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Analytical and numerical homogenization of Channeline GRP structural liners for various geometries

Dr. Dev Chelot
Head of Quality and R&D

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Rehabilitation work in sewage industry

- The existing sewers consists of culverts, bricks, stones, concretes, etc.
- Issues: Effects of H_2S attack, corrosion, structural loading beyond its capability.
- Rehabilitating sewers is necessary for such scenarios.

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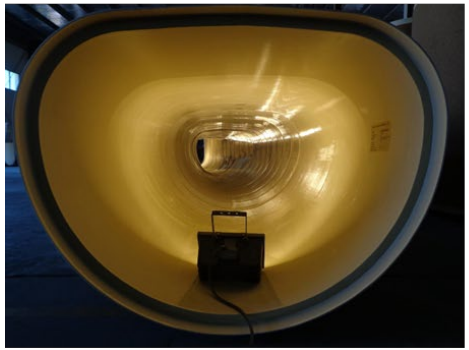
Why Composite materials (GRP)?

- Choice of Resins: Polyester, Vinyl Ester, Epoxy resin
- Multi-functional capabilities
  - ❑ Structural
  - ❑ Chemical Resistant
  - ❑ Light Weight
- Flexible Pipes: Reduced brittle damage
- Can be custom fabricated to any size, shape or form using hand layup method.
- Cost effective Transportation



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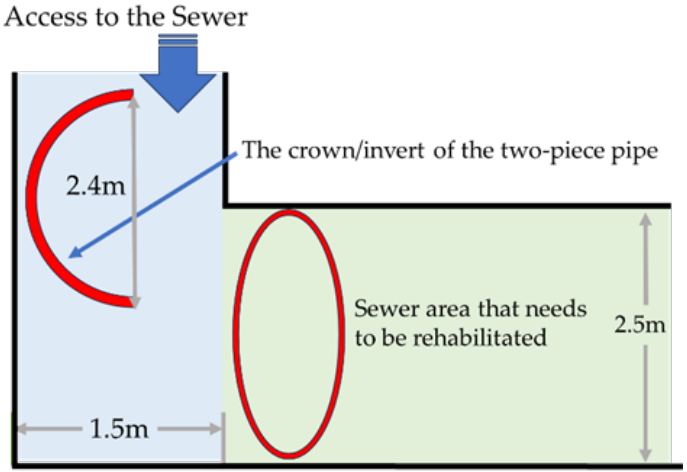
Problems Associated with unitary pipes

- Access to drop large diameter pipes
- Time consuming
- Expensive task



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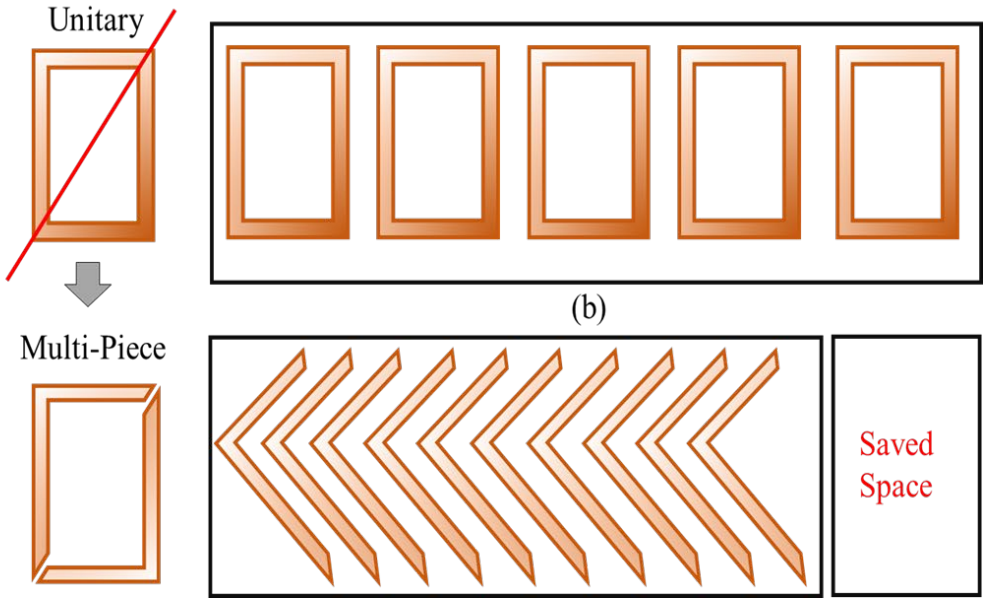
Solution: Unitary ⇒ Multi- Piece

Transportation



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Unitary ⇒ Multi-Piece

Issues specific to Multi-piece pipes

- Usage of the right adhesive
- Mechanical stiffness and strength reduction at joints.
- Corrosive damage to the inside of the pipe

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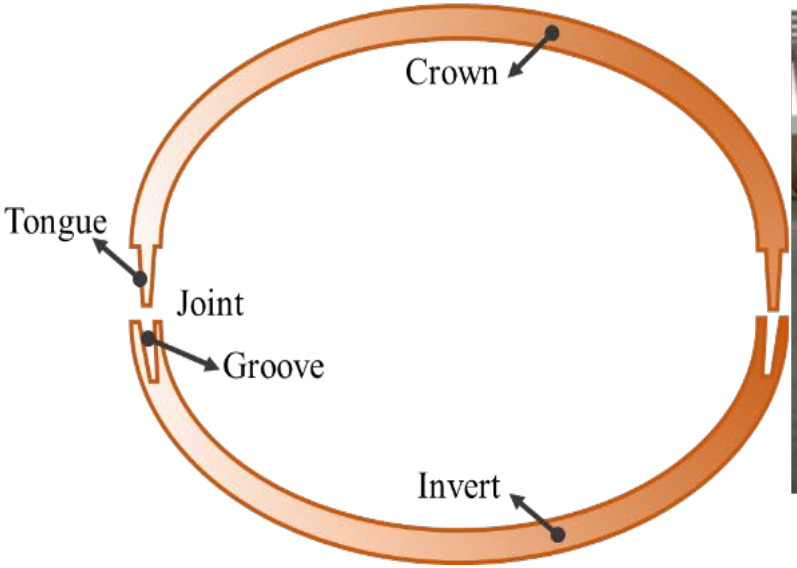
Assembling of multi-segmental pipes

(a)



(b)

(c)

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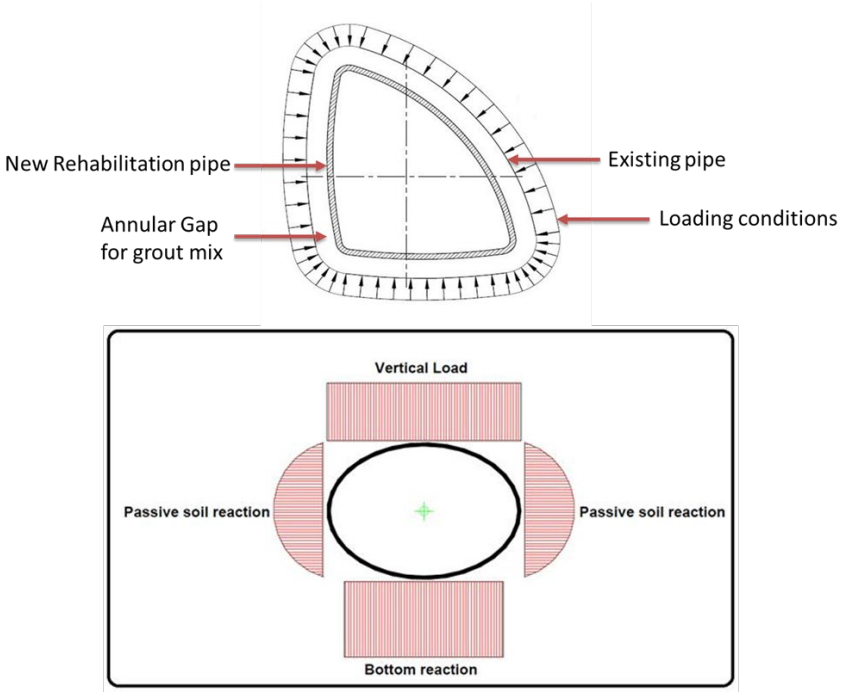
Loading Conditions on a Sewer Pipe



Mechanical Loads:

- Bending
- Tension
- Compression
- Stiffness
- Hoop

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Ring stiffness test / Parallel plate test

Standard: ASTM D2412 Specification

- Ring stiffness test involves ascertaining whether GRP pipes can maintain their shape and structural integrity when exposed to various loads.

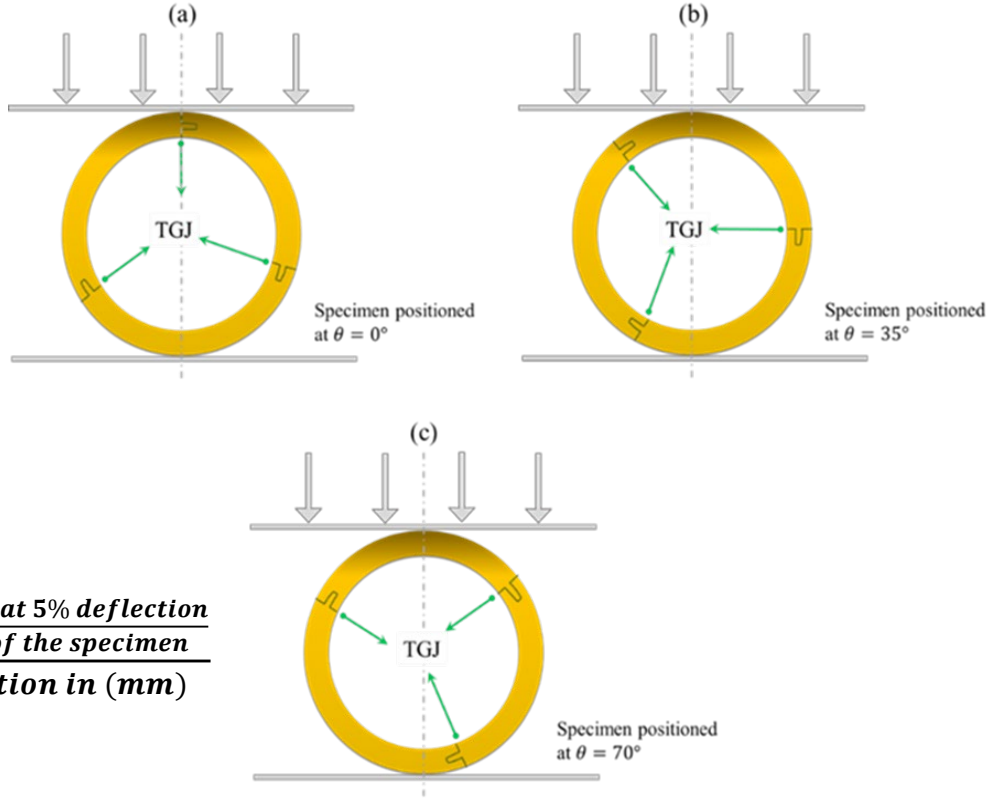
- **Deflection rate:** 12.5mm/min (as per ASTM D2412)

- **Length of the specimen:**
  300mm (+/- 5mm) for ID/H <1524mm
  20% of the ID/H for ID/H >1524mm

Test Outcomes

- Max Load at 5% Deflection in (mm)
- Pipe Stiffness (PS)

$$\mathbf{PS} = \frac{\dfrac{\textit{Max Load at 5\% deflection}}{\textit{Length of the specimen}}}{\textit{Deflection in (mm)}}$$



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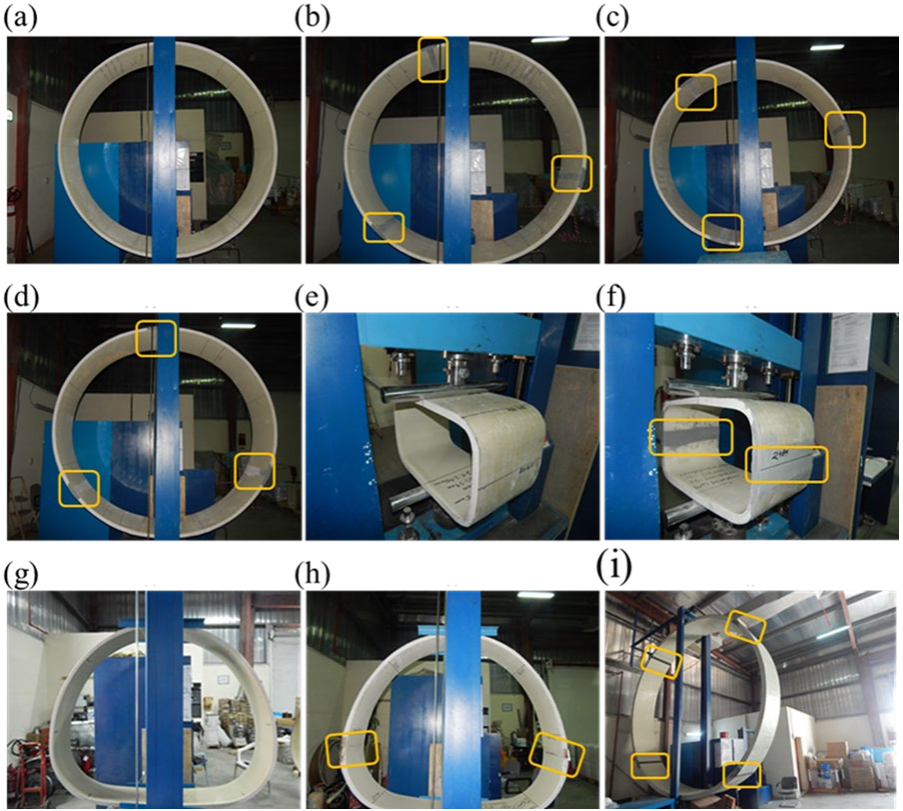

Shapes	Dimension
Circular Pipe 1 (CP1) & Three-Piece Circular (CP1-3)	Internal Diameter: 2200[mm] Length: 440[mm] Wall Thickness 32[mm]
Circular Pipe 2 (CP2) & Four-Piece Circular (CP2-4)	Internal Diameter: 4876.80[mm] Length: 975.36[mm] Wall Thickness 90[mm]
Box Pipe (BP) & Two-Piece Box (BP-2)	Height: 316[mm] Width: 536[mm] Length: 305[mm] Wall Thickness: 25.4[mm]
Semi Elliptical Pipe (SEP) & Two-Piece Semi Elliptical (SEP-2)	Height: 1346.2[mm] Width: 1541.78[mm] Length: 305[mm] Wall Thickness: 28[mm]

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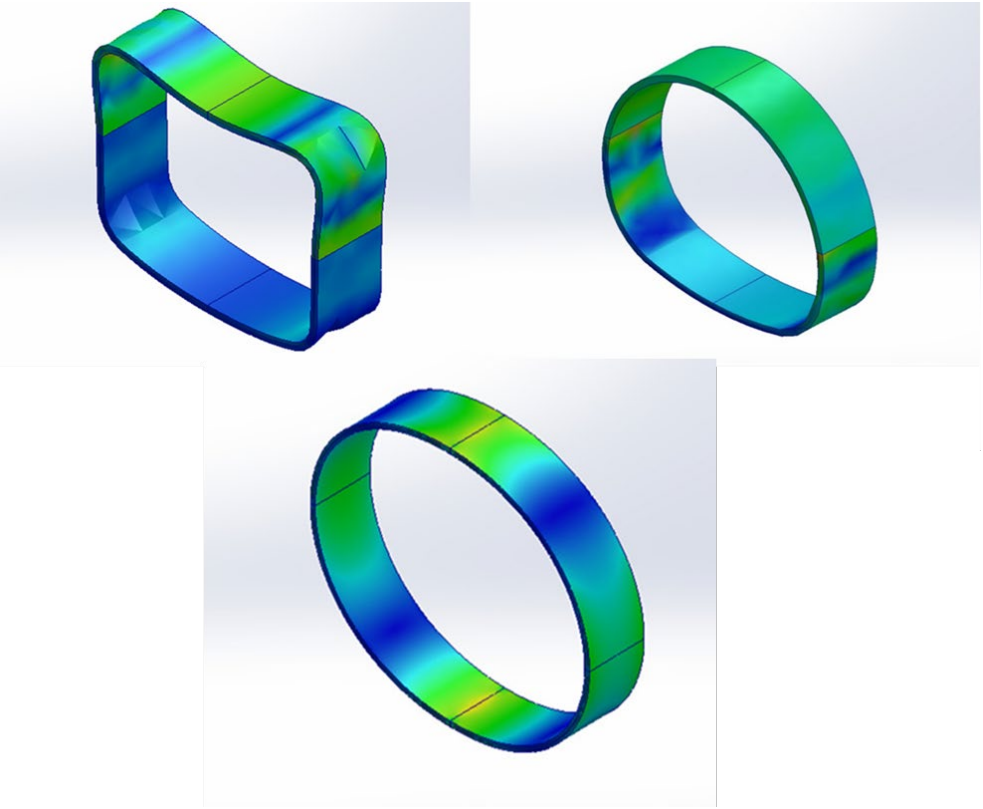
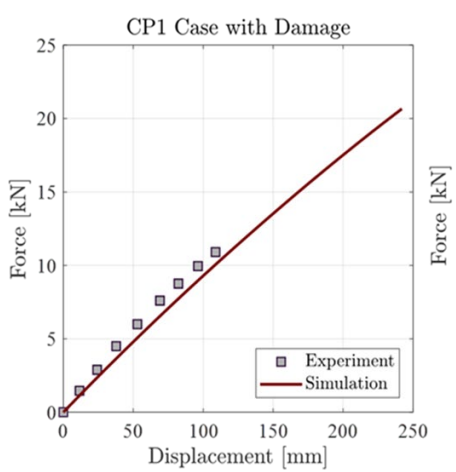
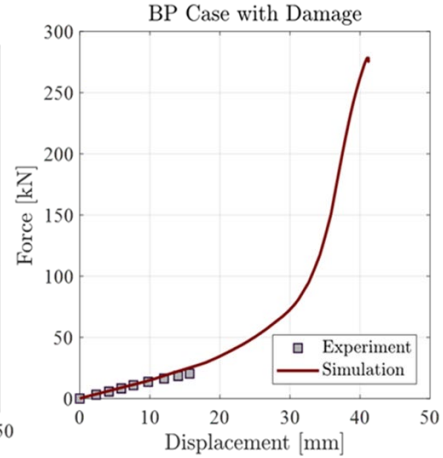
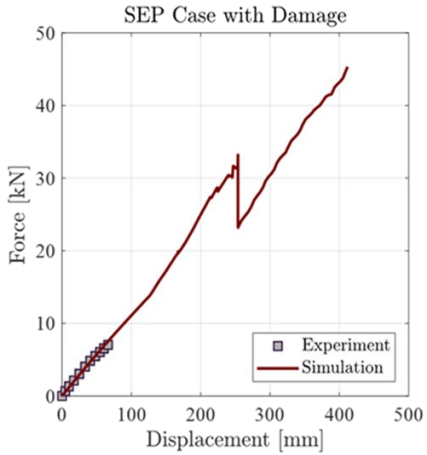



CP1 Case with Damage
Force [kN]
Displacement [mm]
Experiment
Simulation


BP Case with Damage
Force [kN]
Displacement [mm]
Experiment
Simulation


SEP Case with Damage
Force [kN]
Displacement [mm]
Experiment
Simulation

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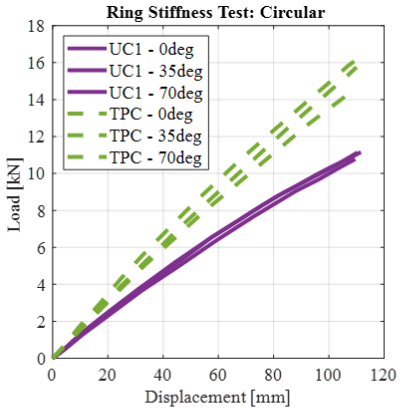
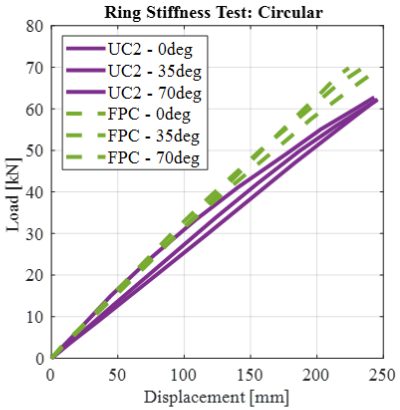
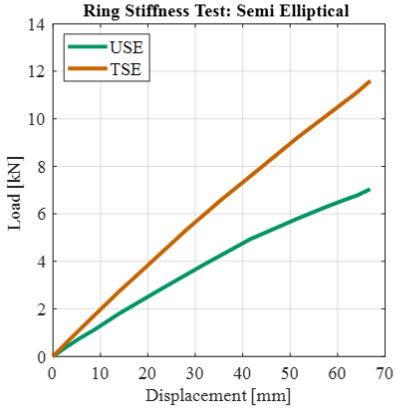
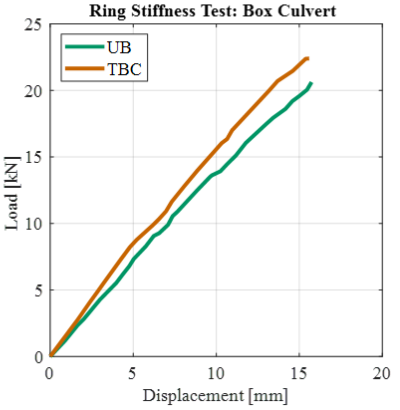
Pipe Type	Load (kN) at 5% deflection	Stiffness (MPa)
CP1 (Unitary)	11.02	0.22
CP1-3 (Three-piece)	15.53	0.32
CP2 (Unitary)	62.40	0.26
CP2-4 (Four-piece)	69.59	0.30
BP (Unitary)	20.61	4.29
BP-2 (Two-piece)	22.39	4.70
SEP (Unitary)	7.04	0.34
SEP-2 (Two-piece)	11.60	0.56









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Conclusion of the Ring Stiffness test results

- Box-shaped pipes demonstrates highest stiffness in comparison to circular and semi-elliptical shaped pipes.
- Multi-piece pipes show equal or higher stiffness than one-piece pipes.
- Two-piece box-shaped pipes demonstrate the highest stiffness.
- FEA shows good accuracy particularly for Box culvert profile and Semi Elliptical profile.

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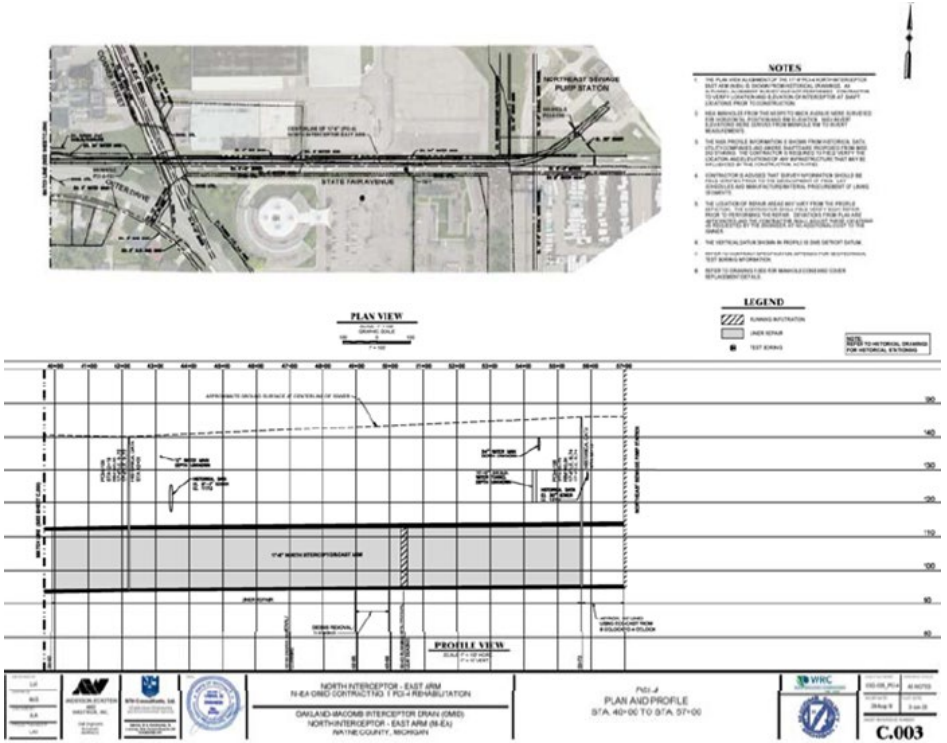
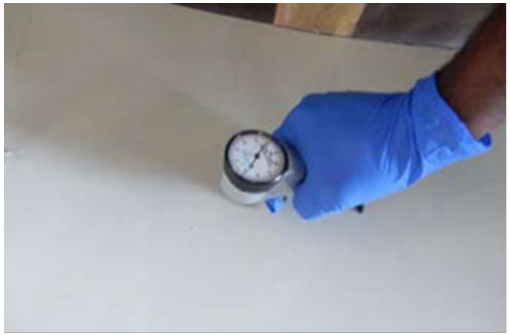
Case study: Rehabilitation of Northeast-Interceptor East Arm (NIEA), Detroit

- Located in Oakland and Macomb county, north of Detroit City
- System was constructed in 6 contract sections between 1969 and 1978
- Approximate length of 79,380 LF
- Ranging in diameter from 12’ to 17’ 6”
- Traditional Rib and Lagging Tunnel construction with a concrete cast in place secondary liner



Case study: Rehabilitation of Northeast-Interceptor East Arm (NIEA), Detroit

- The new GRP liner has an ID of 16’ (4876.8mm) and a wall thickness of 3.54” (90mm) in accordance with AWWA M45 design.
- Prototype pipes were manufactured, and all jointing systems were fully tested for strength, integrity and leak tightness in accordance with relevant ASTM Standards



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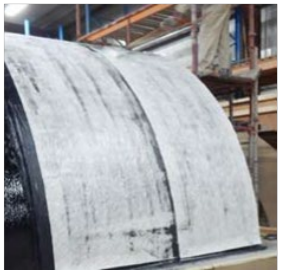
Case study: Rehabilitation of Northeast-Interceptor East Arm (NIEA), Detroit

- Moulds are all built specifically for each individual project
- All liners were manufactured under strict QA/QC guidelines in accordance with ASTM D3262
- Full Inspection Test Procedure Reports were compiled for each Lot and submitted to the owner once the lot was complete.



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- After the manufacturing and finishing process was completed, the liner was crated and loaded into 40ft Seacans.

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- Installation was constructed using a custom designed Pipe Robotic Pipe Carrier.
- The carrier is multi function System that is operated from an Integrated cockpit.
- The system has pipe re-rounder to ensure that each pipe is not deflected under its own weight.
- The carrier also has a forward working platform so that work crews can reach the crown of the pipe to install wooden blocking etc.

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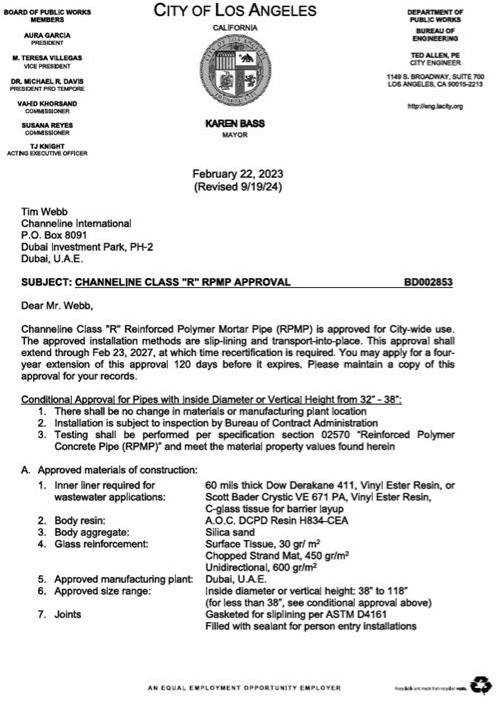
Approvals and certifications for Channeline



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http://eng.lacity.org

February 22, 2023
(Revised 9/19/24)

Tim Webb
Channeline International
P.O. Box 8091
Dubai Investment Park, PH-2
Dubai, U.A.E.

SUBJECT: CHANNELINE CLASS "R" RPMP APPROVAL **BD002853**

Dear Mr. Webb,

Channeline Class "R" Reinforced Polymer Mortar Pipe (RPMP) is approved for City-wide use. The approved installation methods are slip-lining and transport-into-place. This approval shall extend through Feb 23, 2027, at which time recertification is required. You may apply for a four-year extension of this approval 120 days before it expires. Please maintain a copy of this approval for your records.

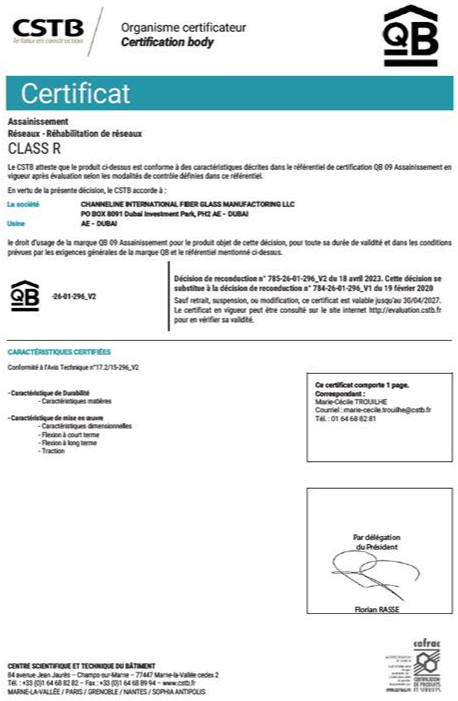
Conditional Approval for Pipes with Inside Diameter or Vertical Height from 32" - 38":

1. There shall be no change in materials or manufacturing plant location
2. Installation is subject to inspection by Bureau of Contract Administration
3. Testing shall be performed per specification section 02570 "Reinforced Polymer Concrete Pipe (RPMP)" and meet the material property values found herein

A. Approved materials of construction:

1.	Inner liner required for wastewater applications:	60 mils thick Dow Derakane 411, Vinyl Ester Resin, or Scott Bader Crystic VE 671 PA, Vinyl Ester Resin, C-glass tissue for barrier layup
2.	Body resin:	A.O.C. DCPD Resin H834-CEA
3.	Body aggregate:	Silica sand
4.	Glass reinforcement:	Surface Tissue, 30 gr/ m²
		Chopped Strand Mat, 450 gr/m²
		Unidirectional, 600 gr/m²
5.	Approved manufacturing plant:	Dubai, U.A.E.
6.	Approved size range:	Inside diameter or vertical height: 38" to 118" (for less than 38", see conditional approval above)
7.	Joints	Gasketed for sliplining per ASTM D4161
		Filled with sealant for person entry installations

AN EQUAL EMPLOYMENT OPPORTUNITY EMPLOYER



CSTB
Organisme certificateur
Certification body

QB

Certificat

Assainissement
Réseaux - Réhabilitation de réseaux
CLASS R

Le CSTB atteste que le produit ci-dessous est conforme à des caractéristiques décrites dans le référentiel de certification QB 09 Assainissement en vigueur après évaluation selon les modalités de contrôle définies dans ce référentiel.

En vertu de la présente décision, le CSTB accorde à :

La société : **CHANNELINE INTERNATIONAL FIBER GLASS MANUFACTORING LLC**
PO BOX 8091 Dubai Investment Park, PH2 AE - DUBAI
Usine : **AE - DUBAI**

le droit d'usage de la marque QB 09 Assainissement pour le produit objet de cette décision, pour toute sa durée de validité et dans les conditions prévues par les exigences générales de la marque QB et le référentiel mentionné ci-dessus.

QB -26-01-296_V2

Décision de reconduction n° 785-26-01-296_V2 du 18 avril 2023. Cette décision se substitue à la décision de reconduction n° 784-26-01-296_V1 du 19 février 2020

Sauf retrait, suspension, ou modification, ce certificat est valable jusqu'au 30/04/2027.
Le certificat en vigueur peut être consulté sur le site internet http://evaluation.cstb.fr pour en vérifier sa validité.

CARACTÉRISTIQUES CERTIFIÉES

Conformité à l'Avis Technique n°17.2/15-296_V2

- Caractéristique de Durabilité
  - Caractéristiques matières
- Caractéristique de mise en œuvre
  - Caractéristiques dimensionnelles
  - Flexion à court terme
  - Flexion à long terme
  - Traction

Ce certificat comporte 1 page.
Correspondant :
Marie-Cécile TROUILHE
Courriel : marie-cecile.trouilhe@cstb.fr
Tél. : 01 64 68 82 81

Par délégation
du Président

Florian RASSE

CENTRE SCIENTIFIQUE ET TECHNIQUE DU BÂTIMENT
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BCCA

BENOR

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BENOR CERTIFICATE

issued on the basis of the provisions of the Implementation Rules for BENOR certification of thermoplastic pipes and accessories, TRA BB 652, to the company

Channeline International Fiber Glass Manufacturing L.L.C.
P. O. Box 8091, Dubai, AE - , Abu Dhabi

for the production of

Monolithic circular and non-circular glass-reinforced thermosetting plastics (GRP) elements for sewer rehabilitation covering the entire surface of the sewer (without pressure): Channeline

manufactured in the production unit

Channeline International Fiber Glass Manufacturing L.L.C.
P. O. Box 8091, Dubai, AE - , Abu Dhabi

in accordance with the

PTV BB-652-100: 2014 "Thermosetting plastics piping systems for sewer rehabilitation (without pressure) – Circular and non-circular elements made of GRP: monolithic elements covering the entire inner surface of the sewer"

By issuing the certificate, BCCA declares that, on the basis of (I) the initial assessment of the product characteristics by means of testing; (II) the initial evaluation and acceptance of the quality assurance in production; (III) the regular external control of the implementation of the quality assurance processes and the control schemes agreed upon; (IV) regular control tests in a recognised external laboratory, sufficient confidence can be given to the measures taken by the certificate holder for guaranteeing conformity with the prescriptions.
The annex to this certificate gives the data with regard to the certified product. This document is an annex to the certificate and is authenticated by BCCA.
Following the issuing of this certificate and as long as it is maintained valid, BCCA grants the right to use the BENOR mark to the certificate holder. The proof of delivery of a product under the BENOR mark is given by a suitable identification on the product. The use of the BENOR mark does not relieve the certificate holder of his responsibilities with regard to the delivered product.
The validity of this certificate can be checked via www.bcca.be.

N° certificate BB-652-4742-652-2-4742-39308 I Valid from 2024-05-30 until 2027-05-29

Issued in Brussels, on 2 July 2024.

Olivier DELBROUCK
General Manager

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The validity of this certificate can be checked on the website www.bcca.be
Further clarification regarding the scope of this certificate and the applicability of the requirements of the standard may be obtained from the certified organisation.

BELGIAN CONSTRUCTION CERTIFICATION ASSOCIATION NPO
HEADQUARTERS: CANTERSTEEN, 47 BE – 1000 BRUSSELS
OPERATIONAL HEADQUARTERS: HERMESLAAN, 9 BE – 1831 DIEGEM
TEL.: + 32 2 230 24 11
MAIL@BCCA.BE I WWW.BCCA.BE

BELAC 021-PROD

www.channeline.com

channeline

Approvals and certifications for Channeline

Our Ref: 15000/CL/2

23rd April 2009

Mr T Webb
Channeline International Ltd
GRP Structural Lining Systems
P.O. Box 8091
Dubai
UAE

Dear Mr Webb

Suitability of the Channeline longitudinal bonded joint for SRM Type II applications

Further to your letter dated 23rd April 2009 I can confirm that last year WRc assessed whether the Channeline tongue and groove jointed segmental GRP lining complies with the requirements of the WRc Type II structural design.

The assessment included desk based analysis of the stresses and bending moments within a circular lining wall when under loading conditions to estimate the maximum values expected in service. My colleague, Kevin Adams visited Channeline premises in Dubai and witnessed the longitudinal joints being made for three test lining rings and, once the epoxy resin had cured, witnessed mechanical testing of each of the lining rings.

The joints were located at the ring sample springings (the 3 and 9 o'clock position when looking longitudinally along the pipe) and the sample was loaded at the crown. When defining the testing criteria WRc calculated the ring sample vertical deflection required to achieve specified bending stresses at the joint. The maximum short term bending stress of 110 N/mm^2 equated to a vertical deflection of 253mm, three ring samples were deflected to that extent and no structural failure occurred.

The conclusions of the assessment were that:

- The testing undertaken demonstrates that the jointing technique is structurally sufficient to allow the Channeline longitudinal bonded joint to be considered appropriate for SRM Type II applications.
- On-site longitudinal joints need to be installed in accordance with the Channeline installation manual and the epoxy resin used to seal the longitudinal joint must be used in accordance with the manufacturers' instructions.

Ring stiffness testing was undertaken as this is representative of the loading condition a lining would experience in-service.

As stated in your letter it is an established fact that conducting three-point testing upon curved samples can detrimentally effect the test results. To reinforce this point the short term flexural

WRc plc, Frankland Road, Blagrove, Swindon, Wiltshire, SN5 8YF.
Telephone: + 44 (0) 1793 865000 Fax: + 44 (0) 1793 865001
Email: solutions@wrcplc.co.uk

Our Ref: 15000/CL/1

7th November 2008

Mr T Webb
Channeline International Ltd
GRP Structural Lining Systems
P.O. Box 8091
Dubai
UAE

Dear Mr Webb

Assessing the suitability of the Channeline longitudinal bonded joint for SRM Type II applications

Background
The Channeline system consists of segmental GRP linings with a longitudinal tongue and groove joint. Lining units are manufactured in two halves which are then bonded together on-site using an epoxy resin putty. This makes manufacture and transport much easier than for single discrete linings.

In September 2008 Channeline International Limited requested WRc to assess whether their tongue and groove jointed segmental GRP lining complies with the requirements of the WRc Type II structural design. The WRc Sewerage Rehabilitation Manual, Volume 2 states that "The long-term performance of jointing systems for two piece and multi piece lining systems under an external head of water has not been demonstrated".

The assessment undertaken by WRc was devised so as to provide evidence that the Channeline longitudinal bonded joint was suitable for SRM Type II applications. WRc conducted desk based analysis of the stresses and bending moments within a circular lining wall when under loading conditions to estimate the maximum values expected in service. Kevin Adams of WRc then visited Channeline premises in Dubai and witnessed the longitudinal joints being made for three test lining rings and, once the epoxy resin had cured, witnessed mechanical testing of each of the lining rings.

Stress and bending moment analysis
Channeline supplied WRc with the following specification for material properties and lining dimensions:

- short-term bending stress S_s: 110 N/mm^2
- long-term bending stress S_L: 60 N/mm^2
- short-term bending modulus E_S: 10,000 N/mm^2
- long-term bending modulus E_L: 4,000 N/mm^2
- wall thickness: 35 mm
- internal diameter: 1964 mm

WRc plc, Frankland Road, Blagrove, Swindon, Wiltshire, SN5 8YF.
Telephone: + 44 (0) 1793 865000 Fax: + 44 (0) 1793 865001
Email: solutions@wrcplc.co.uk

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Channeline multi-segmental projects

- NIEA, Detroit, Michigan

- City of Boston, Stoughton

- City of Los Angeles, California

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Thank you - any questions?

Get in touch

Email: tim.webb@channeline.com;
dev@channeline.com

Website: www.channeline.com