Large Diameter, Non-Circular Culvert Rehabilitation Using Structural GRP Lining Systems

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CULVERT LINING USING GLASS REINFORCED - GROUTED IN PLACE PANEL LINING

History of Water Research Centre:
• In 1979 Water Research Centre (WRc) was commissioned by the UK Government and Water Companies to undertake an intensive research program on materials and methods of design for the structural rehabilitation of sewers.

• The main reason behind this study was to accumulate sufficient data to justify design predictions for a 50 - 100 year service life.

• Channeline Design Consultants worked in cooperation with WRc to test and evaluate structural segmental and one piece Polymeric lining systems for Large Diameter, Non-circular Sewers and Culverts.

• The study took 5 years with a £10 million budget.
In 1984 WRc published the Sewerage Rehabilitation Manual

The WRc Sewerage Rehabilitation Manual (Sewer Renovation) presents two structural design methods that are meant to give the following results:

**Structural Design Philosophy**

- Offer cost effective lining solutions.
- Suggest a list of proven products and techniques that have a tangible, expected service life performance of 100 years minimum.
- Put forward best practice construction techniques to minimize long term social disruption and construction footprint.

- Not applicable for non-man entry sewers
- Composite Rigid structure that carries Ground and Traffic loads
- A good shear bond is required between the grout and liner
- Design can be checked for long term buckling due to hydrostatic pressure
- Assumes the existing sewer carries compressive load and the lining carries the tensile load
Type I Design Procedure:
- Determine critical length (l) and mean sewer diameter (d)
- Determine external loads (P)
  - Soil and live loads
  - Hydrostatic
- Determine applied bending moment (M)
- Assume liner thickness (t)
- Check tensile forces in liner (F)
- Check shear capacity at liner/grout interface
- Iterate until Factor of Safety (FS) above 2

Applicable for Man-entry sewers and non-Man entry

Flexible design that uses the existing sewer and ground support where possible

In most cases the liner is only designed to withstand ground water as the existing sewer will continue to support ground and traffic load

Produces a thicker liner body and uses lower strength grout
**Type II Liner Design**

- Can be used with any liner
- Circular and non-circular designs

**Type II Design Procedure:**
- Determine critical section
- Determine external loads
  - Soil and live loads (Only included in special cases as host pipe assumed to take overburden loads)
  - Hydrostatic (in all design cases)
- Determine liner thickness based on:
  - Full overburden pressure
  - Hydrostatic pressure
- Using the following:
  - Structural checks for applied bending stress
  - Serviceability checks on wall deflection

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**GRP Liner Construction:**

- Inner corrosion barrier consists of 1.5mm (0.6”) of isophthalic, vinyl ester or epoxy resin
- Consolidated, bi-direction fiberglass mat and resin
- Center core consists of silica sand and resin
- Second layer of fiberglass mat and resin
- Outside surface is treated with bonded aggregate to enhance adhesion with grout as required by WRc Type 1 composite design method

The result is a flexible but structural liner that will resist live loads, dead loads and hydrostatic pressure.

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**Designing Large Diameter, Non Circular Liners**

Most commonly used Design is the WIS 4-34-02, Specification for Glass Fiber Reinforced Plastic (GRP) Sewer Lining. (Taken from WRc Sewerage Rehabilitation Manual.

Other standards are the with BS5480 and ASTM D3262. (for circular pipes) and ATV - M-127-2.

NOTE: Where the above design methods are not acceptable, Finite Element Analysis can be used, however very expensive.

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**Hydraulic Capacity**

- Channeline will give an improvement to the flow capacity and hydraulic self cleaning ability. Using Manning the “K” value is 0.23% and the coefficient value of “n” 0.009.
- Using Colbrooke White method the Ks value of the liner is 0.03.
- GRP sheds slime easily but if allowance for slime is required the value of 0.6 is used.
In some environmentally sensitive areas such as Fish Bearing creeks, it is necessary to slow down the flow.

This can be done by applying a non-slip surface to the liner invert.

Fish Baffles can also be incorporated into the invert.

Main benefits of GRP Channeline Structural Lining Systems

• Panels are custom built for each project, to maximize the cross sectional area
• Allows for transitions, bends and other pipe/culvert anomalies to be rehabilitated
• Low-Tech installation, small construction foot print

• GRP panels are supplied in either one piece or multiple piece.
• Two piece panels are designed to offer massive savings on shipping costs.
• Larger odd shaped profiles can then be nested or stacked to allow far greater numbers of pipe section to be shipped.

• Quality control is in accordance with ISO 9000.
• Random samples are taken twice daily and tested for mechanical properties.
• Every manufactured liner is issued with its own identity number giving full trace-ability.
• All liners are checked for Barcol hardness to ensure full resin cure.
• Flexural Modulus and Bending Stress test values issued for each contact if requested.
Pre Construction Testing

• The contract stated that should a Type 1 Design be proposed that Third Party Testing would be required to confirm Grout Strength and Shear Bond.
• All testing was carried out by CATT (Centre for the Advancement of Trenchless Technology - University of Waterloo).
• Flat plate samples were manufactured shipped along with grout samples.
• Samples where then cast and cured for 28 days.

• Testing is conducted as per WRc IGN 4-34-02, Appendix E – Method for the Determination of Shear Bond Strength
• A value of 98psi (0.68 Mpa) was used

Design purposes
• Recent mean Average for Test Data Showed 110psi (0.75 Mpa)
• Specified Compressive Strength for Grout was 1740psi (12 Mpa)
• Break tests showed results of over 5801 psi (40 Mpa)

Jointing System

• GRP Panels are supplied with a bell and spigot joint with is used in conjunction with a gasket or construction sealant.
• GRP two piece and multi-piece lining units come with a tapered tongue and groove longitudinal joint and a bell and spigot radial joint.
• Channeline invert liners come with 3” (75mm) deep radial tongue and groove joint to ensure liners are locked together after placing in the sewer.

• Channeline SL (Sliplining) Panels are provided with a Silicone Filled Roll over Gasket that fits into the Bell and Spigots Joint.
• Rubber Gasket Specifications EPDM synthetic rubber compound ASTM C361, C443, C425, C1619 and CSAA257
• Rated for high concentration of sewer gases and chemicals present in municipal sanitary sewer systems.
• SPWCC Greenbook Approved (ASTM C425)
• Pressure Tested to 30 PSI (2bar)

NOTE: Gaskets can be difficult on flat profiles
**GRP Traditional Non-circular Lining**

- Custom built to suit any gravity pipe or tunnel environment.
- Liner has a 30 plus year history with no known failures.
- Can be installed as a one or multi piece liner.
- No limitation of size, profile or location.

**Slip-Lining Panels**

- Pipe is designed for round and non round slip lining in lengths of up to 1500ft
- Centralizing skid system acts to both reduce jacking loads and help prevent floatation during annular grouting
- Designed to withstand full force jacking

**Our in line high strength joints are combined with lubricated silicon filled rollover gasket to providing ease of connection and a high integrity pressure tight seal.**
Curved Panel Lining

Made to Measure Molded Curved Panels

- A unique Solution for Lining Bends for any size or shape with Integral Gasket Seal.
- Can be used for both Slip Lining or Traditional Liners.
- Requires Laser or LIDAR scanning prior to design and manufacture.

Conversion of Field Measurements or Multi-sensor Data into production drawings

Plans to Manufacturing
Toronto Transit Commission
Leslie Street Transition Zone – Toronto 2014

GRP STRUCTURAL LINING SYSTEMS

Multi-piece Panels

• Developed to service the growing market for larger diameter tunnels and pipes.
• By manufacturing a multi-piece panel that can be "flat packed."
• Savings of up to 50% can be achieved.
• The Multi-piece system is easily assembled on site and uses an FRP Ring seal and patented silicone filled Gasket to ensure water tightness.

Leslie Street Transition Zone – Toronto 2014

GRP STRUCTURAL LINING SYSTEMS

Multi-piece Panels

• This allows an infinite number of shapes, lengths, and joining systems to be used to offer the optimum tunnel liner design for maximum capacity or maximum flow designs.
Survey of Host Pipe

- Steps were then taken to accurately measure the host pipe for Liner size and length.
- Traditional measuring technic used by transporting a mandrel through the Sewer.
- Mandrel is built to proposed Liner OD and length.
- Mandrel dimensions are then sent to Manufacturer for engineering and shop drawings.
- Multi-sensor/Lasar Profiling Equipment can also be used.

Non circular Slip Lining in LA

Slip Lining / Pipe Jacking
PULL IN PLACE WITH RAIL SYSTEM

Carried in Place Using a Custom Built Cart or Pipe Carrier

UK Installation in Live Creek
GRP STRUCTURAL LINING SYSTEMS

UK Installation in Live Creek

Carried in Place Using a Custom Built Cart or Carrier

Automated Pipe Carrier for Longer Lengths

Bulkheads can be built in several ways - Brick and mortar construction, concrete form, Expandable foam grout.

Bulkhead Construction
Annulus grouting is performed from inside the liner at pre-determined intervals along each section. The grout should be a non-aggregate material to ensure even distribution. Typically, Flyash, cement and water, although Cellular grout can be used with a Type 2 design.

Recommended Grout strength by design types (according to WRc Sewerage Rehabilitation Manual Volume 3, Section 7 Grouting Materials):

<table>
<thead>
<tr>
<th>Grout Function</th>
<th>Minimum Compressive Strength at 28 days (N/mm²)</th>
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</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>12 (approx. 1740psi)</td>
</tr>
<tr>
<td>Type 2</td>
<td>3 (approx. 435psi)</td>
</tr>
<tr>
<td>Exterior Void Filling</td>
<td>2 (approx. 290psi)</td>
</tr>
</tbody>
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Erie County, Buffalo, New York
Rehabilitation of Dick Road Culvert
Installation of Channeline Sewer System, GRP Lining of (14ft x 6ft x 115ft) 4200mm X 1800mm X 35m Elliptical CSP Storm Sewer.
Completion Date: December 2002
**GRP STRUCTURAL LINING SYSTEMS**

**Carlaw Avenue Box Culvert Rehabilitation, City of Toronto, ON.**
Rehabilitation of Existing Box Culvert
Installation of Channeline Sewer System, GRP Lining of (5.5ft x 5.5ft x 2460ft) 1650mm X 1650mm X 750m Box Profile Storm Sewer.
Completion Date: October 2003

**Zaventem, Brussels**
Rehabilitation of Existing Box Culvert
Installation of Channeline Sewer System, GRP Lining of (10.6ft x 4.5ft x 492ft) 3200mm X 1350mm X 150m Rectangle Profile RCP Storm Sewer.
Completion Date: April 2004

**Abbey Street, Reading, United Kingdom**
Rehabilitation of Existing Box Culvert (Various Size with Transitions)
Installation of Channeline Sewer System, GRP Lining of (11.5ft x 2.3ft) 3450mm X 700mm + (11.5ft x 5.1ft) 3450mm X 1550mm + (11.5ft x 3.5ft) 3450mm X 1050mm Profiles Rectangle Profile RCP Storm Sewer.
Completion Date: July 2005

**Carlaw Avenue Box Culvert Rehabilitation, City of Toronto, ON.**
Rehabilitation of Existing Box Culvert (Phase 2)
Installation of Channeline Sewer System, GRP Lining of (5.5ft x 5.5ft x 5413ft) 1650mm X 1650mm X 1650m Box Profile Storm Sewer.
Completion Date: January 2006
Milwaukee Metropolitan Sewerage District, Milwaukee
Rehabilitation of Existing RCP Highway Culvert
Installation of Channeline Sewer System, GRP Lining of (5.3ft x 3.2ft x 3599ft) 1598mm X 988mm X 1097m Box Profile Combined Sewer.
Completion Date: May 2010

Central Ave, Windsor Ontario, ON.
Rehabilitation of CSP Culvert under Hwy 401.
Installation of Channeline Sewer System, GRP Lining of (4.04ft x 2.4ft x 672ft) 1212mm X 737mm X 205m Elliptical Profile Storm Sewer.
Completion Date: January 2011

Mill Creek, Cleveland, Ohio
Rehabilitation of Mill Creek Interceptor
Installation of Channeline Sewer System, GRP Lining of 11.4ft x 4.8ft x 236ft) 3434mm X 1466mm X 72m Box Profile Combined Sewer.
Completion Date: August 2011

Warrensville Rd, Shaker Heights, Ohio
Rehabilitation of Shaker Heights Box Culvert
Installation of Channeline Sewer System, GRP Lining of (9.58ft x 4.5ft x 116ft) 2874mm X 1350mm X 35m Box Profile Combined Sewer.
Completion Date: September 2015
City of Edmonton Alberta
Rehabilitation of 99th Ave Deep Tunnel
Installation of Channeline Sewer System, GRP Lining of 5.26ft x 3.02ft x 720ft) 1578mm X 908mm X 220m Semi Elliptical Profile Combined Sewer. (33m deep)
Completion Date: May 2015

Arch Culvert, Richmond BC
Rehabilitation of Bath CSP Arch Outfall Pipe
Installation of Channeline Sewer System, GRP Lining of (10.5ft x 4.24 x 31.9ft) 3170mm X 1273mm X 9.75m Elliptical Profile Combined Sewer.
Completion Date: September 2015

Winnipeg, Manitoba
Rehabilitation of Mission St and Selkirk Large Diameter Egg Shaped Sewers
Installation of Channeline Sewer System, GRP Lining of (12.14ft x 5.47ft x 162ft) 2642mm X 1642mm X 50m and (5.8ft x 4.6ft x 433ft) 1750mm X 1390mm x 132m Egg Profile Combined Sewer.
Completion Date: February 2016

Richmond BC
Rehabilitation of No. 1 Road Box Culvert
Installation of Channeline Sewer System, GRP Lining of (9.3ft x 5.03ft x 1049ft) 2795mm X 1510mm X 320m Box Profile Combined Sewer.
Completion Date: September 2016
North American Projects completed in the following cities

USA
- Chicago
- Cleveland
- Los Angeles
- Rhode Island
- New Jersey
- Buffalo
- St Paul
- Milwaukee

Canada
- Toronto
- Ottawa
- Windsor
- Hamilton
- Edmonton
- Winnipeg
- Richmond
- Victoria

Presently there are 10 Experienced Contractor in North America

Channeline is an international company with over 30 years experience with offices or partnering agreements in the following countries.

USA
- Czech Republic & Slovakia
- United Arab Emirates
- Russia
- Canada
- UK
- Ireland
- Belgium
- France
- Holland
- Luxembourg
- Sweden
- Switzerland
- Germany
- Poland
- Denmark
- Portugal
- Czech Republic & Slovakia
- United Arab Emirates
- Russia
- Canada
- USA
- Argentina
- Uruguay
- Hong Kong
- Finland
- India
- Italy

Thank you

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