Trenchless Rehabilitation of Non-Circular Wastewater Conveyance Pipe and Tunnels using Advanced Glassfibre Reinforced Polymer Mortar Panels

February 18th, 2016
Pipe User’s Group
24th Annual Sharing Technology Seminar

Timothy Webb, Channeline Vice President - UAE
Ladan Sahafi, Channeline Representative - Western US
Agenda

• City of Los Angeles Approach
• Rehab Methods for Non-circular Pipes
• GRP FRPM Fiberglass Pipe Approval
• Pipe Manufacturing
• Recent Projects in Los Angeles
• Lessons Learned
• Questions & Answers
City of Los Angeles NC Sewers

1. 6,600 Miles of Sewer Pipe (all sizes)
   1. Started modern rehabilitation in 1989
   2. Secondary Sewer Renewal Program to rehab 63 miles per year

2. 64 Miles of sewer mains are NC
   1. 105" Lower North Outfall Sewer
   2. 39" La Cienega Interceptor Sewer
   3. North Outfall Sewer is the longest run
City of Los Angeles NC Sewers

1. Started NC sewer rehabs in 2000’s
   A. 105” Lower North Outfall Sewer
   B. 39” La Cienega Interceptor Sewer
   C. North Outfall Sewer is the longest run

2. First Tested NC GRP in 2003
   A. Woodvale Ave. Storm Drain
   B. 450 LF of 39” Semi-elliptical
Los Angeles
Fun, Fun, Fun!
LA Rehab Methods for NC Pipes

1. Man-entry with full By Pass Option
   A. Formed/Cast in Place PVC Liner
      a) Arrow-Lock (modified T-Lock)
      b) Danby (Grooved and Locked PVC)
   B. Machine Spiral Wound PVC Liner
      a) SPR (non-structural, requires rebar)

2. None Man-entry Live Flow Sliplining GRP
LA Rehab Methods for NC Pipes

- Formed/Cast in Place PVC Liner
- Full Bypass Required
- Full Surface Cleaning
- Rebar or Reinforced Mesh Placed
- Forms and LINER are Placed
- 4,000 psi Grout is Pumped Behind Liner
- Move Forms Forward and Repeat

- Labor Intensive
- Invert Remained Unlined
- Slow Process (50 ft/day)
LA Rehab Methods for NC Pipes

None Man-entry Live Flow Sliplining GRP
CITY OF LOS ANGELES NC GRP PROJECT HISTORY

Previously …
1. NOS Emergency at LA River – Vido Artukovich and Sons (2008)
2. 23rd Street at Trinity Emergency (Ameron RPMP) – Tomovich (2009)
3. NOS Maze V Rehab – Spiniello (2010-11)

Currently in Final Stages …
1. NOS Units 2 and 5 (under construction) – Spiniello
2. West LA Interceptor Sewer (under construction) – Colich
3. COS Rehab from Slauson to Vernon (under construction) – Buntich

Future Construction …
1. NOS Unit 3 (Bid in July 2015) – (6600 ft Test Project)
2. NOS 18 (to bid)
3. NOS 6 and NOS 7 (to bid)
CHANNELINE GRP APPROVAL

London Sewer System
1600’s Built
HISTORY:

- Started in 1978
- In London
- Specialized in Corrosion
- Specialized in Structural Rehab

- 1979 London’s major water agency retained Water Research Centre (WRc) for investigation of structural and corrosion problems in large diameter sewers (300 year old brick-lined sewer pipelines)

  - (WRc) undertook 5 year research
  - Study materials and methods of rehab (HDPE, PVC, Spray-up Mortar, GRP, ...)

Beyond the Ordinary
Water Research Centre Work Included:

- Finite element studies and computer modelling
- Mechanical testing
- Wet abrasion testing
- Flow/Hydraulic monitoring
- Corrosion resistance evaluation
- Strain corrosion testing
After 5 years research and a £10 million budget

- **1984** WRc Sewerage Rehabilitation Design Manual was finally published

- **1984** Channeline became a Manufacturing Company to specifically produce and market STRUCTURAL MAN-ENTRY GRP lining systems under: Channeline Sewer Systems Ltd.

- **Since then**, many innovations in production of GRP panels were made and several patents were issued to Channeline
MANUFACTURING - Standards:

- Channeline GRP meets and exceeds
  - WRc Guidance WIS 4-32-02 for Materials
  - British Standard BS5480
  - ASTM D3262, Type 1, Liner 2 and Grade 3 Cell Class
DESIGN - Standards:

- Round Pipe Standards DO NOT DIRECTLY Correlate to ODD shapes.
  - AWWA M45: Manual for Fiberglass Pipe Design (Chapter 5)
  - WRc: Guidance WIS 4-32-02 for Materials
  - FEA: Finite Element Analysis Check
ASTM D-2412 Parallel Plate Test for Plastics
FEA for Maximum Cover Depth

<table>
<thead>
<tr>
<th>Type</th>
<th>Min</th>
<th>Max</th>
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<tbody>
<tr>
<td>VON: von Mises Stress</td>
<td>22.8975 psi</td>
<td>2789.99 psi</td>
</tr>
<tr>
<td>Node: 13883</td>
<td></td>
<td>Node: 13196</td>
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</table>

COS LINER MAXIMUM COVER-MAXIMUM COVER-Stress-Stress1
Good News
This won’t be on the test today!

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stress1</td>
<td>VON: von Mises Stress</td>
<td>3.69734e-03</td>
<td>201.01 psi</td>
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<tr>
<td>Displacement1</td>
<td>URES: Resultant Displacement</td>
<td>0 in</td>
<td>3.39796 in</td>
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</table>

Node: 6560
Node: 3097
MANUFACTURING - Make-up of Liner:

- **60 mil (1.5 mm) Inner Corrosion Barrier**
  - Isophthalic Polyester
  - Vinyle Ester
  - Epoxy

- **Inner Fiberglass**
  Consolidated bi-direction Fibreglass Mat and Resin

- **Center Core**
  Silica Sand, Resin and Chopped Fiberglass

- **Outer Fiberglass Mat and Resin**
  complimented with **Chopped Glass**
  (chopped fiberglass for sliplining flush-bell joint where gasket groove and coupling shelf will be machined out)

- **Bonded Corse Aggregate OD**
  Enhances Adhesion with Grout as Required by WRc Type 1 composite design method
### MANUFACTURING - Joint Systems:

<table>
<thead>
<tr>
<th>Component</th>
<th>Type</th>
<th>Joint Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe</td>
<td>One-piece</td>
<td>Gasket BellxSpigot</td>
</tr>
<tr>
<td>Panel</td>
<td>Multi-piece</td>
<td>Tapered Tongue &amp; Groove Longitudinal Joint</td>
</tr>
<tr>
<td>Invert Liner</td>
<td>Clam-shell</td>
<td>75 mm Deep Radial T&amp;R</td>
</tr>
</tbody>
</table>
MANUFACTURING - Gasketed Joints:

- Gaskets are Silicone Filled roll-over type
- Gaskets fit 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 100 PSI
MANUFACTURING - Quality Control:

- All Channeline renovation systems conform to the requirements of the WRc rehabilitation design manual and the relevant BS, ISO & ASTM standards.
- Quality control is in accordance with ISO 9000.
- Random samples are taken twice daily and checked for mechanical properties.
- Every manufactured liner is issued with its own identity number giving full trace-ability.
- Impact Test - 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.
MANUFACTURING - Traceability

MANUFACTURED BY CHANNELINE INTERNATIONAL LTD.

PROJECT: COS REHABILITATION OF CENTRAL OUTFALL SEWER (SLAUSON AVE. TO VERNON AVE.)
CLIENT: CITY OF LOS ANGELES
CONTRACTOR: MLADEN BUNTEH CONSTRUCTION CO., INC.
WORK ORDER / CONTRACT NO.: SZC12534 / CL 071
PANEL NUMBER: PROTOTYPE PANEL 02
LOT NUMBER: PRE - PRODUCTION
DIMENSIONS: (H)1702mm (67") x (W)1245mm (49") x (L)2.44m (8'') / WALL 25mm (1'')
MOULD I.D. NUMBER: DM 002
DATE OF MANUFACTURE - SHIFT: 05/02/2015 - 1st Shift
MADE IN UNITED ARAB EMIRATES

ASTM D3262 1-2-3
EQUIV. PIPE STIFFNESS 63.4 MIN. VE.LINER
MANUFACTURING - Custom Made

- Gather data for the Host Pipe (VERY CRITICAL)
  - CCTV and Sonar
  - 3D Laser Profiling
- Prepare the Pipe Profile Drawings
Measure Twice – Cut Once!
MANUFACTURING - Custom Made

- Submittals
- Making of the Mold
MANUFACTURING - Inspection
MANUFACTURING - Inspection
GRP PIPE FEATURES

- Custom-Made Production in any Size and Shape
- Fully Structural Rehabilitation Solution
- Maximizing Hydraulic Capacity
- Excellent Corrosion Resistance
- Excellent Impact and Abrasion Resistance
- Expected Service Life of Over 50 Years
GRP PIPE - Applications

- Sewer Main Pipelines
- Sewer Overflow Pipelines
- Sewer Interceptor Pipelines
- Sewer Inverts
- Storm Water Drains
- Seawater Cooling Pipelines
- Large Diameter Culverts and Tunnels
GRP PIPE - Shapes and Sizes

- Ovoid
- Egg shaped
- Elliptical
- Flattened Elliptical
- Arch barrel
- Box shaped

<table>
<thead>
<tr>
<th>DIMENSIONS</th>
<th>LENGTH IN METERS</th>
<th>NO. OF PANELS PRODUCED</th>
<th>NO. OF MOULDS MADE</th>
<th>PROFILE</th>
<th>CONTRACTOR / LOCATION / YEAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1640mm x 1.0m / Wall 30mm</td>
<td>11</td>
<td>11</td>
<td>1</td>
<td>CIRCULAR (ONE PIECE)</td>
<td>JETROD PIPELINE CONSULTANT &amp; ENGINEERING LTD, HONGKONG (2013)</td>
</tr>
</tbody>
</table>
GRP PIPE - Performance

Hydraulic Capacity:

- Maximizes Cross Sectional Area of the Liner compared to Host Pipe
- Relative Surface Roughness Smooth
- Low Manning’s Coefficient of 0.009
- GRP sheds slime easily
PRODUCTS - Performance

Flow Capacity Generally Improves After Lining with GRP
Flow Capacity  
\[ Q = \left( \frac{1.49}{n} \right) A R^{2/3} S^{1/2} \]

- \( n \) = Manning’s Coeff.
- \( A \) = Cross Sectional Area
- \( R \) = Wet Radius
- \( S \) = Slope

Reducing Two Simultaneous Equation On The Same Slope

\[ \frac{Q_1}{Q_2} = \left( \frac{n_2}{n_1} \right)^{8/3} \left( \frac{D_1}{D_2} \right)^{4/3} \]

- \( n_1 \) = Manning’s Coeff. Host
- \( n_2 \) = Manning’s Coeff. Channeline
- \( D_1 \) = Equivalent Mean Circular Diameter of Host
- \( D_2 \) = Equivalent Mean Circular Diameter of Channeline
Channeline CL

Made to Measure Molded Curved Panels
Box Culvert
Box Culvert - Completed Liner
Flat Bottom Non-Circular
Egg Shaped
Curved Box
Flat Bottom and Transition Pieces
Transition & Reducer Piece
Transition & Reducer Piece
RECENT PROJECTS IN LOS ANGELES
North Outfall Sewer (NOS) Unit 2 and Unit 5 Rehab
LARGEST GRP SLIPLINE PROJECT TO DATE

<table>
<thead>
<tr>
<th>Location:</th>
<th>Los Angeles, California</th>
</tr>
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<tbody>
<tr>
<td>Contractor:</td>
<td>Spiniello</td>
</tr>
<tr>
<td>Project Size:</td>
<td>$15,694,000</td>
</tr>
<tr>
<td>Pipe Size:</td>
<td>72” and 66”</td>
</tr>
<tr>
<td>Length:</td>
<td>10,500 LF</td>
</tr>
<tr>
<td>Liner Type:</td>
<td>Single Piece Liner Pipe</td>
</tr>
<tr>
<td>Joint Type:</td>
<td>Positive Gasket Seal Low</td>
</tr>
<tr>
<td>Profile</td>
<td>Bell x Spigot</td>
</tr>
<tr>
<td>Installation:</td>
<td>Jacked Sliplining Under Live-Flow</td>
</tr>
</tbody>
</table>
<pre><code>                  | Man-entry under low flow (curves) planned |
</code></pre>
<p>| Year:            | 2013 – 2015 (under construction) |
| Current:         | 100% manufactured and shipped |</p>
North Outfall Sewer (NOS) Unit 2 and Unit 5 Rehab

$15,694,000

Unit 2:  5,351 LF 72” SE Slipline
Unit 2:  800 L F72” SE Man-entry
Unit 5:  3,980 LF 66” SE Slipline
Unit 5:  213 LF of 66” SE Man-entry
Unit 5:  195 LF of 66” SE Man-entry

Multiple Curved alignments
North Outfall Sewer (NOS) Unit 2 and Unit 5 Rehab
North Outfall Sewer (NOS) Unit 2 and Unit 5 Rehab
North Outfall Sewer (NOS) Unit 2 and Unit 5 Rehab
North Outfall Sewer (NOS) Unit 2 and Unit 5 Rehab

Curve Data

<table>
<thead>
<tr>
<th>No.</th>
<th>$\Delta$</th>
<th>R</th>
<th>T</th>
<th>L</th>
<th>PJ STA.</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>90°00'50&quot;</td>
<td>50</td>
<td>50</td>
<td>78,55'</td>
<td>51+41,69</td>
</tr>
<tr>
<td>6</td>
<td>89°53'20&quot;</td>
<td>49.80</td>
<td>49</td>
<td>78,44'</td>
<td>54+63,11</td>
</tr>
</tbody>
</table>

Notes:

1. Stationing shown on these plans, measured on tangents per original plan 298559. Use curve length for actual distance.
North Outfall Sewer (NOS) Unit 2 and Unit 5 Rehab
North Outfall Sewer (NOS) Unit 2 and Unit 5 Rehab
North Outfall Sewer (NOS) Unit 2 and Unit 5 Rehab
North Outfall Sewer (NOS) Unit 2 and Unit 5 Rehab
North Outfall Sewer (NOS) Unit 2 and Unit 5 Rehab

Lessons Learned:

- Damage during Unloading (dropped a container)
- Proper Gasket Installation (bonded to spigot)
- Bulkhead Integrity (Hidden side sewers)
- Lateral Connections
# Rehabilitation of Central Outfall Sewer (COS) – Slauson to Vernon

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
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</thead>
<tbody>
<tr>
<td><strong>Location:</strong></td>
<td>Los Angeles, California</td>
</tr>
<tr>
<td><strong>Contractor:</strong></td>
<td>Buntich</td>
</tr>
<tr>
<td><strong>Project Size:</strong></td>
<td>$6,844,442</td>
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<tr>
<td><strong>Pipe Size:</strong></td>
<td>72”</td>
</tr>
<tr>
<td><strong>Length:</strong></td>
<td>5,246 LF</td>
</tr>
<tr>
<td><strong>Liner Type:</strong></td>
<td>Single Piece Liner Pipe</td>
</tr>
<tr>
<td><strong>Joint Type:</strong></td>
<td>Positive Gasket Seal Low</td>
</tr>
<tr>
<td><strong>Profile</strong></td>
<td>Bell x Spigot</td>
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<td><strong>Installation:</strong></td>
<td>Jacked Sliplining Under Live-Flow</td>
</tr>
<tr>
<td><strong>Year:</strong></td>
<td>2015 (under construction)</td>
</tr>
<tr>
<td><strong>Current:</strong></td>
<td>100% manufactured and shipped</td>
</tr>
</tbody>
</table>
REHABILITATION OF CENTRAL OUTFALL SEWER (COS)  
SLAUSON TO VERNON

Top Heavy Ovoid Will Tilt During Sliplining  
Skids or Spacers Were Suggested
Channeline - SL

Skids (aka centralizers)

1. Reduce Jacking Loads
2. Prevent Floatation During Annular Space Grouting
3. Prevent Top Heavy Shapes from Tilting
Channeline - SL

Skids (aka centralizers)

1. Factory Installed
2. Four per Pipe Section
What Happened to the Skids?

ALL SKIDS WERE REMOVED FROM 2, 4, 8 and 10 O’clock LOCATIONS BY THE CONTRACTOR!!!
What Happened to the Skids?

STEEL MANDREL SHOWED CONTACT AT 2, 4, 8 and 10 O’clock LOCATIONS DURING CLEANING AND MANDREL TESTING!!!
What Happened to the Skids?

"Extent of Sewer Damage Varies Along Alignment.....etc."

What does that mean?

Sections of COS were repaired about 50 years ago with an additional layer of bricks, just not sure where exactly!!

NOTES:

1. EXTENT OF SEWER DAMAGE VARIES ALONG ALIGNMENT. SEE SPECIFICATIONS FOR BEST AVAILABLE INFORMATION.
2. THE CONTRACTOR SHALL SELECT ONE OF THE REHABILITATION OPTIONS LISTED HEREIN FOR THE ENTIRE ALIGNMENT AND ACCOMMODATE FOR LATERALS WHERE THEY OCCUR.
3. WHEN PERSONNEL ENTRY IS REQUIRED, THE CONTRACTOR SHALL PROVIDE ANY AND ALL NECESSARY SAFETY PROCEDURES AND SYSTEMS AS DEEMED NECESSARY BY THE SAFETY OFFICER AND CALOSHA.
4. SEE CIVIL DRAWINGS FOR THE REACHES OF THE 2 AND 3 BRICK LAYERED PIPE. 3 BRICK LAYER PIPE SHOWN.

G 1  EXISTING 57 x 72 BRICK COS

NOT TO SCALE
REHABILITATION OF COS

If the Host Pipe is Too Small

A. Reduce the GRP Liner Size
   a) Too Late (all pipe onsite)

B. Force remove the extra Brick Layers
   a) Under homes and yards, potential for collapse
   b) No good mechanism other than man entry
Checking joint seal after each segment pushed.
What Happened to the Skids?

- GRP made the same contacts as steel mandrel
- Jacking machine overloaded the GRP beyond its design limits, damaging joints
- GRP string/train tilted to one side, point loading trailing joints.
- GRP had no grouting support, so it lifted up, deflecting the joints upwards

**Rehabilitation of COS**

GRP is easily repairable
- Once the liner was sliplined in'
- The City okayed man-entry
- The delaminations were fiberglass patched
- Annular space grouted
- Job done!
Lessons Learned: 3D Laser Scan the System before bid
Existing connections are normally brought into the liner as they are reached.

It is not necessary to block off the connections during lining.
Finishing RC Manhole

NEW MH FRAME & COVER PER STD PLAN S-288-2

SYM ABOUT E

EXIST SURFACE

NEW MH SHAFT PER STD PLAN S-142-0

PROTECTIVE LINING

4" MIN GUNITE SLAB WITH 5"X6" X 4" W/ 1.4 WWF @ CENTERLINE (TYP ALL SIDES)

#5 @ 6, TYP

#5 @ 6, TYP

#5 @ 6, TYP

3 - #5

1 1/8" MIN

#5 @ 6, TYP

#5 @ 6, TYP

NEW SLUPLINER PIPE

REINF CONC BLANKET

NON-SHRINK GROUT (F_C = 2,000 PSI)

4" MIN GUNITE SLAB WITH 6X6" X 4" W/ 1.4 WWF @ CENTERLINE

A 11 SECTION

SCALE: 3/8" = 1'-0"
Finishing RC Manhole
Casting Manhole Structure

Grouting Process
Channeline is a global product with over 30 years of installation history.
FUTURE PROJECTS:

• Domestic:
  • San Francisco
  • City of Los Angeles
  • Greater Chicago Metropolitan Sewer District

• International:
  • Canada
  • Mexico and Columbia
  • Romania
  • Thailand
  • Hong Kong
Questions?