BEST PRACTICE GUIDELINES FOR

CULVERT LINER SELECTION

GENERAL

Rehabilitation of culverts with pipe liners is one of several methods available for extending the life of an existing culvert. It is often cost effective when compared to complete replacement, particularly where there are deep fills or where trenching would cause extensive traffic disruptions. A thorough examination of the existing culvert must be performed prior to discussing possible alternatives and cost-effective solutions.

HISTORY

The choice of pipe material for rehabilitating deteriorated culverts should be based on functionality and life cycle costs. Over the years many options have been used for rehabilitating deteriorated culverts such as:

1. Auguring smooth wall steel pipe and abandoning the deteriorated culvert.
2. Jacking of concrete pipe and abandoning the deteriorated culvert.
3. Lining deteriorated culvert with smooth wall steel pipe.
4. Lining deteriorated culvert with smooth wall PVC pipe.
5. Lining deteriorated culvert with smooth wall polyethylene pipe.

Alberta Transportation has successfully been installing plastic pipe liners for rehabilitating existing deteriorated culverts (culverts up to 1200-mm diameter) throughout the province since 1989. Plastic pipe liners have become very cost effective and a successful method of rehabilitating existing culverts. Specifications have been developed for the supply and installation of plastic pipe.

BACKGROUND – TYPES OF LINERS

PVC Pipe

Perma-Loc Polyvinyl Chloride Pipe fabricated by IPEX. This product has a bell and spigot connection with a rubber gasket friction joint. It has a smooth interior and spirally ribbed exterior. A concern in using PVC pipe as a liner is that it is brittle and easily damaged during installation. UV rays will deteriorate the liner ends from exposure to sunlight. Perma-Loc pipe is only fabricated up to 900-mm diameter; therefore it is limited to lining existing culverts up to 1200 mm in diameter. Over 7000 metres of PVC pipe has been used for lining culverts.

Polyethylene Pipe

Weholite Lightweight Polyethylene Pipe distributed by Plainsman Manufacturing Inc. is a smooth wall, high-density polyethylene pipe and is now available in a wide range of sizes from 200 mm to 3048 mm in diameter. The Weholite pipe is normally threaded together or connected using heat shrunk sleeves. The flush connection featured on this product allows for the use of larger diameter pipes as compared to other products.

Big "O" Boss 2000 Pipe, manufactured by Armtec has a smooth wall interior and uses a bell and spigot connection with a rubber gasket friction joint to joint segments. The bell and spigot connection reduces the size of pipe that can be used. Boss 2000 is currently manufactured in sizes ranging from 100 mm to 900 mm in diameter. However the external corrugation profile of this product may limit its usefulness.

The polyethylene pipe contains carbon black additive, which protects the pipe from ultraviolet light.

Smooth Wall Steel Pipe

Smooth wall steel pipe is typically used for auguring new culvert through the roadway embankment. The type of smooth wall steel pipe used is a 9.5-mm thick steel walled pipe. The smooth wall steel pipe has also been used as a culvert liner. In areas where the existing culvert is located in a corrosive environment, lining with steel pipe may not be ideal, and not recommended, as the steel pipe would eventually rust out. Lining with steel pipe may be practical where the liner may require force to push through the existing pipe.

Concrete Pipe

The use of concrete pipe is mainly restricted to high fills such as at interchanges and corrosive environments. Concrete pipe is costly and very heavy; its use has been restricted on projects near urban centres. Jacking of concrete pipe was tried by the department on two projects, however this method has not been used again due to its extremely high cost.

DESIGN CRITERIA

It is important to note that when lining deteriorated culverts (especially bridge sized culverts, 1500 mm diameter and greater), the water flow capacity of the liner must be determined and compared to the original culvert flow capacity. Design discharge for the liner must be evaluated with consideration that it may have changed (flows may have increased over the years as a result of urban development, re-directing flows, etc.) since the original culvert was placed. It is incorrect to assume that if a liner will pass the discharge for which the existing culvert was designed that all design requirements have been met.

For Larger (bridge size) culverts the liner will require a site specific hydrotechnical design and meet all structural requirements for lining bridge size culverts (see the current version of Standard Bridge Drawings S-1621 and S-1622). Typically the designer will also have to consider the following issues when handling bridge size culverts:

- ice or drift problems
- assess the impact of increased backwater on adjacent land/property
- assess effects of increase in saturation levels on roadway fill (upstream side)
- assess the effects of increase in velocity in the downstream side – loss of riprap, increase in streambed scour, fish passage concerns, etc.
- ensure that the design is in accordance with the following Guidelines; Guideline for Bridge Structures Standards, Approvals and Design (SAD), Design Guidelines for Culverts, and that all provincial and federal permits are in place.

Pipe used as a liner will not typically be subjected to the degree of loading experienced by the original culvert. In most cases, although the invert of the original culvert has deteriorated, the load carrying capacity has not been significantly diminished. As a result, strength requirements of a liner pipe are more dependant on the determination of potential grouting pressures and the need for the liner pipe to withstand handling and installation stresses.

Smooth wall pipes typically have a lower Mannings "n" value than corrugated products. However, there are other hydraulic factors to consider such as inlet or outlet control when lining culverts.

> Inlet Control, the discharge capacity is governed by the inlet geometry; the headwater depth is a result of this and the storage capacity upstream. The roughness, length and outlet conditions are not factors in determining culvert hydraulic performance.
>
> Outlet Control, involves the additional considerations of the tailwater in the outlet channel and the slope, roughness and length of barrel.
>
> Suitability, what is the shape of the existing culvert, are there major deflections, settlement, will the liner be able to slide through the existing culvert.

The majority of the department's small centerline culverts are 800-mm and 900-mm diameter. These culvert sizes are used to minimize maintenance in order to facilitate pipe-cleaning operations. Typically diameters provide flow capacities well in excess of design requirements.

PIPE DIMENSIONS

When determining the warrants for lining an existing culvert, an assessment of the discharge capacity of the liner must be made to verify that the liner pipe will allow the design discharge to be passed (due to its smaller diameter than the existing culvert). To make this assessment, selection of the liner must consider the effect on the liner diameter due to liner wall thickness and in particular, the space requirements of the liner joints. This maximum exterior dimension of the liner must be able to be inserted through the existing culvert, while also considering deformations in the existing culvert, minor culvert bends, and any other disturbances in the bore of the existing pipe.

The following tables provide industry supplied pipe inside and outside diameters:

PVC PERMA-LOC PIPE

Nominal Pipe Size (mm)	Inside Diameter (mm)	Inside Diameter Bell (mm)	Outside Diameter Bell (mm)
450	448.3	492.3	529.8
525	527.1	575.1	618.7
600	596.9	652.8	704.1
675	673.1	734.1	789.9
750	749.3	816.9	878.6
900	901.7	983.2	1058.4

Note: This product is only fabricated up to 900 mm in diameter.

POLYETHYLENE PIPE (WEHOLITE)

Nominal Pipe Size (mm)	Inside Diameter (mm)	Outside Diameter (mm)
450	457.2	514.1
500	495.3	552.2
525	533.4	600.7
600	609.6	687.3
675	685.8	772.9
750	762.0	859.0
900	914.4	1032.5
1000	1016.0	1148.1
1050	1066.8	1205.7
1200	1219.2	1365.5
1350	1371.6	1536.2

POLETHYLENE PIPE (BOSS 2000)

Nominal Pipe Size (mm)	Inside Diameter (mm)	Outside Diameter of Bell (mm)	Outside Diameter of Bell Flair (mm)
375	375	464.2	480.3
450	450	562.1	579.9
525	525	650.0	678.0
600	600	747.8	772.0
750	750	922.0	947.0
900	900	1113.0	1178.0

Note: This product is only fabricated up to 900 mm in diameter.

SMOOTH WALL STEEL PIPE

Nominal Pipe Size (mm)	Inside Diameter (mm)	Outside Diameter (mm)
400	387.4	406.4
450	438.2	457.2
500	489.0	508.0
550	538.8	558.8
600	590.6	609.6
750	743.0	762.0
900	895.4	914.4
1050	1047.8	1066.8
1200	1200.2	1219.2

CONCRETE PIPE

Nominal Pipe Size (mm)	Inside Diameter (mm)	Outside Diameter of Bell (mm)
375	381	600
450	455	710
525	530	810
600	609	900
675	684	1000
750	760	1099
900	916	1301
Concrete Pipes larger than 900 mm have Tongue and Groove Connections		
1050	1065	1335 (OD)
1200	1221	1475 (OD)
1350	1370	1650 (OD)

LINER SELECTION

The following table is used to select non-bridge sized culvert liners; the comparable flow capacities for the liners are only based on the Mannings “n” factor. Factors such as inlet and outlet control are generally not required for these sizes.

The Liner Selection Table includes imperial CMP sizes as the majority of culverts being rehabilitated are approximately 30 years old.

LINER SELECTION TABLE

EXISTING CMP SIZE (INSIDE DIAMETER)	PLASTIC LINER SIZE						STEEL	
	PVC		WEHOLITE		BIG "O" BOSS 2000		SMOOTH WALL STEEL PIPE	
(mm)	Size (mm)	Outside Diameter Bell (mm)	Nominal Size (mm)	Outside Diameter (mm)	Nominal Size (mm)	Outside Diameter Bell Flair (mm)	Nominal Size (mm)	Outside Diameter (mm)
600	450	529.8	500	552.2	375 *	480.3	550	558.8
609.6 (24")	450	529.8	500	552.2	375*	480.3	550	558.8
700	525	618.7	525*	600.7	450 *	579.9	600	609.6
762 (30")	600	704.1	600	677.5	525*	678.0	600	609.6
800	600	704.1	675	772.9	525 *	678.0	750	762.0
900	675	789.9	750	859.0	600 *	772.0	750	762.0
914.4 (36")	675	789.9	750	859.0	600*	772.0	750	762.0
1000	750	878.6	750*	859.0	750	947.0	900	914.4
1066.8 (42")	750	878.6	750*	859.0	750*	947.0	900	914.4
1200	900	1058.4	1000	1148.1	750 *	947.0	1050	1066.8
1219.20 (48")	900	1058.4	1000	1148.1	750*	947.0	1050	1066.8
1400	-	-	1200	1365.5	900*	1178.0	1200	1219.2

* Note: Reduced flow capacity when compared to existing CSP size.

NOTE: It is important to note that the Liner Selection Table is only a guide for selecting a plastic liner size. Condition of existing culvert must be known such as existing culvert deformations, changes in alignment and any other obstructions that may be present in the existing culvert. The plastic liner sizes shown on this table are based on the existing culverts having minimum deformations. Deformations of the existing culvert may warrant a further decrease in size of liner as long as flow capacity is determined to be adequate.

When the existing culvert is elliptical in shape, the span and rise dimensions are required to determine suitability for lining. Flow capacity will need to be calculated to determine feasibility of lining on elliptical culvert.

In situations where the manufacturer (e.g. Weholite polyethylene plastic pipe) uses a pulling head to pull a liner through the existing culvert, the additional decrease in liner size may not be required.

FLOW CAPACITIES

The following table shows pipe flow capacities. The flow capacities are based on the Manning formula for pipes flowing full. Inlet and outlet control are not considered. This table is only intended as a guide for selecting a liner size, more detailed computations may be required by the designer.

PIPE FLOW CAPACITIES (m^3)/SECOND

SIZE (mm)	PLASTIC				CONCRETE	STEEL
	C.M.P.	P.V.C.	Polyethylene "Boss 2000"	Polyethylene "Weholite"		
400						0.190
450		0.411	0.370	0.285	0.285	0.265
500						0.355
525		0.620	0.558	0.430	0.430	
550						0.461
600	0.332	0.886	0.797	0.613	0.613	0.589
675		1.213	1.092	0.840	0.840	
700	0.501					
750		1.606	1.446	1.112	1.112	1.085
800	0.716					
900	0.980	2.612	2.351	1.808	1.808	1.782
1000	1.297			2.395		
1050				2.728	2.728	2.714
1200	2.110			3.895	3.895	3.895
1350	2.889			5.333	5.333	

<u>Friction Factors Used</u>:
Plastic
- PVC n = 0.009
- Boss 2000 n = 0.010
- Weholite n = 0.013

C.M.P. n = 0.022 to 0.024
Concrete n = 0.013
Steel n = 0.013

Note:
- Mannings equation used
- 1% slope used
- Inlet or Outlet control not considered

GROUTING

Full length grouting of the liner is recommended. This provides a more secure attachment to the existing culvert and also reduces the potential for joint leakage to create piping problems. It also provides additional bearing strength around the culvert if there is deterioration of the existing culvert.

The grout shall be suitable for low pressure pumping into the void between the plastic liner and the surrounding existing culvert and have a minimum compressive strength of 500 kPa at 28 days. Care must be taken when pressure pumping so that excessive pressure will not damage the liner.

DETERMINING LIFE CYCLE COSTS

The most economic alternative material choice should be determined through a “Life Cycle for Culverts Cost Analysis” computation. Before any life cycle cost comparisons of materials can be made, the basic project life must be established (50 year time period is generally used).

The manufacturers of the listed pipes provided the estimated life for these materials:

PVC	- 100 years – Non UV exposed pipe (will require slope end replacement per 50-year cycle)
Polyethylene	- 100 years
Smooth Wall Steel Pipe	- 30 years – Note: Could vary substantially due to soil/water conditions.
Concrete	- 100 years

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