NEW ENGLAND WATER ENVIRONMENT ASSOCIATION
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NARRAGANSETT BAY COMMISSION REHABILITATION OF LARGE DIAMETER BRICK SEWER WITH GEOSPRAY GEOPOLYMER MORTAR

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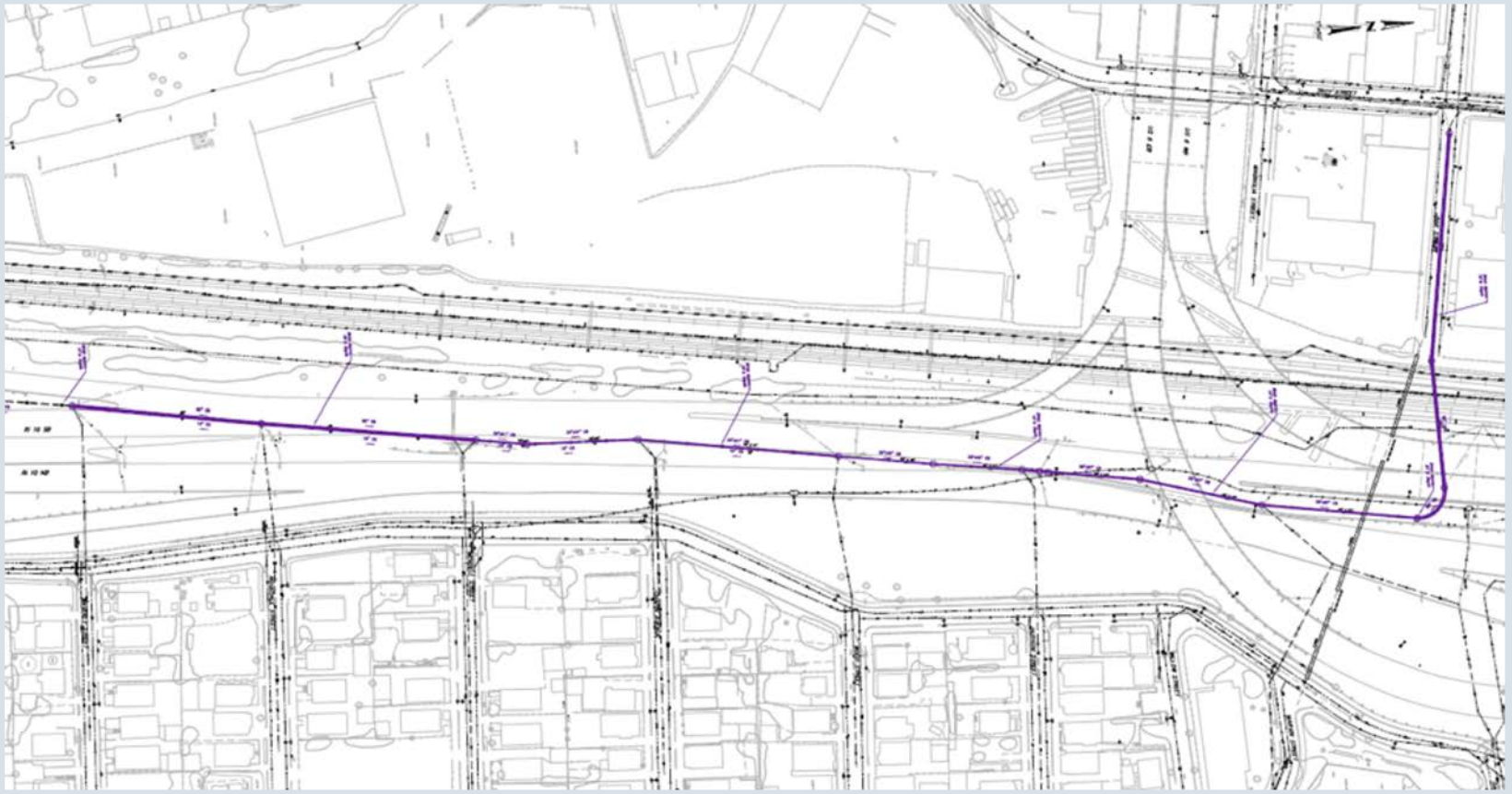
Route 6 & 10 Connector – NBC Interceptor Rehabilitation

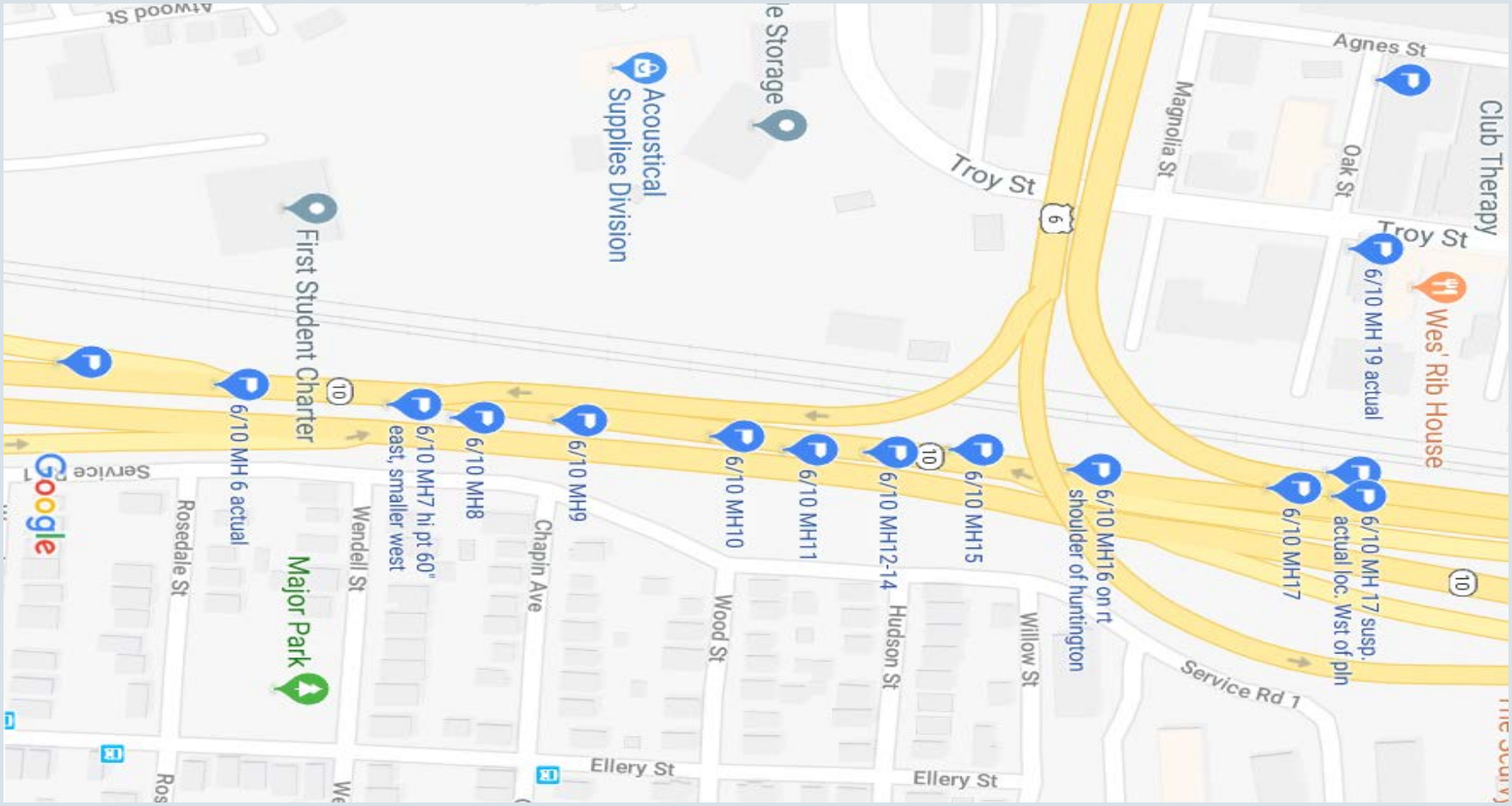
Project Details:

- Owner / Designer – Narragansett Bay Commission
- 2,430 feet of large diameter brick sewer up to 60”
- The Route 6 & 10 Connector built on top of the sewer interceptor
- Various defects within brick pipes creating high level of infiltration and structural defects
- Repaired with GeoSpray geopolymer from Milliken Infrastructure
- Contractor Installer – National Water Main Cleaning

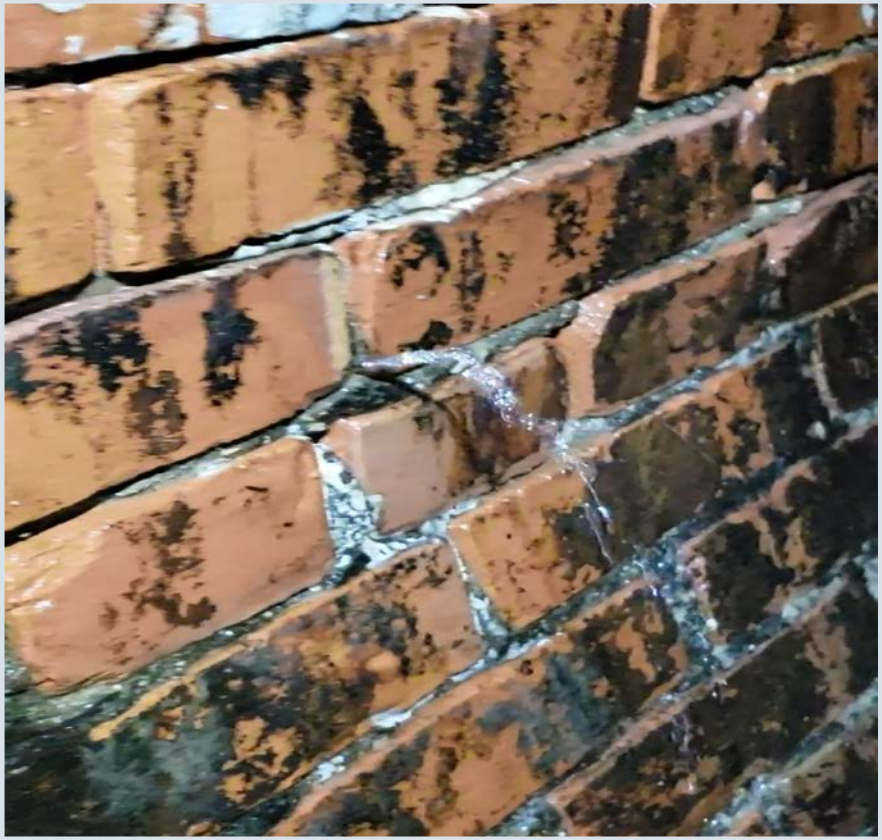
Project Location – RT 6 & 10 Connector



Project Location – RT 6 & 10 Connector



PIPE DEFECTS



Lining Options Considered

- Cured in Place Pipe (CIPP)
  - 60” liner required MH removal, repaving and traffic redirection
  - Over hole wet out large construction footprint not desired
  - Construction not possible at transition in pipe diameter
  - Concerns over fins and folds causing obstructions
- Slip Line
  - Similar to CIPP, the desire was to avoid MH removal or insertion pits; Significant capacity reduction
- Dig and Replace
  - Pipe depth and location under the highway made it too $$$
- Centrifugally Cast Concrete Pipe (CCCP)
  - Portland cement material concerns on water intrusion and desired corrosion protection
- Spin Cast Geopolymer Lining (SCGL)
  - Selected for stopping infiltration, small footprint, no excavation, no lane closure, corrosion protection, longevity, less bypass required

SCGL Liner Design (6 methods to pick from)

- Distributed Beam Load over a Partial Ring Model

$$Tmin = \sqrt{\frac{0.0744\, Q_T r^2}{S_F}\ \frac{N}{c}}$$

$$Tmin = X" \sqrt{\frac{1500}{S_F}}$$

Tmin =	Minimum Liner Thickness, inches
Q_t =	Total External Load as calculated from ASTM F 1216-09 for fully deteriorate pipe
r =	Radius of the interior crown of the pipe or ½ the largest interior horizontal dimension, inches
N =	Safety Factor = 2
S_F =	The 28 day Flexural Strength (or Modulus of Rupture) as determined by ASTM C78, psi.
c =	Ovality Reduction Factor as defined in ASTM F 1216-09

  - 10-17 feet crown cover assume water at surface
  - 30” x 45” & 38” x 57” Vertical Ellipse & 60” Round Brick Pipe
  - 50 plus years
  - AASHTO HS 25 and E80 Rail

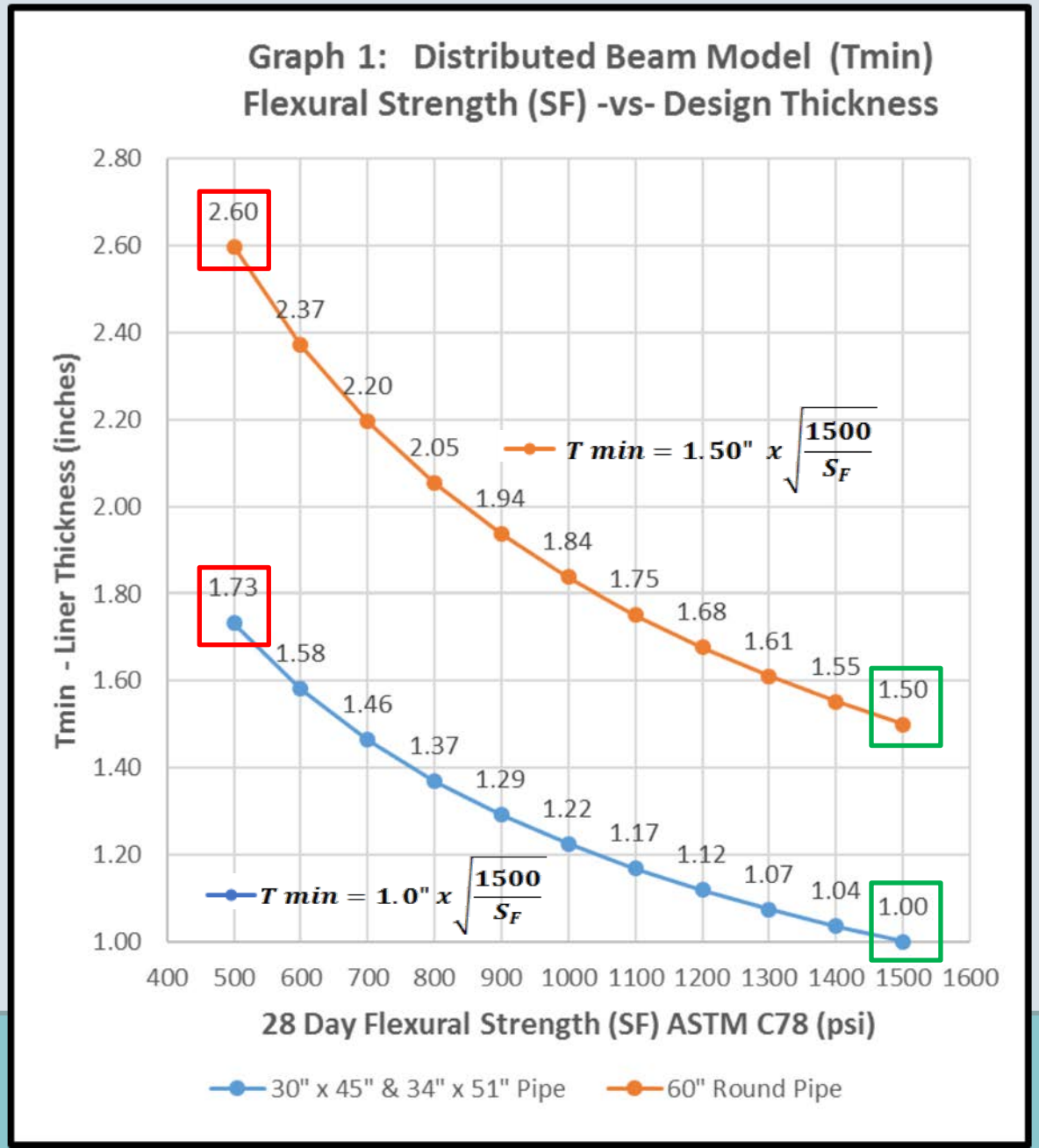
- Result: t = 1” for smaller pipes and 1.5” for 60” Pipe (based on ASTM C78 Flexural Strength = 1500 psi)

Comparison of GeoSpray Geopolymer & OPC

Material	*28 day Flexural Strength (SF) per ASTM C78 (psi)	Pipe size = 30" H x 45"V and 34"H x 51"V	Pipe Size = 60" Diameter
		$T\ min = 1.0" \ x \sqrt{\frac{1500}{S_F}}$ (in)	$T\ min = 1.50" \ x \sqrt{\frac{1500}{S_F}}$ (in)
GeoSpray Geopolymer	1500	1.00	1.50
Ordinary Portland Cement (OPC)	500	1.73	2.60
% Delta	-67%	73%	73%

When all dead load geometry and live load values are held constant, the distributed beam model can be simplified per the formula above. This shows how the 28 day Flexural Strength per ASTM C78 has a direct correlation to liner thickness that is almost linear. OPC has 67% less flexural strength however a theoretical equal load bearing design would require 73% more thickness. In addion, typically wire mesh would be added to the OPC because the flexural strength is so low.

Comparison of GeoSpray Geopolymer & OPC



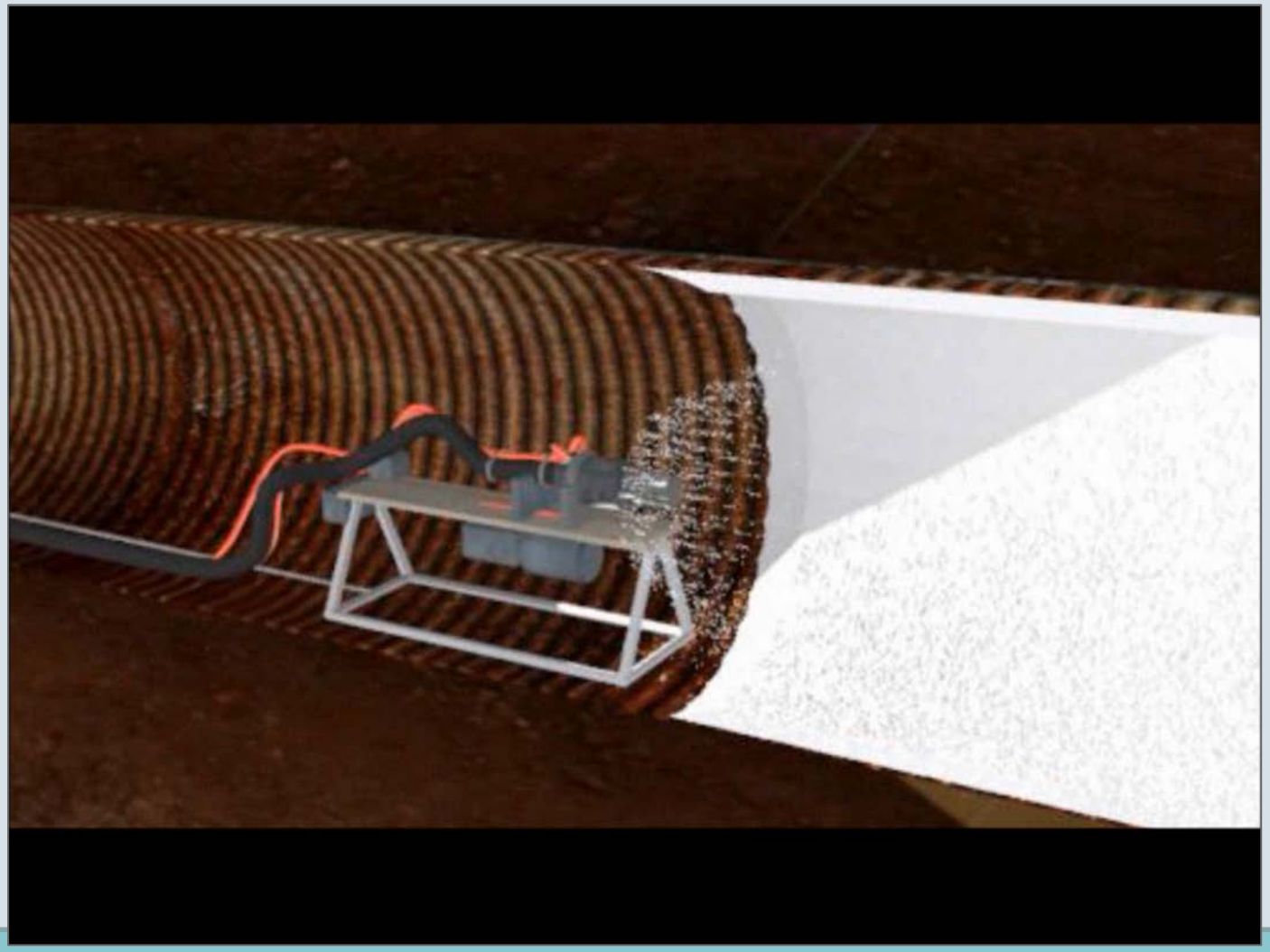
What is a Geopolymer?

- Not a Plastic
  - Not HDPE/PVC/Epoxy

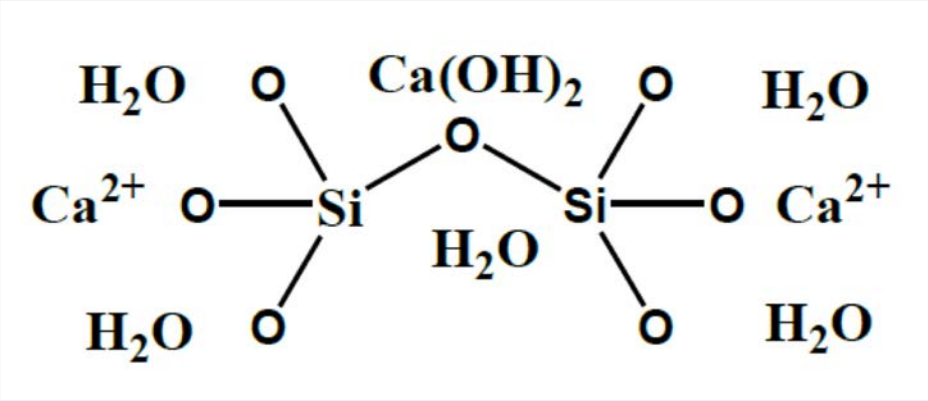
- Looks and feels like cement
  - Workability
  - Material Properties
  - Service Life

- Chemical structure like natural stone
  - Monolithic
  - Durable
  - Corrosion Resistant

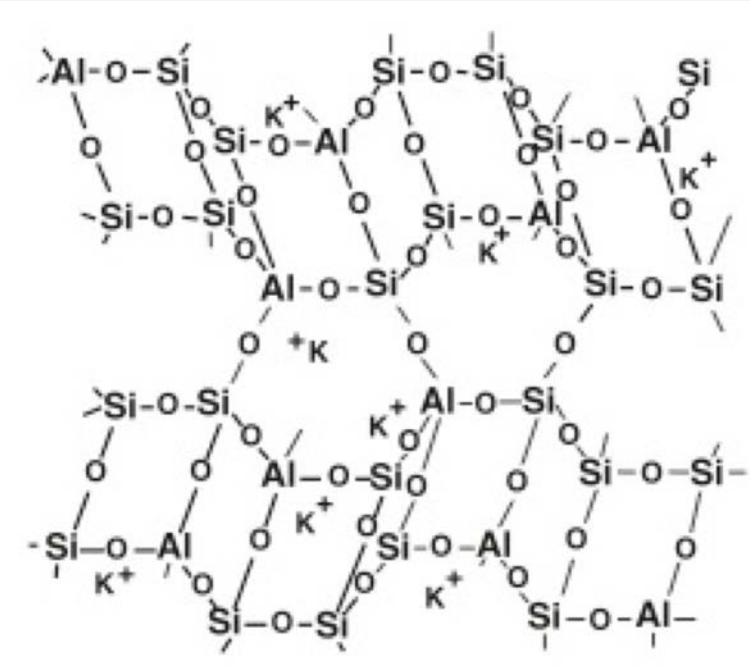
Spin Casting Geopolymer Pipe (SCGL) Process



Geopolymer Chemistry Primer



Typical Hydrated OPC Structure

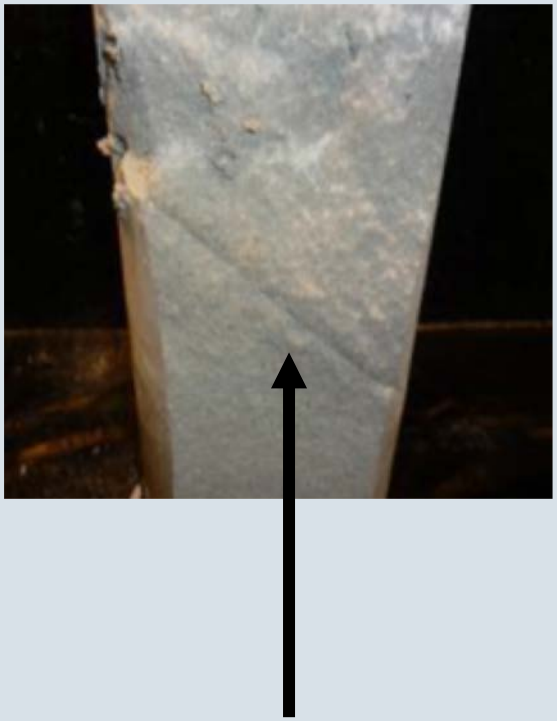


Typical Geopolymer Structure

Cold Joints

Experimental Parameters:

- On the first day a series of 2” by 4” cylinders were cast half full and cured with an approximately 45 degree angle
- On subsequent days (1, 7, 14 and 28) the top half of the cylinders were cast and filled creating a 45º angled joint in the center of the cylinders
- Compressive strength tests were conducted 28 days after the top half of the cylinders were cast



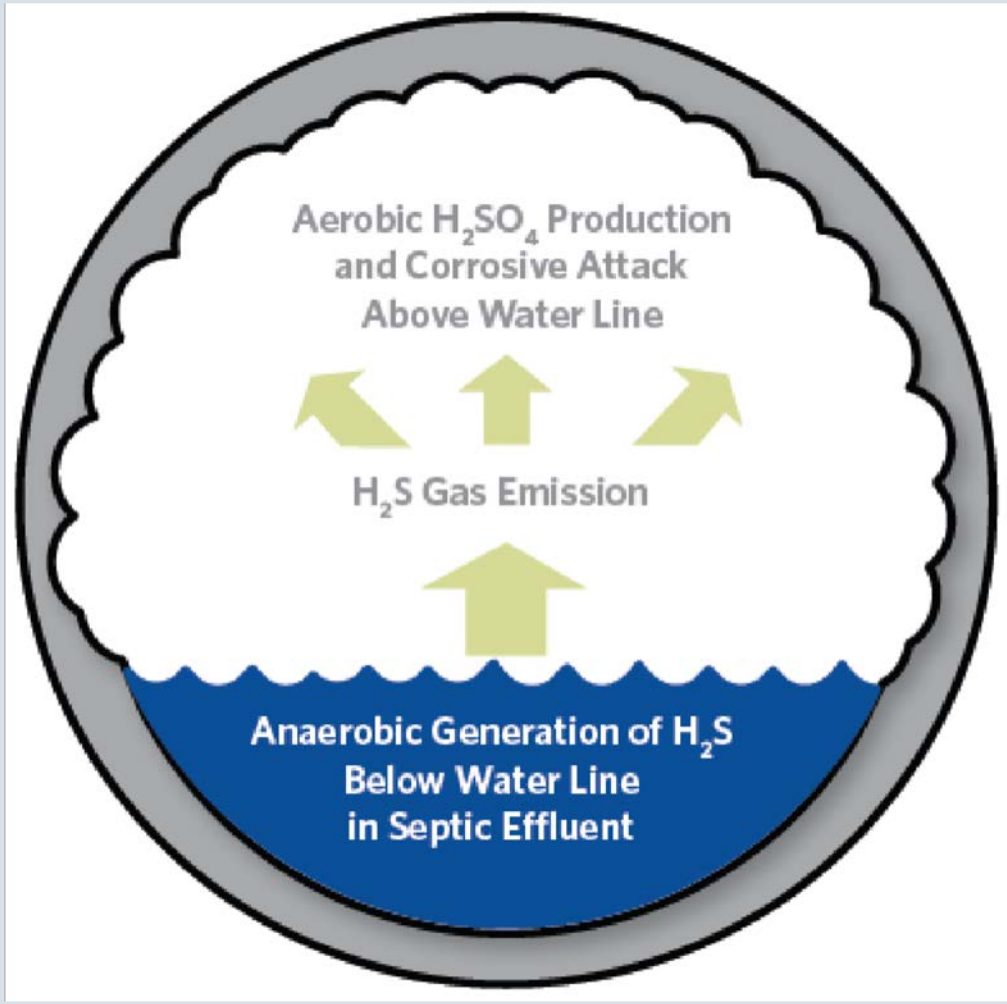
Joint in Tested Sample

Cold Joints – Testing Data

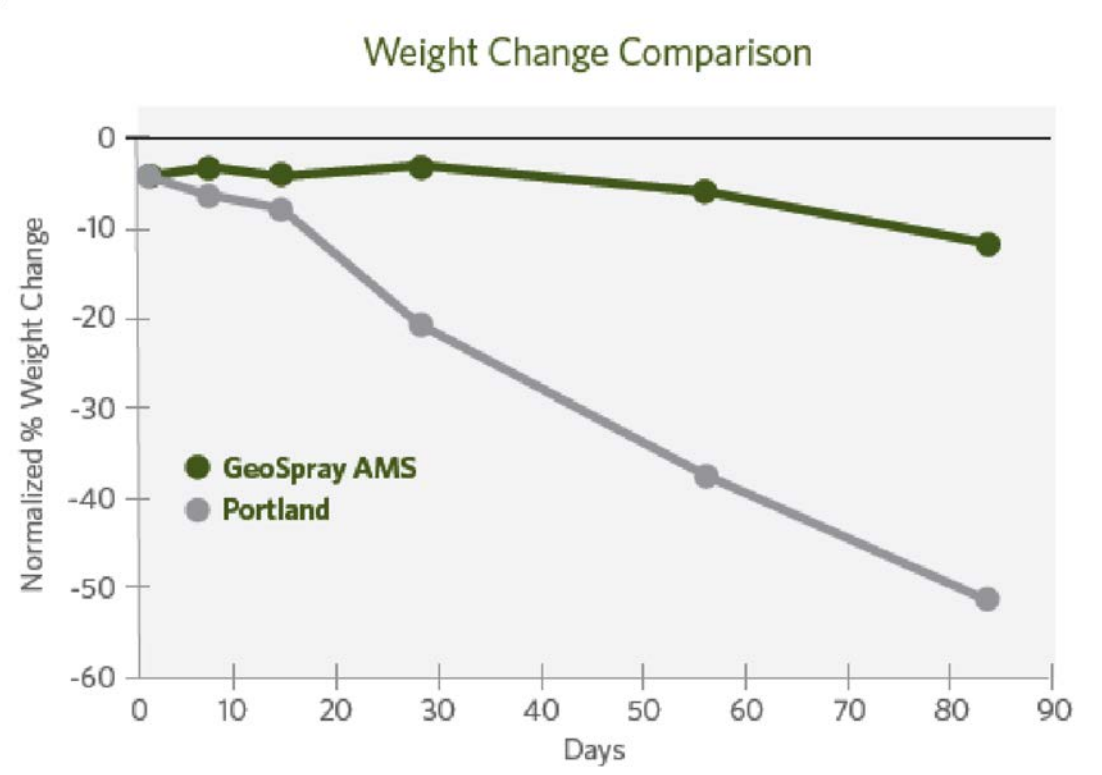
Results:

- Samples cast of GeoSpray Geopolymer (both halves) when tested under compression did not break at the joint
- The chemical nature of GeoSpray allows for chemical bonding across the interface even with pours 28 days apart resulting in a monolithic structure
- Samples cast of competitive cement mortars always broke along the angled joint essentially creating 2 separate layers

Microbial Induced Corrosion (MIC) Mechanism



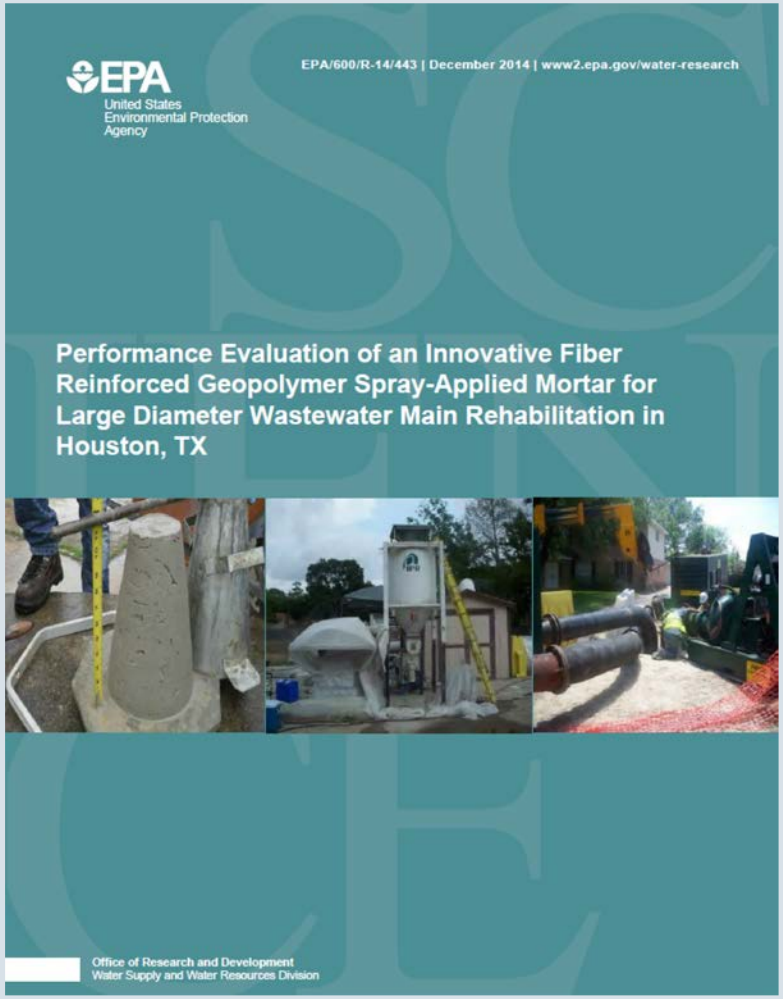
Geopolymer Advantage – Corrosion Protection



Independent Testing and Analysis

EPA Evaluation:

- U.S. Environmental Protection Agency developed an innovative technology demonstration program to evaluate technologies that have potential to reduce costs and increase the effectiveness of the operation, maintenance and renewal of aging water distribution and wastewater collection systems
- The EPA observed and monitored this project as part of this program



See www2.epa.gov/water-research (search Geopolymer)

NWMCC SCGL – Small Construction Footprint

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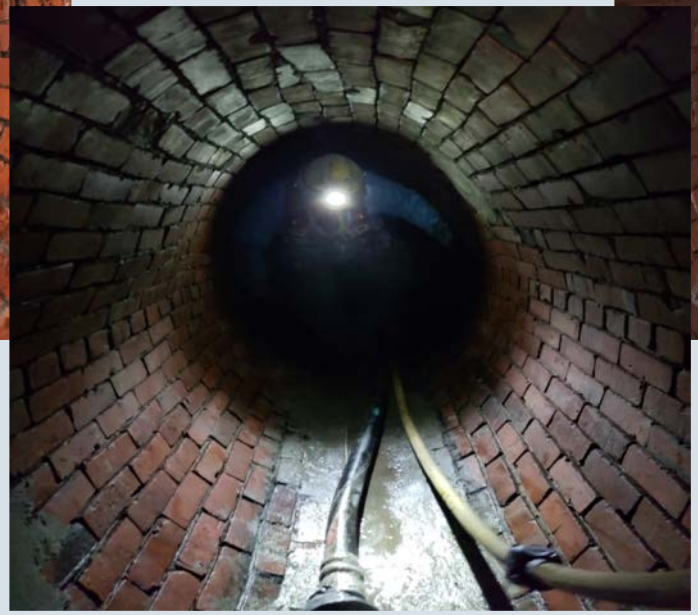
Construction Footprint / Pipe Access

INFILTRATION ISSUES

Crown Repair & Infiltration Control

Liner Thickness / Depth Gauges

Various Pipe Sizes of Rehab



Pipe Rehabilitation

Application of First Layer and Final Layer

Internal Bypass
SCGL Through 90 Degree Bend

Completed Structure

Challenges and Lessons Learned

- No National ASTM Design Standard Exists
  - Counting FEM there are 6 minimum design methods
  - 2” of SCGL ≠ 2” of CCCP ≠ 2” Portland Concrete
- Mobilization & Demobilization
  - Evaluate leaving equipment and barricades in place during day
  - Getting tractor trailer with GeoSpray in and unloaded in median
- Wet Weather Go / No Go Decision
  - Old CIPP rule - if chance of rain at 5 AM, scrub work
  - New – with geopolymer NBC let NWMCC decide to work or not
- Four Season Liner
  - Geopolymer is more resilient in hot cold and wet weather, so Geopolymer is a new tool for NBC on future projects

Thank You & Questions?

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