All results are displayed in Table 2.

Table 2. Analysis of wet versus dry weights of six Insituform liner samples.

Wet vs. Dry Weight Comparison				
Sample	Designation	Wet Weight (g)	Dry Weight (g)	Weight Loss (%)
1	Poor	54.670	48.381	11.5
2	Poor	50.884	43.060	15.4
3	Good	67.130	63.781	5.0
4	Good	57.665	52.867	8.3
5	Control	43.574	41.745	4.2
6	Control	44.086	42.110	4.5

It is interesting to compare the percentage of weight loss between the poor, good and control samples. The weight loss from a wet to dry condition is fairly consistent between the good and control samples although sample 3, with no observed water infiltration following compaction, displayed the least amount of weight loss as compared to sample 4, a good area with observed water flow. However, the poor samples exhibited a far greater percentage of weight loss, approximately 2.5 times greater than the other samples. This clearly indicates a difference in the material properties between the poor and good samples most likely due to either inconsistent manufacturing of the liner or irregularities during the curing process.

<u>Microscopy Analysis</u>

Microscopic analysis was performed on the four field samples to assess corrosion penetration and differences in porosities. This was accomplished by slicing the samples perpendicularly to the inside and outside face of the liner. Visual observations were recorded along with photo documentation. Thin slices, of roughly 2 mm thickness, were then cut with a saw and examined under the microscope. Figure 7 and Figure 8 provided below displays a standard view of the cross sections and same cross section at a 40x zoom.

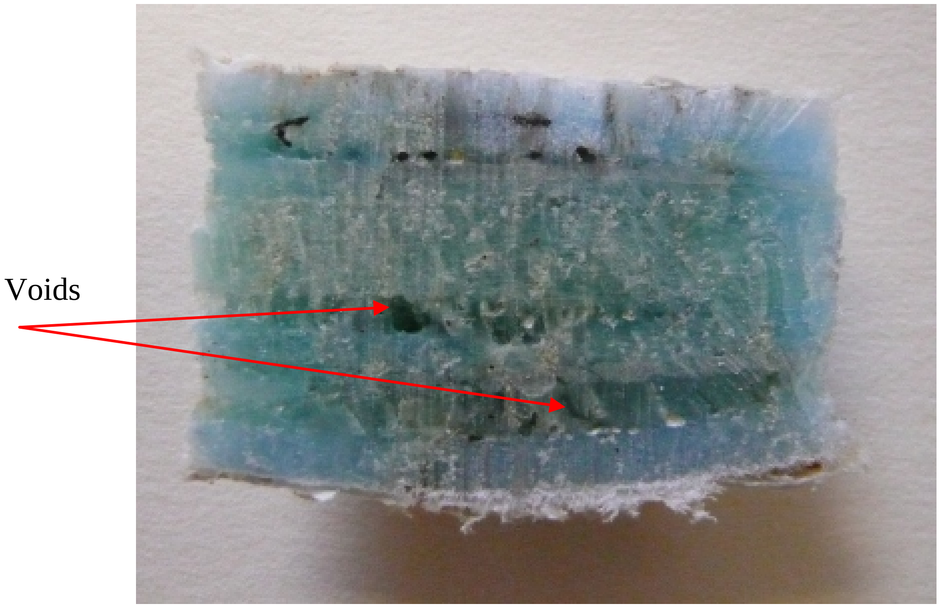

Figure 7. Cross sections of a 'good' sample (top) and 'bad' (bottom).

Figure 7 shows a distinct difference between a sample from a “good” location with no visible rust colored stains and a “poor” location with visible staining. The top image is very solid with few voids present, while the bottom shows large areas of voids and lines of corrosion migrating into the liner. Also present, at the location of the large areas of voids, is a seeming separation of layers of the liner, as was most likely the reason for the separating, or delamination, of the second ‘bad’ sample. This delamination appears to have occurred due to the polymer pulling apart before it hardened. This appears consistent with the possibility that the defects might have been caused by a reduction of steam pressure during the curing process. Sample 2, as mentioned earlier, was separated into two pieces when extracted, with an outer layer delaminating from the remaining liner.

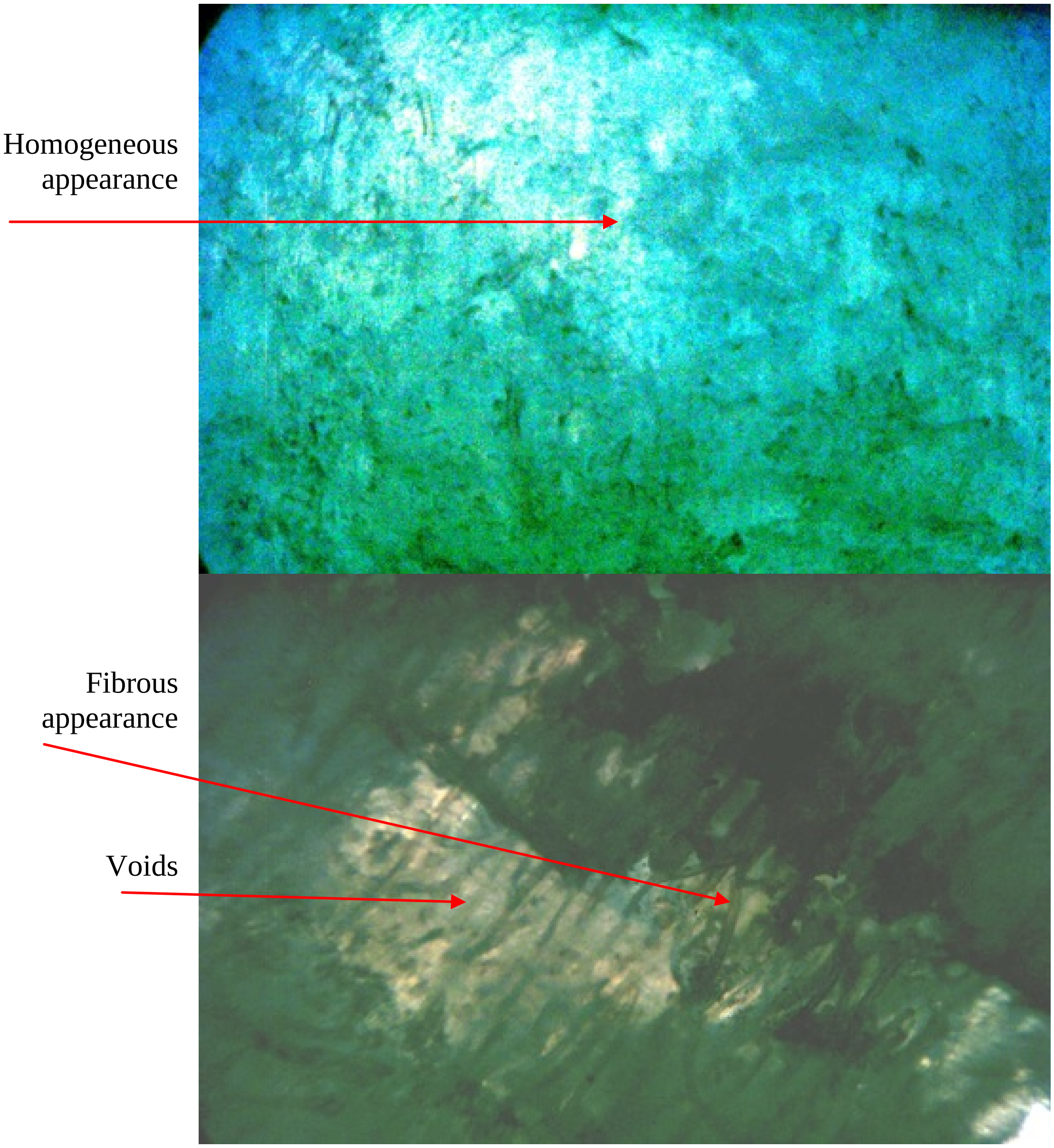

Figure 8. Microscopic images of cross sections of a 'good' sample (top) and a 'bad' sample (bottom) at 40x.

Figure 8, under 40x, also shows that the defective areas are much more porous and permeable than the intact liner, as rust colored stains could be seen throughout the cores, which indicates that the liner is somewhat permeable. The intact areas seem much more amorphous, indicating homogeneity, than the defective areas, which have a more fibrous appearance. Small fibers are contained inside most voids. This fibrous appearance could possibly be due to the stretching of the partially cured polymer during inflation of the liner and also during deflation if steam pressure was lost.

Miscellaneous

Inspection video logs, documented by Insituform, were obtained and viewed, along with installation videos documented by VTrans personnel. Inspection logs show no evidence of flaws and/or voids to the casual observer and nothing out of the ordinary was denoted in the logs. Installation videos also show no signs of diminished quality.

A site visit was also performed to the second Barnet culvert that was repaired under the same project. Upon a brief visual inspection, this culvert liner shows no signs of the same residue seepage present in the first liner. A walkthrough was not done throughout the entire length of the culvert, however neither the outlet nor inlet shows visible signs of staining. This indicates that little to no voids are present or that there is no means of conveyance of culvert corrosion through the liner. A future site visit will be scheduled to inspect the culvert liner located in the town of Rockingham which was also repaired by Insituform in the fall of 2008.

Curing logs, as documented by Insituform, for both culverts are attached as Appendix A. The first two pages are for the suspect northern 54” culvert, while the third page is for the southern 60” culvert. Logs indicate fairly consistent steam pressure and temperatures, with both logs showing the same patterns as one another. The main noticeable difference between the two is the duration of curing, approximately 5 hours for the northern (visible staining present) culvert versus approximately 8 for the southern (no visible staining) culvert. It is currently unverified as to why the southern culvert was under steam pressure for a longer duration.

Insituform Assertions

Through discussions with VTrans’ Traffic Safety and Roadway Design Section, Insituform was contacted for their thoughts on the original pictures that were sent to VTrans via the private entity. Mark E. Szela, P.E. of Insituform provided the following response to the pictures.

“The staining that you see in the photographs are small volumes of seeping water carrying particles of soil and perhaps oxidized portions of the host pipe. In some of the CIPP staining the volumes are so small the flow has probably stopped due to the pathway channel has been blocked with the transported particles.

ITI has identified the issue causing a “pinhole effect” on this CIPP liner. The issue was a product of irregular heat dissipation during the resin’s exothermic reaction, or while the liner was “curing”. ITI has studied this effect and rectified the installation procedure to more thoroughly dissipate heat created by the chemical reaction and minimize the risk of reoccurrence. These seeps do not negatively impact the short or long-term structural performance of the installed CIPP liner.

Again this does not impact the short or long-term structural performance of the CIPP liner.”

Nothing found within the scope of this site visit and report has refuted these hypotheses, nor has it confirmed the statement that the voids will not impact structure performance.

Summary and Conclusions

Materials and Research personnel performed a site visit on Tuesday, November 24th to examine the current condition of a 54” cure-in-place liner manufactured and installed by Insituform Technologies, Inc. located at MM 117.96 along I-91 in the town of Barnet to examine current condition and extract samples for laboratory examination. During the site visit 4 samples were extracted, two from poor locations with evident rust colored staining and two from good locations with little to no observed staining or other discrepancies. Samples of the rust color staining inside the culvert and “slimy material” descending down the concrete headwall were also collected for laboratory analysis.

The vast majority of the lining appears to be in good condition with little to no observed staining. Structurally the culvert liner appears to be sound. However, rust colored stains are visible roughly 80% of the circumference of the culvert liner with an increase in residue as it descends to the bottom of the culvert. During extraction of the culvert liner samples, water infiltration was noted in samples 1, 2, and 4. Continuous flow was documented at sample locations 1 and 2 during the length of the site visit. This observation is of concern and may indicate a site-specific hydraulic issue.

Laboratory analysis on the rust colored residue show that the material is mostly iron and iron bacterium particulates attached to detritus, a common substance for these conditions. These findings support the hypothesis that corrosion from the original metal culvert is migrating through the new liner.

Results from wet versus dry weight determinations suggest that samples extracted from “poor” areas readily absorb more moisture than from “good” areas. Samples from “poor” locations contained approximately twice as much water as good samples, indicating a much more porous structure with numerous voids that allow for water entrapment.

Microscopic analysis confirmed the above weight analysis, with “poor” samples exhibiting a greater amount of rust staining through the cross sections along with a more fibrous structure. Good samples, conversely, show a more amorphous and homogenous structure with less corrosion shown migrating through.

Insituform believes that the issue with this liner was that there was irregular heat dissipation during the curing process, which the microscopic analysis would support. It is unclear as to why this may have occurred. It is Insituform’s assertion that this will not affect the long term structural performance of the liner.

Again, the vast majority of the in-place lining appears to be in excellent condition, and the area of concern has several contributing factors, none of which assert an increasing long term risk. There may remain opportunities for site specific action (voids related mitigation) and design strategy (saturated conditions surrounding the entire pipe) to be further determined.

APPENDIX A

Will 508 479 7204

Cure Schedule and Log Sheet

General Information

Wetout Bessemer, AL
Wetout date 23-Jun-08
Resin Type Polyester/ 102NA
Catalyst Phase II

Job Number 160588
Shot Number 001B-277106
Install type PP Steam Cure Inv
Sample Reqd? YES
Sample Type Restrained - PVC

Turn Rope reqd? NO
Rope location
Crew Superintendent William K Markey
Pallet Number 064411M

Diameter 54 in.
Thickness 15.6 mm
Wet length 322 ft
Dry Length 6 ft
Total Length 328 ft

54"

Inversion Heads/Pressures

Minimum Head	6.0	feet	2.6	psi	Maximum Head (Hot) - Cure	13.0	feet	5.6	psi
Recommended Head	7.7	feet	3.3	psi	Maximum Head (Cold) - Invert	26.1	feet	11.3	psi

Note: This does not take into consideration the grade or length restrictions in the pipe (for Water Inversion).

Cure Schedule

	Water	Steam	
Minimum Required Cure Time :	#REF!	3	hrs
Start cure time when far end interface thermocouple reaches :	110	130	deg F

If interface temperature cannot be reached, contact your Operation Manager or GS

For Water cure:

Raise the temperature of the cure water to 180 deg F.
Hold the cure water at 180 deg F for the cure time.
Place a thermo at far end water and monitor for 180 deg F.

For Steam Cure:

Minimum 210 deg F steam / air mixture.

Cool Down:

Cool down until interface reaches 100 deg or 30 minutes

Thermocouple:

At a minimum, use one thermo wire under the tube at far end (6 O'Clock)
Use thermo wire in intermediate manholes, if accessible.

Extend Cure (water or steam) times for the following conditions:

For every 10 deg F below the interface temperature, add	1	hour
When sags or dips are present, add	1	hour
For deep installs with wet/cold conditions, extend cure by	50%	

Use preliners for small/medium dia lines with running or heavy infiltration.

Note: For iPlus Infusion (ILS), follow the expansion, warmup and heat up procedure in the work instructions before starting the full cure.

Cure Log

Install Date 29-Jun-08
MH to MH 0+85/3+90
Job # 160588
Shot # 001B-277106
Boiler # TK 1601
Thermo box # OHC-331
Up/Downstream cure? UP [✓ DOWN]
Operator
Weather (circle applicable) RAIN SNOW HOT COLD NORMAL

Note: The pressures and temperatures should be logged every 15 minutes throughout the curing process (including warm up and cool down)

STEAM CURE LOG							WATER CURE LOG						
Time	Boiler Pressure (psi)	Boiler Outlet Temp (F)	Chip Pressure (psi)	Thermo #1 (F)	Thermo #2 (F)	Thermo #3 (F)	Time	Discharge temp (F)	Pump pressure (psi)	Suction Temp (F)	Thermo #1 (F)	Thermo# 2 (F)	Thermo #3 (F)
Warm up													
				top	Bottom								
Full Steam	320												
3:45	8	235	4.5	68	57								
4:06	8	240	5	73	61								
4:15	8	240	4.5	247	144								
4:30	9	240	4.5	281	145								
4:45	9.5	240	5	205	147								
5:00	9	240	4.5	177	135								
5:15	9	240	4.5	171	130								
5:30	9	240	4.5	150	130								
5:45	9	240	4.5	152	130								
6:00	9	240	4.5	152	130								
6:15	9	240	4.5	152	130								
6:30	9	240	4	150	132								

Reviewed by: ____________

Date: ____________

Cure Log

Install Date 29-Jul-09 **Job #** 160559 **Boiler #**

MH to MH 0 + 85 / 3 + 90 **Shot #** 0019-277106 **Thermo box #**

Up/Downstream cure? UP DOWN

Operator

Weather (circle applicable) RAIN SNOW HOT COLD NORMAL

Note: The pressures and temperatures should be logged every 15 minutes throughout the curing process (including warm up and cool down)

STEAM CURE LOG							WATER CURE LOG						
Time	Boiler Pressure (psi)	Boiler Outlet Temp (F)	Chip Pressure (psi)	Thermo #1 (F)	Thermo #2 (F)	Thermo #3 (F)	Time	Discharge temp (F)	Pump pressure (psi)	Suction Temp (F)	Thermo #1 (F)	Thermo# 2 (F)	Thermo #3 (F)

7:30	9	240	4	151	132								
8:00	8	240	4	160	132								
8:15	8	240	4	151	133								
Cool Down													

Reviewed by: ____________

Date: ____________

Cure Log

Install Date [redacted] Job # [redacted] **Boiler #** TTK1601 **Up/Downstream cure?** UP [✓ DOWN]

MH to MH [redacted] Shot # [redacted] **Thermo box #** OTC-331 **Operator** Fran

3->4 60" 002 **Weather (circle applicable)** RAIN SNOW HOT COLD [✓ NORMAL]

Note: The pressures and temperatures should be logged every 15 minutes throughout the curing process (including warm up and cool down)

STEAM CURE LOG							WATER CURE LOG						
Time	Boiler Pressure (psi)	Boiler Outlet Temp (F)	Chip Pressure (psi)	Thermo #1 (F)	Thermo #2 (F)	Thermo #3 (F)	Time	Discharge temp (F)	Pump pressure (psi)	Suction Temp (F)	Thermo #1 (F)	Thermo# 2 (F)	Thermo #3 (F)
				top	Bottom								
10:15	Steam On												
10:30	11	240	4.5	59	53								
11:00	11	240	4.5	61	64								
11:15	11	240	4.5	169	71								
11:30	10	240	4.5	135	86								
11:45	10	240	4.5	130	83								
12:00	10	240	4.5	126	83								
12:15	10	240	4.5	128	85								
12:30	10	240	4	127	85								
12:45	9	240	4	127	86								
1:00	9	240	4.5	126	83								
1:15	10	240	4	126	82								
1:30	9	240	4	124	80								
1:45	9	240	4	122	80								
2:00	9	240	4	122	78								
2:15	9	240	4	120	77								
2:30	9	240	4	120	75								
2:45	9	240	4	121	76								
3:00	9	240	4	123	79								
3:15	10	240	4	123	79								
3:30	10	240	4	123	79								
3:45	10	240	4	121	79								
4:00	10	240	4	121	79								
4:15	8	240	4.5	122	79								
4:30	8	240	4	121	79								
5:00	7	240	4	124	80								
5:15	8	240	4	124	80								
5:30	8	240	4	123	79								
5:45	8	240	4	123	79								
6:00	8	240	4	124	80								
6:15													
6:30													
Cool Down													

Reviewed by: ____________________ 2 of 3 Date: __________