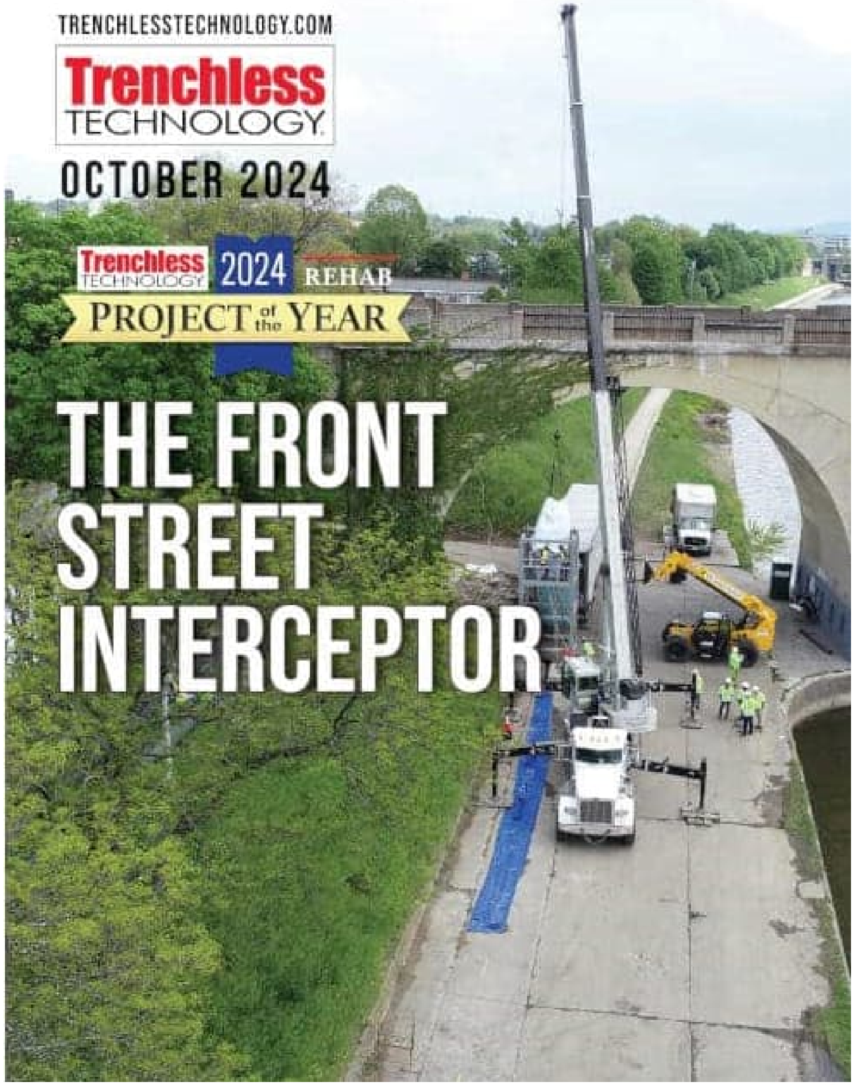
Utilizing MOP 145 Design for the Front Street Interceptor(FSI) CIPP Rehabilitation Project

Chris Macey – AECOM

Andrew Costa – Azuria

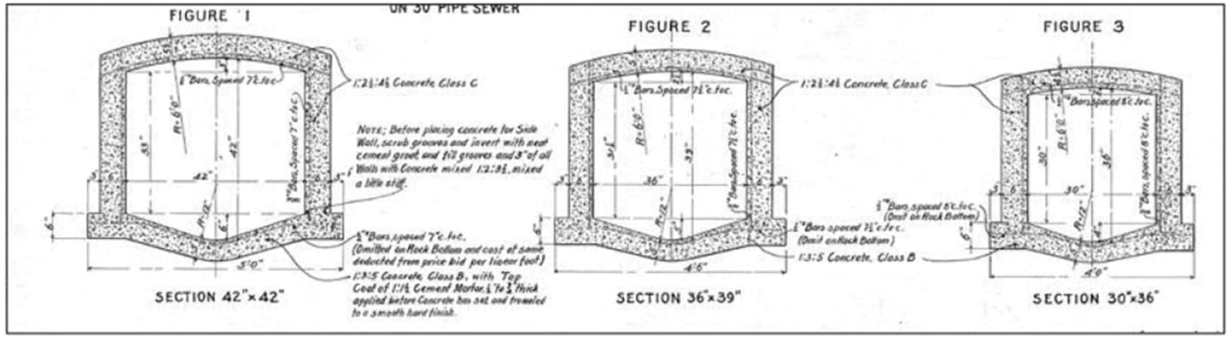
Overview

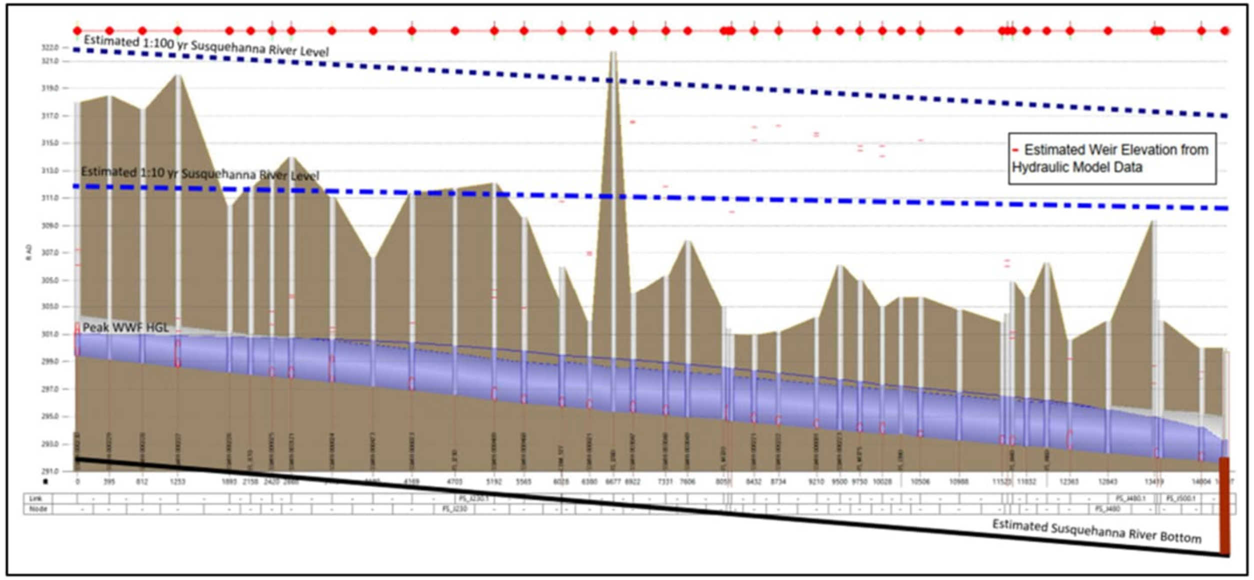
- Project Overview
- What we did
    - Construction Challenges
    - Innovation
- How we did it
    - Design
    - Verification
- Closure and Conclusions



Front Street Interceptor (FSI)

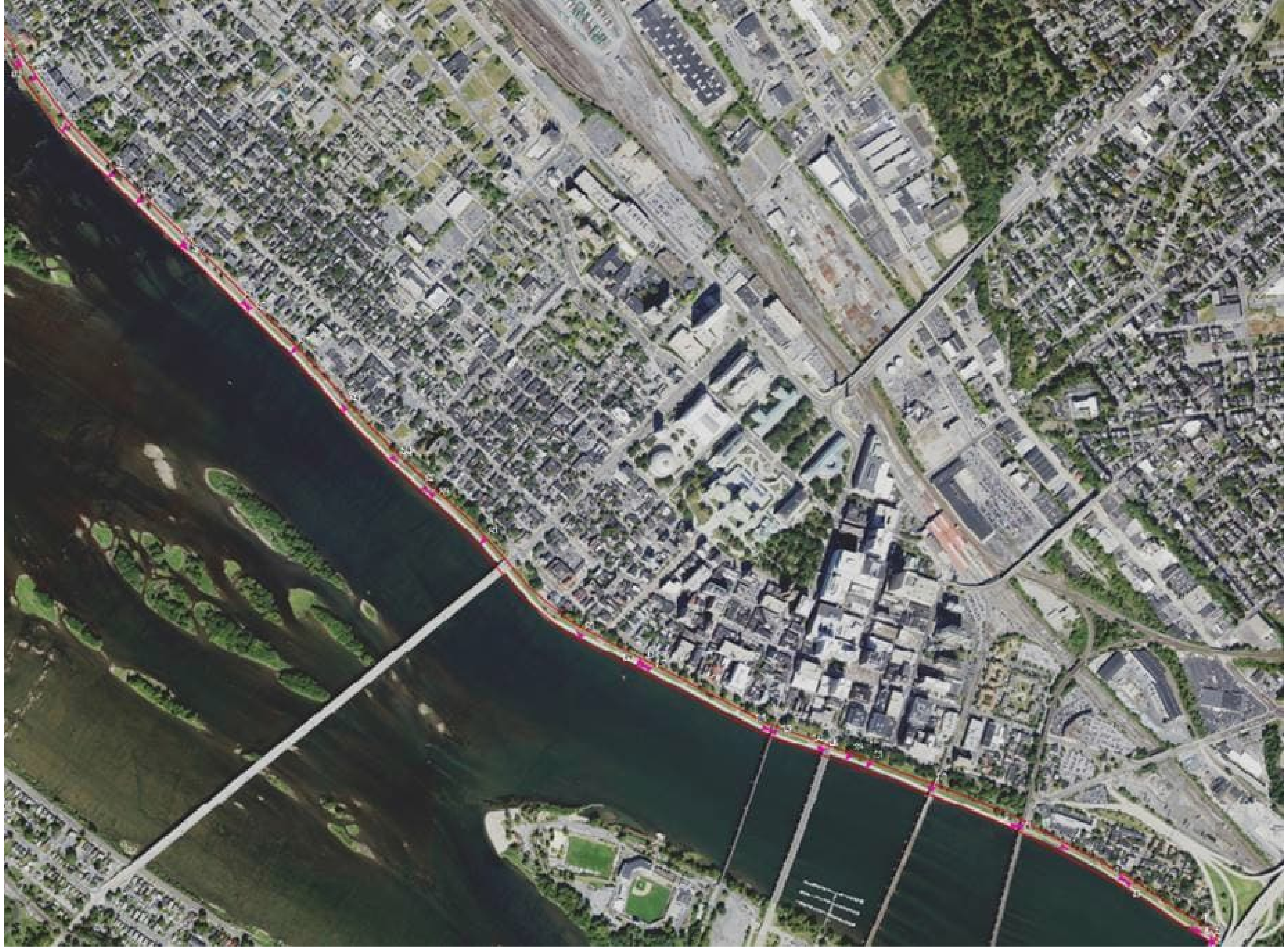
- 27 sections of cast-in-place concrete "box" constructed in 1911
    - 1 section of circular 30"
    - 4545 m (14,911') of non-circular interceptor
- In the heart of the historic and popular Susquehanna Riverfront Park
- Carrying over 25 MGD in a wet weather event
- And sitting completely within the 100-year flood inundation extent





Project Overview

- The FSI was a very challenging undertaking
    - 725,000 pounds of resin in 28 shots (27 of those, the complex "box" from 1911!)
    - Very innovatively transported to the site and processed without a single OTH install
    - *Designed and Verified* with the aid of ASCE MOP 145
- $18.4 M of CIPP rehabilitation on a critical sewer interceptor between Seneca Street and the I-83 bridge
    - Along the Susquehanna Riverfront in downtown Harrisburg, PA
- A lot of innovation to achieve success
    - Excellent process control and a pile of testing ultimately saved the day
    - Following NASTT CIPP Good Practices to a tee, made success both achievable and verifiable



This was a Challenging Site to Work At!!!

CIPP Constructability

Did we say this was a complex site to access?

- From FSPS to @ Maclay St, FSI west (below) flood berm, adjacent to or on river walk
- From Maclay St to Seneca St, alignment closer to Front Street, under Greenbelt
- Access to the southern river walk area was challenging, but feasible, minimal disruption to Front Street
- Access to northern area off Front Street, likely result in loss of lane, loss of pathway, or both

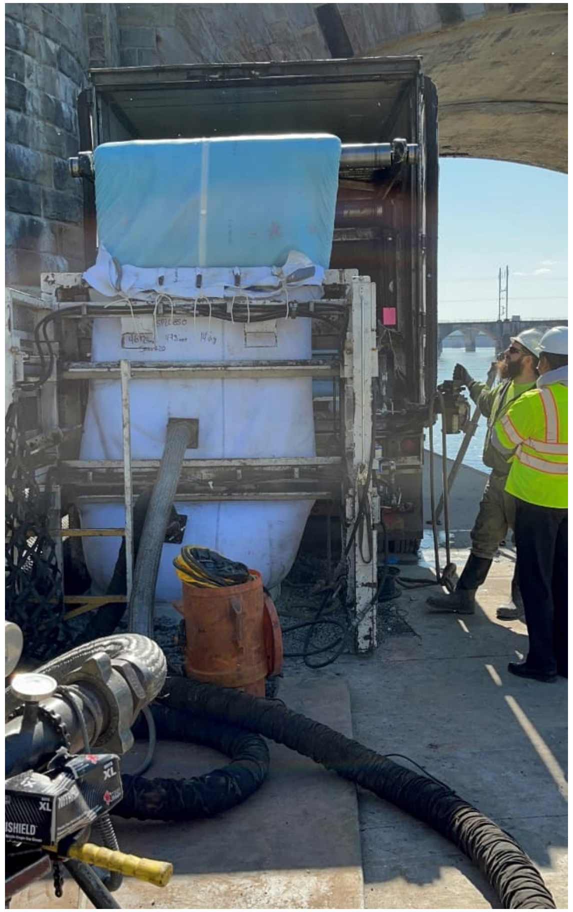
Bypass Setup

Bypass Setup

https://youtu.be/t_SFvIdlDWY?si=_eAyp0wT0CnI9Fc2

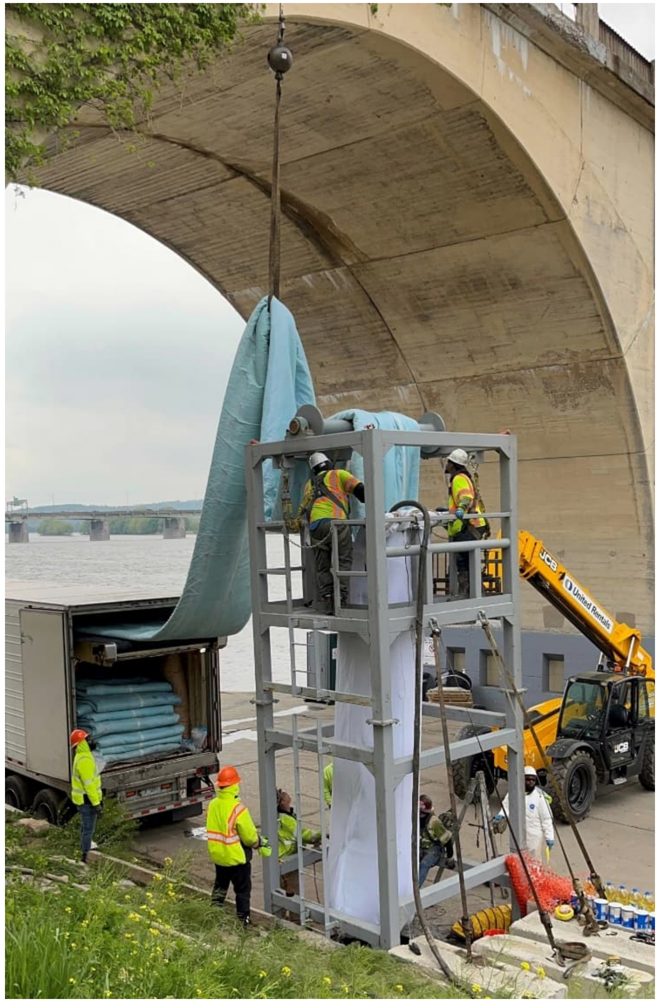
CIPP Installation Setups – MOP 145 and iPlus

100% Factory Resin Wet-Outs



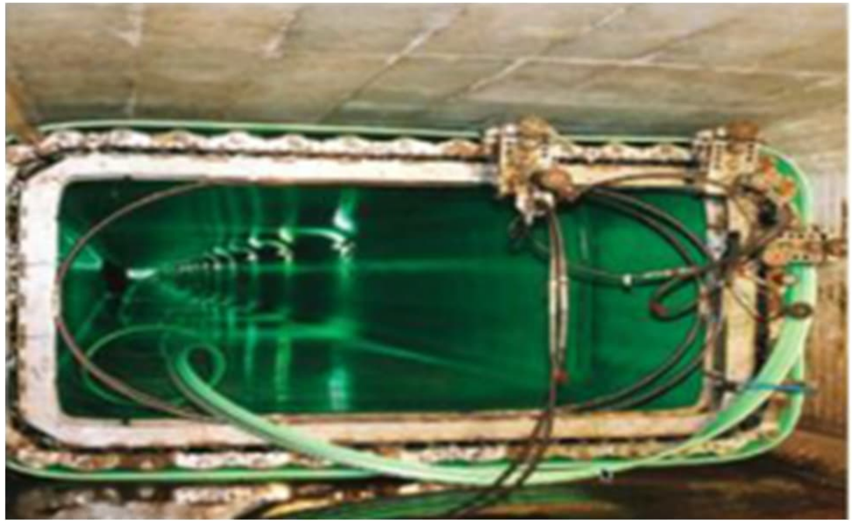
0% On-Site/Over the Hole Wet-Out

CIPP Installation



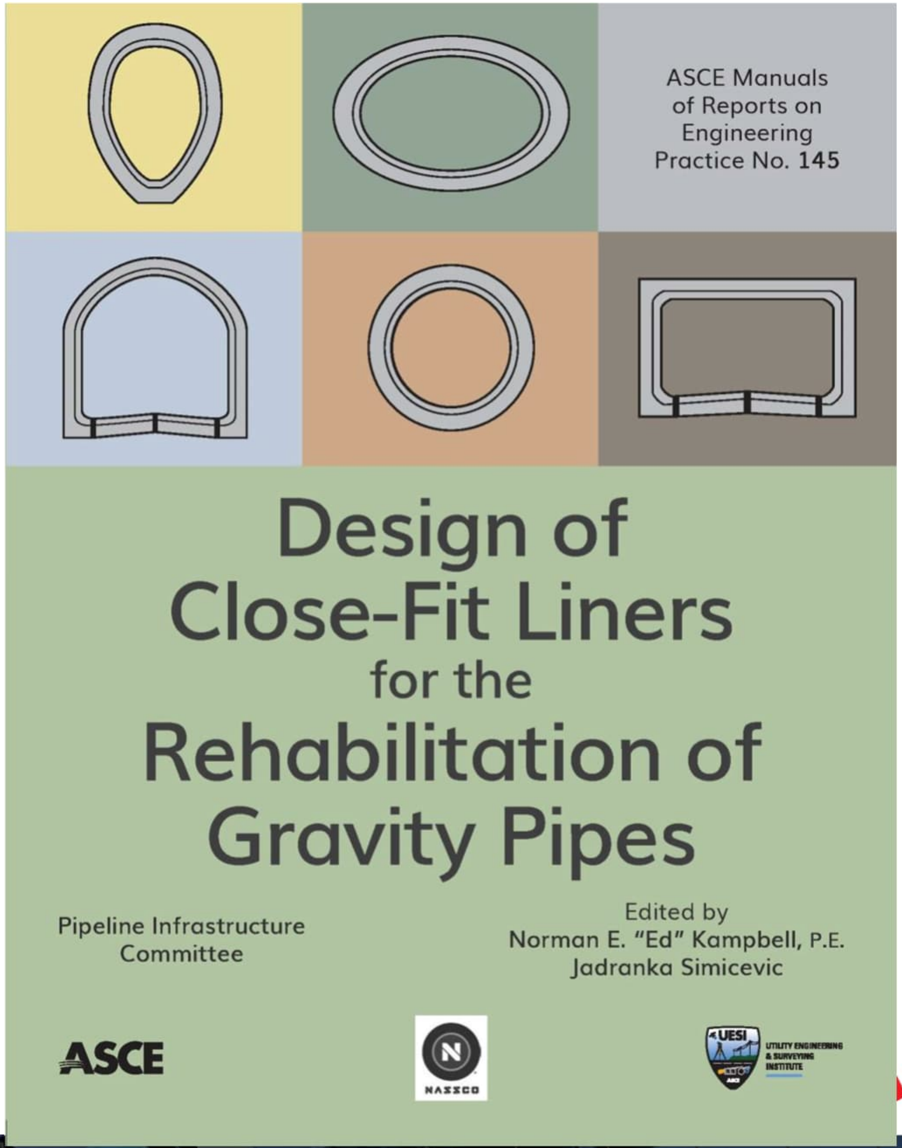
Design Alternatives

- Reviewed all of the full segment technologies applicable to Non-Circular Sections
    - Cured in Place Pipe (CIPP) with glass and/or carbon reinforced tubes
    - Discrete pipe/Segmental sliplining with GRP composites
    - Spiral Wound PVC strip lining
    - Spray applied pipe liners (SAPL)
        - Cementitious and Geopolymer Based Spray-on Products
    - Bonded FRP laminates
- CIPP and GRP technically feasible with reasonable risk profiles and cost
    - CIPP advanced to detailed design based on hydraulics



ASCE MOP 145 Design

- Predesign predated release of MOP 145.
    - Was carried out with French Standard ASTEE 3R -2014 and WRc reviews
    - ASTEE 3R formed the primary technical basis for MOP 145
- AECOM was part of Blue Panel review of MOP 145 which was actively in Final Review at that time
- Early design transition to MOP 145 was not a problem for the Design Team
- Considerably more complex to communicate to Bidders (and Owner)



To facilitate the Bid Process

MOP 145 has a lot of moving parts…

- Designers need to do some design
- For this project:
  - Ran over 2000 load cases to clarify range of limit states that would control design over a range of CIPP products
  - Developed “Rating curves” to relate mechanical properties to minimum design thickness for base Bids.
  - Included Contract mechanism for any major change in liner thickness due to a change in cross section or design conditions after bidding
  - Articulated all of the above clearly in a Technical Memorandum
- Need to articulate enough of controlling design parameters for Bidder to understand risk
- Need to balance that with the ability to manage change and fully meet more complex design objectives

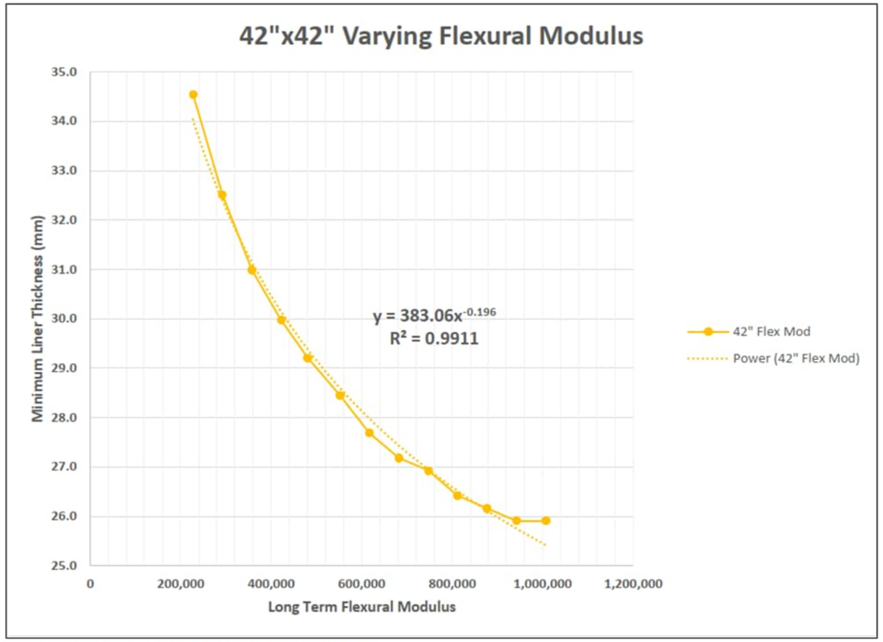


Figure 4: Thickness vs LT Flex Mod (42" Section)

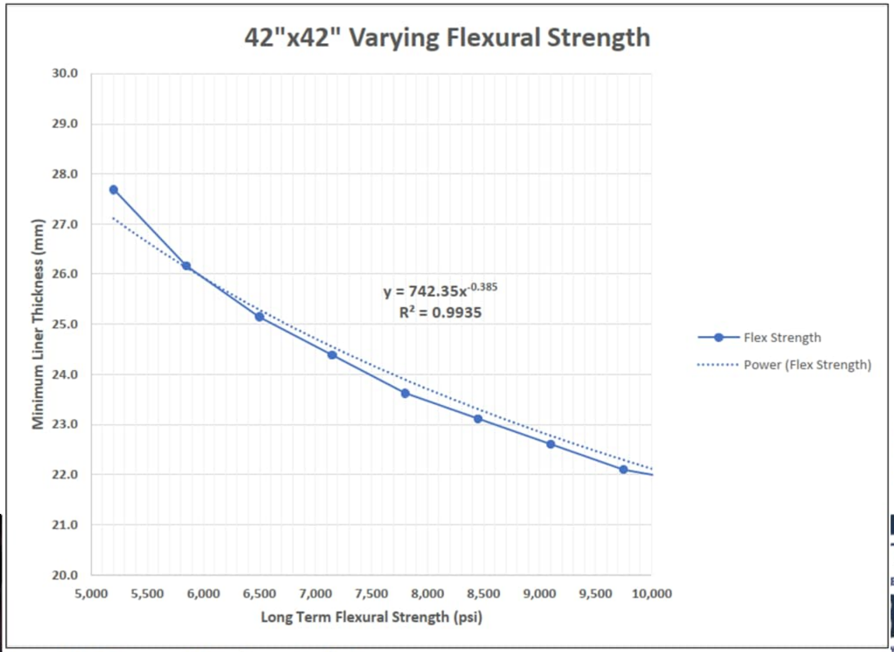
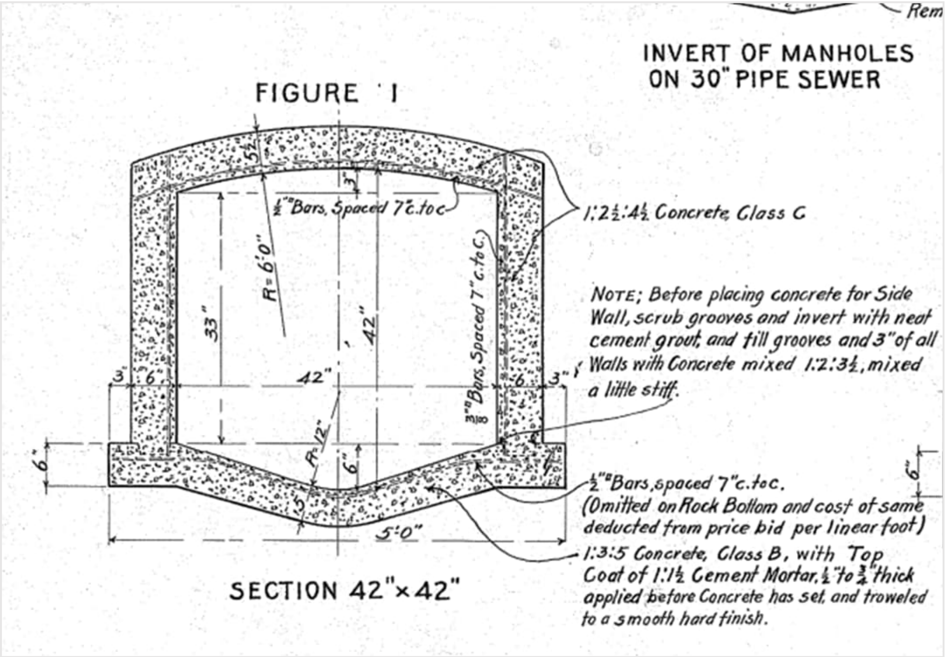


Figure 5: Thickness vs LT Flex Strength (42" Section)

In this configuration it meant conveying dimensional stability too

- ASTEE 3R-2014 and MOP 145 have minimum corner radius checks for stability
- A flexible close-fit liner needs curved corners to be structurally stable
- Preformed corners were initially required but successfully Bidder knew something unique about CIPP
  - It doesn't snap to corners with proper process control
  - Actual radius if a function of thickness design and "other" factors
- Bid process was modified by Addendum
  - Contractor option to pre-form or grout post-install
  - Verification checks at Contractor risk for dimensional stability, post install
  - Grouting spec added for grouting post-install

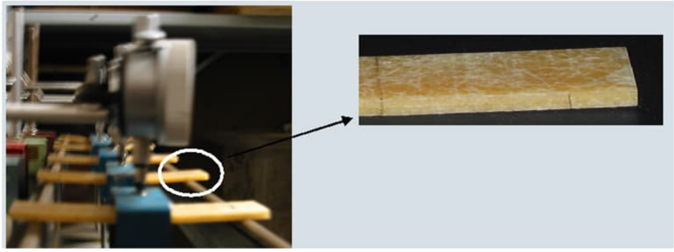


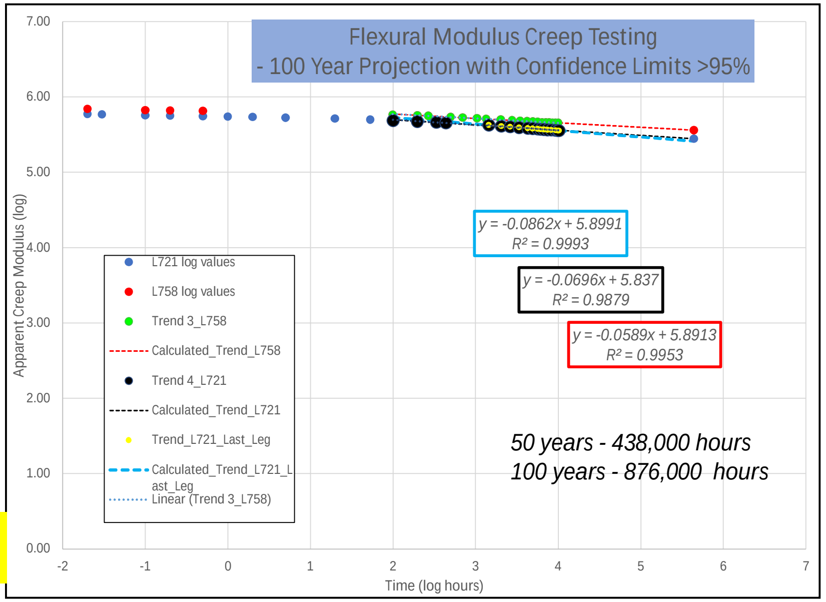
We didn't have to invent the Verification Process – but sampling sure made it challenging

1. *Functional design*
2. *Type testing*
3. *Detail design*
4. *Installation process control*
5. *Verification*

CIPP Good Practices - 2024

Functional Design and Type Testing





Design basis

Wet out and Installation Logs

Sampling Approach to confirm design (e.g. mechanical properties, degree of cure, etc.)

Acceptance/Verification Testing

Design Reconciliation/Verification Concept and Process

1. *The correct amount of resin goes into the correct nominal thickness tube and the viscosity and thixotropic properties are monitored at the wet out.*
2. *Installation and curing heads are maintained and the cure cycle is either fully completed or extended to completion if the heat sink is observed to be complex.*
3. *Visually, the liner installation should meet all fit and finish standards with respect to degree of fit with the host pipe and the resin distribution in the cured pipe wall.*
4. *The overall liner's initial structural resistance (the unique combination of a liner's flexural modulus - stiffness, flexural strength and wall thickness) is checked versus the design loads with full consideration and all load and resistance factors used in the design process.*

Do your design and then…

1. *Audit the Wet-Out Process for Each Install*
2. *Complete Installation Process Control Audit*
3. *Meet all visual conformance standards*
   - *Additional dimensional checks for stability*
   - *Post install grouting and termination seals*
4. *Testing all mechanical properties to confirm all design objectives met*
   - *Additional challenges due to both sampling process and minimum size requirements for anisotropic material*

Wet out and Cure Process Reviews

Insituform
Global Pipeline Protection

Form #: FCD-0307 rev date 19AUG2015

Owner/Engineer QA Wetout Information

Job Name	Capitol Region	
Job #	390780	
Shot #	6	
Diameter	37.00	inches
Thickness	21.0	mm
Gap Setting	45.0	mm
Wet Out Date	8/14/2023	
Wet Out Manager	Jason Berry	
Wet Length	845	feet
Total Length	859	feet
Pallet #	498511	
Resin Type	102N	
Calculated Resin Amount	35752	lbs
Resin Yield	42.31	lbs/ft
Gel Test Slug 1	Pass	
Gel Test Slug 2	Pass	
Resin Temp	66	degrees

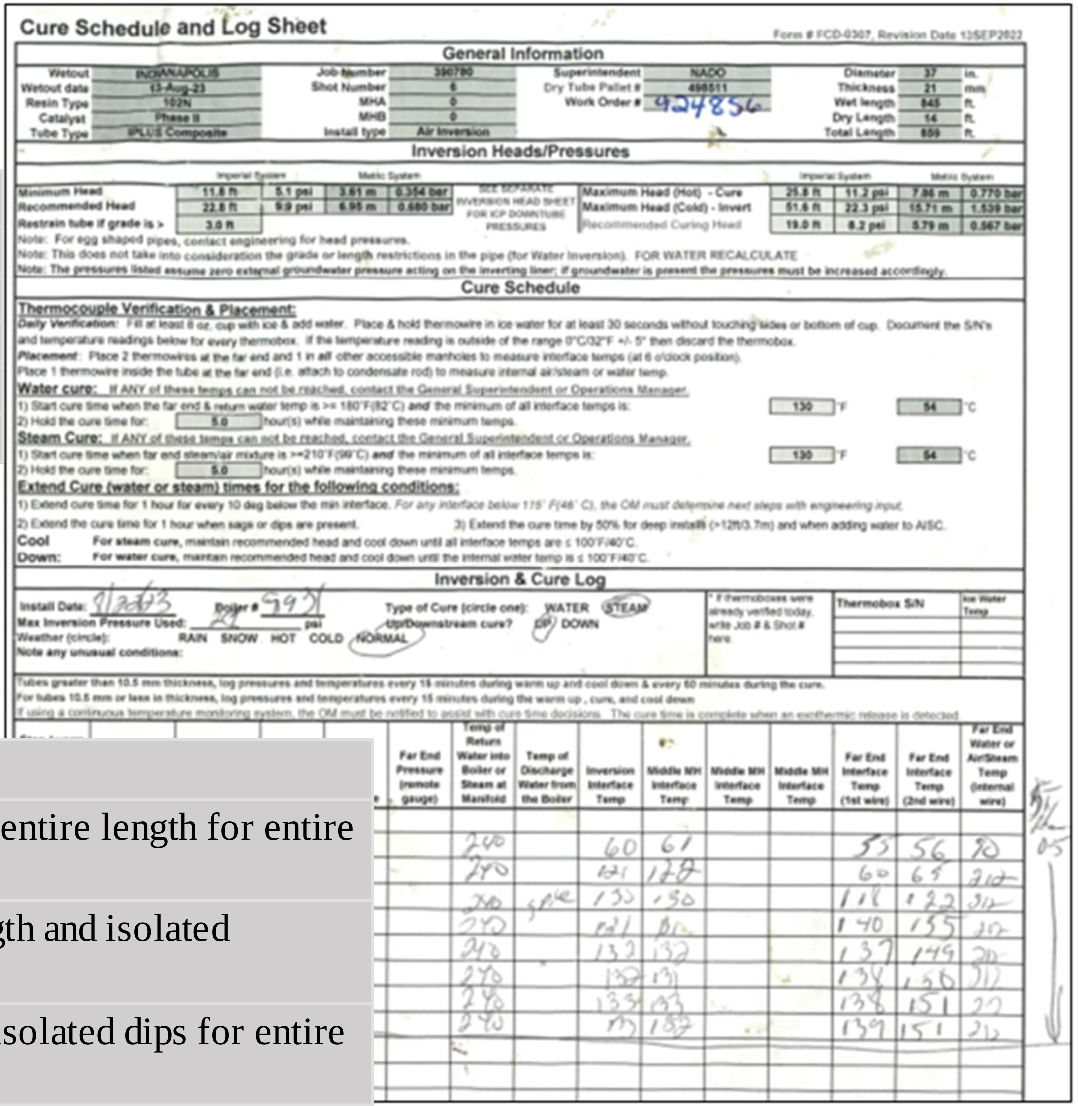
Figure 2: Shot 6 Wet Out Log - Typical

[1] Exotherm trigger classification

i. <120=bad for all
ii. 120-130=moderate for steam
iii. 120-140= moderate for water
iv. >130=good for steam
v. >140=good for water

[2] Continuous inspection interpretation

i. Exotherm and cook consistent for entire length for entire cure= excellent
ii. Exotherm achieved for entire length and isolated dips=good
iii. Exotherm with isolated dips and isolated dips for entire cure=moderate
iv. No exotherm and serious cold spots in many areas=bad



Cure Schedule and Log Sheet

Form # FCD-0307, Revision Date 13SEP2022

General Information

Wetout	INDIANAPOLIS	Job Number	390780	Superintendent	NADO	Diameter	37 in.
Wetout date	13-Aug-23	Shot Number	6	Dry Tube Pallet #	498511	Thickness	21 mm
Resin Type	102N	MHA	0	Work Order #	924856	Wet length	845 ft.
Catalyst	Phase II	MHB	0			Dry Length	14 ft.
Tube Type	iPLUS Composite	Install type	Air Inversion			Total Length	859 ft.

Inversion Heads/Pressures

	Imperial System		Metric System				Imperial System		Metric System	
Minimum Head	11.8 ft	5.1 psi	3.61 m	0.354 bar	SEE SEPARATE INVERSION HEAD SHEET FOR ICP DOWNTUBE PRESSURES	Maximum Head (Hot) - Cure	25.8 ft	11.2 psi	7.86 m	0.770 bar
Recommended Head	22.8 ft	9.9 psi	6.95 m	0.680 bar		Maximum Head (Cold) - Invert	51.6 ft	22.3 psi	15.71 m	1.539 bar
Restrain tube if grade is >	3.0 ft					Recommended Curing Head	19.0 ft	8.2 psi	5.79 m	0.567 bar

Note: For egg shaped pipes, contact engineering for head pressures.
Note: This does not take into consideration the grade or length restrictions in the pipe (for Water Inversion). FOR WATER RECALCULATE
Note: The pressures listed assume zero external groundwater pressure acting on the inverting liner; if groundwater is present the pressures must be increased accordingly.

Cure Schedule

Thermocouple Verification & Placement:
Daily Verification: Fill at least 8 oz. cup with ice & add water. Place & hold thermowire in ice water for at least 30 seconds without touching sides or bottom of cup. Document the S/N's and temperature readings below for every thermobox. If the temperature reading is outside of the range 0°C/32°F +/- 5° then discard the thermobox.
Placement: Place 2 thermowires at the far end and 1 in **all** other accessible manholes to measure interface temps (at 6 o'clock position).
Place 1 thermowire inside the tube at the far end (i.e. attach to condensate rod) to measure internal air/steam or water temp.

Water cure: If ANY of these temps can not be reached, contact the General Superintendent or Operations Manager.
1) Start cure time when the far end & return water temp is >= 180°F(82°C) **and** the minimum of all interface temps is: 130 °F 54 °C
2) Hold the cure time for: 5.0 hour(s) while maintaining these minimum temps.

Steam Cure: If ANY of these temps can not be reached, contact the General Superintendent or Operations Manager.
1) Start cure time when far end steam/air mixture is >=210°F(99°C) **and** the minimum of all interface temps is: 130 °F 54 °C
2) Hold the cure time for: 5.0 hour(s) while maintaining these minimum temps.

Extend Cure (water or steam) times for the following conditions:
1) Extend cure time for 1 hour for every 10 deg below the min interface. *For any interface below 115° F(46° C), the OM must determine next steps with engineering input.*
2) Extend the cure time for 1 hour when sags or dips are present. 3) Extend the cure time by 50% for deep installs (>12ft/3.7m) and when adding water to AISC.

Cool Down: **For steam cure,** maintain recommended head and cool down until all interface temps are ≤ 100°F/40°C.
For water cure, maintain recommended head and cool down until the internal water temp is ≤ 100°F/40°C.

Inversion & Cure Log

Install Date: 9/2/23 Boiler # 5931
Max Inversion Pressure Used: 21 psi
Type of Cure (circle one): WATER STEAM
Up/Downstream cure? UP DOWN
Weather (circle): RAIN SNOW HOT COLD NORMAL
Note any unusual conditions:

* If thermoboxes were already verified today, write Job # & Shot # here.

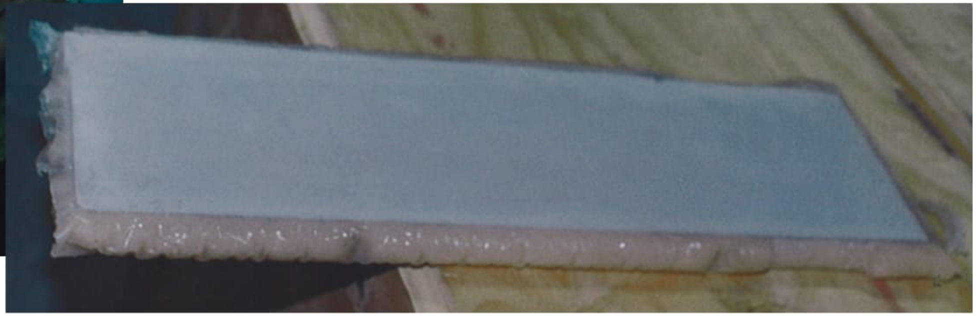
Thermobox S/N	Ice Water Temp

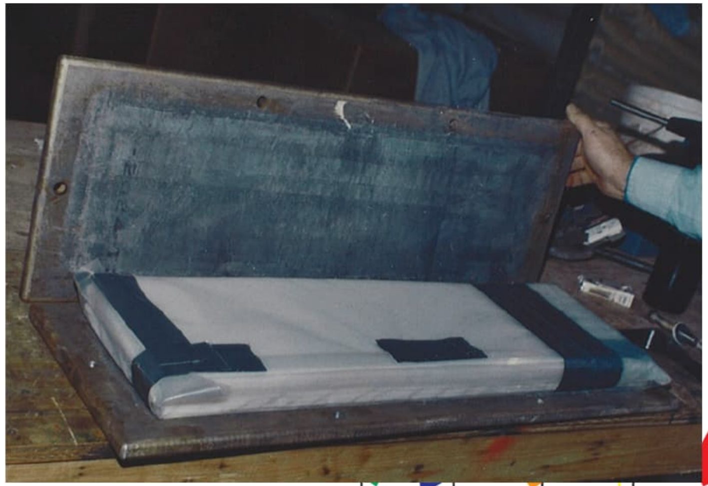
Tubes greater than 10.5 mm thickness, log pressures and temperatures every 15 minutes during warm up and cool down & every 60 minutes during the cure.
For tubes 10.5 mm or less in thickness, log pressures and temperatures every 15 minutes during the warm up, cure, and cool down
If using a continuous temperature monitoring system, the OM must be notified to assist with cure time decisions. The cure time is complete when an exothermic release is detected.

Far End Pressure (remote gauge)	Temp of Return Water into Boiler or Steam at Manifold	Temp of Discharge Water from the Boiler	Inversion Interface Temp	Middle MH Interface Temp	Middle MH Interface Temp	Middle MH Interface Temp	Far End Interface Temp (1st wire)	Far End Interface Temp (2nd wire)	Far End Water or Air/Steam Temp (internal wire)
	240		60	61			55	56	90
	240		121	128			60	65	210
	240	spike	133	130			118	122	212
	240		121	[illegible]			140	155	210
	240		132	132			137	149	210
	240		132	131			138	150	210
	240		133	133			138	151	212
	240		133	133			139	151	212

Plate Samples are always complex

- Plate samples need additional verification to confirm wall thickness
- Need on-site cure in heat sink reasonably representative as installed liner
- For reinforced sample, they need to be really big!
  - When sampled in wrong direction, you need to do a lot more sampling!!!
- Review included 110 design cases; a deep, deep, dive into the Type Testing for the Product, and a pile of supplemental testing





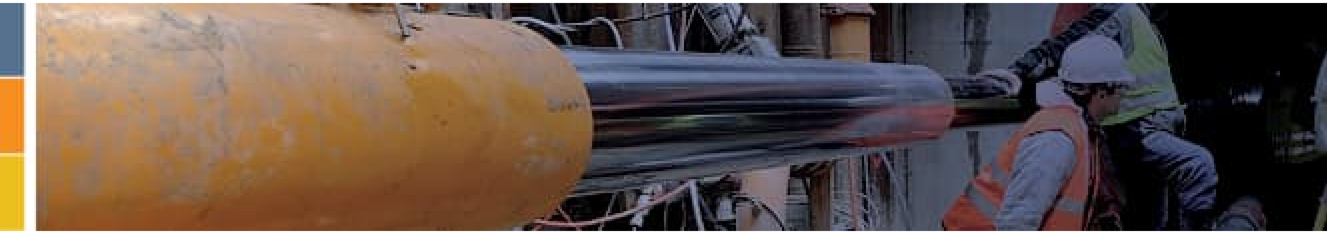
Hoop to Axial Assessment

Deep dive into type testing and the following additional job specific tests:

- All sites except Install 6 had valid testing which could be reviewed either directly or indirectly versus the design objectives
- Additional tests included:
    - 10 tests each of flexural modulus and strength determined in both the hoop and axial directions. Note, as each test is comprised of 5 samples, 10 tests included 50 unique samples that were tested.
    - 17 tensile tests in the hoop direction with comparative measurements in flexure in the hoop direction. Note, as each test is comprised of 5 samples, 17 tests included 85 unique samples that were tested.

Table 1: Comparative Testing Summary – Type Testing versus Project Specific Testing

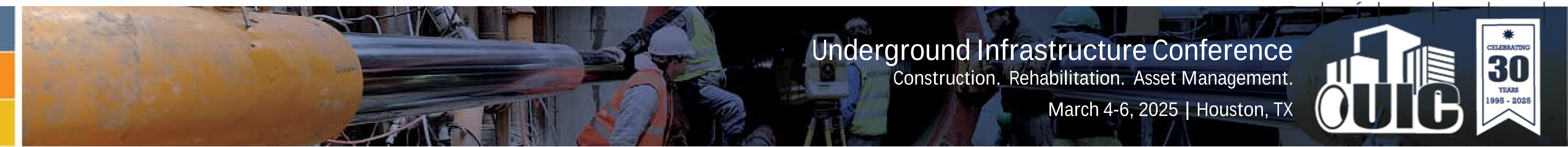
Property Comparison	Hoop / Axial Direction Testing		Flexure / Tensile Testing in the Hoop Direction	
	Type Test Ratio	Project Values Ratio	Type Test Ratio	Project Values Ratio
Flexural Modulus – (Direction)	2.35	1.92	N/A	N/A
Flexural Strength (Direction)	7.67	3.18	N/A	N/A
Flexure – Tensile Modulus	N/A	N/A	1.07	1.03
Flexure – Tensile Strength	N/A	N/A	1.55	1.34



Design Reconciliation Summary – 110 Load Cases

Appendix 1: Summary of Quality Assurance/Quality Control Review and Design Reconciliation

Liner Material Name	Design State	Burial Depth to invert (ft)	Ground Water Depth (ft)	Minimum Required Thickness (in)	Minimum Required Thickness (mm)	Actual Wall Thickness (mm)	Actual Wall Thickness (in)	Governing Required Thickness (in)	Actual to Governing with full LRFD Values (%)	Mechnical Properties	Wet out compliance	Cure Rating	Resolved by Increased Cure Time	Flexural Modulus (psi)	Flexural Strength (psi)	Basis of Estimate
LinerName	State	H_Soil	WaterDepth	t	t											
Shot 2	State II	20	-4.5	0.44	11.25	19.80	0.78	0.44	43.17%	Direct Measure	Yes	Excellent	N/A	415,000	4,230	Actual
Shot 2-LT	State II	13	0	0.38	9.73											
Shot 3	State II	20	-4.5	0.58	14.81	20.41	0.80	0.77	4.05%	Direct Measure	Yes	Excellent	N/A	635,000	18,300	Actual
Shot 3	State II	20	-4.5	0.77	19.58											
Shot 3-LT	State II	19	0	0.57	14.35											
Shot 3-LT	State II	19	0	0.75	18.97											
Shot 4	State II	20	-4.5	0.55	13.89	21.73	0.86	0.73	14.31%	Direct Measure	Yes	Excellent	N/A	743,000	16,000	Actual
Shot 4	State II	20	-4.5	0.73	18.62											
Shot 4-LT	State II	20	0	0.54	13.77											
Shot 4-LT	State II	20	0	0.73	18.44											
Shot 5	State II	20	-4.5	0.54	13.77	22.98	0.90	0.85	5.83%	Direct Measure	Yes	Excellent	N/A	757,000	10,400	Actual
Shot 5	State II	20	-4.5	0.85	21.64											
Shot 5-LT	State II	15	0	0.48	12.24											
Shot 5-LT	State II	15	0	0.65	16.48											
Shot 6	State II	20	-4.5	0.57	14.50	22.28	0.88	0.87	0.83%	Estimated	Yes	Excellent	N/A	675,000	11,742	1 SD less than average
Shot 6	State II	20	-4.5	0.76	19.18											
Shot 6-LT	State II	15	2	0.48	12.24											
Shot 6-LT	State II	15	2	0.87	22.10											
Shot 7	State II	20	-4.5	0.56	14.20	20.80	0.82	0.75	8.79%	Direct Measure	Yes	Moderate	N/A	708,000	14,900	Actual
Shot 7	State II	20	-4.5	0.75	18.97											
Shot 7-LT	State II	16	0	0.51	12.88											
Shot 7-LT	State II	16	0	0.68	17.20											
Shot 8	State II	20	-4.5	0.55	14.05	23.17	0.91	0.73	19.64%	Direct Measure	Yes	Excellent	N/A	730,000	12,600	Actual
Shot 8	State II	20	-4.5	0.73	18.62											
Shot 8-LT	State II	16	0	0.50	12.75											
Shot 8-LT	State II	16	0	0.67	17.02											
Shot 9	State II	20	-4.5	0.55	13.89	21.92	0.86	0.73	15.89%	Indirect Measure - Axial	Yes	Moderate	N/A	753,843	13,563	1 SD less than average
Shot 9	State II	20	-4.5	0.73	18.44											
Shot 9-LT	State II	15	0	0.48	12.24											
Shot 9-LT	State II	15	0	0.65	16.48											
Shot 10	State II	20	-4.5	0.56	14.20	23.63	0.93	0.74	20.45%	Direct Measure	Yes	Excellent	N/A	713,000	14,300	Actual
Shot 10	State II	20	-4.5	0.74	18.80											
Shot 10-LT	State II	13	0	0.47	11.86											
Shot 10-LT	State II	13	0	0.63	15.88											
Shot 12	State II	20	-4.5	0.70	17.73	21.98	0.87	0.80	8.13%	Direct Measure	Yes	Poor	No	710,000	13,100	Actual
Shot 12	State II	20	-4.5	0.80	20.19											
Shot 12-LT	State II	9.5	0	0.52	13.13											
Shot 12-LT	State II	9.5	0	0.59	14.96											
Shot 13	State II	20	-4.5	0.71	18.08	24.88	0.98	0.81	17.21%	Indirect Measure - Tensile	Yes	Excellent	N/A	675,000	12,501	1 SD less than average
Shot 13	State II	20	-4.5	0.81	20.60											
Shot 13-LT	State II	9	0	0.51	13.00											
Shot 13-LT	State II	9	0	0.59	14.96											
Shot 14	State II	20	-4.5	0.71	18.08	24.88	0.98	0.81	17.20%	Indirect Measure - Tensile	Yes	Poor	Yes	675,000	12,166	1 SD less than average
Shot 14	State II	20	-4.5	0.81	20.60											
Shot 14-LT	State II	6.2	0	0.44	11.25											
Shot 14-LT	State II	6.2	0	0.50	12.75											
Shot 15	State II	20	-4.5	0.66	16.66	23.18	0.91	0.76	17.27%	Direct Measure	Yes	Poor	Yes	840,000	16,000	Actual
Shot 15	State II	20	-4.5	0.76	19.18											
Shot 15-LT	State II	6.1	0	0.41	10.34											
Shot 15-LT	State II	6.1	0	0.46	11.73											
Shot 16	State II	20	-4.5	0.71	18.08	25.52	1.00	0.81	19.29%	Indirect Measure - Tensile	Yes	Excellent	N/A	675,000	11,066	1 SD less than average
Shot 16	State II	20	-4.5	0.81	20.60											
Shot 16-LT	State II	6.1	0	0.44	11.25											
Shot 16-LT	State II	6.1	0	0.50	12.62											
Shot 17	State II	20	-4.5	0.71	18.08	24.12	0.95	0.81	14.61%	Indirect Measure - Tensile	Yes	Moderate	Yes	675,000	11,938	1 SD less than average
Shot 17	State II	20	-4.5	0.81	20.60											
Shot 17-LT	State II	6.3	0	0.45	11.35											
Shot 17-LT	State II	6.3	0	0.50	12.75											
Shot 18	State II	20	-4.5	0.66	16.66	23.08	0.91	0.76	16.90%	Direct Measure	Yes	Poor	Yes	829,000	13,600	Actual
Shot 18	State II	20	-4.5	0.76	19.18											
Shot 18-LT	State II	6.3	0	0.41	10.44											
Shot 18-LT	State II	6.3	0	0.47	11.99											
Shot 19	State II	20	-4.5	0.71	18.08	25.51	1.00	0.85	15.17%	Indirect Measure - Tensile	Yes	Poor	Yes	675,000	12,166	1 SD less than average
Shot 19	State II	20	-4.5	0.85	21.64											
Shot 19-LT	State II	9	0	0.51	13.00											
Shot 19-LT	State II	9	0	0.61	15.57											
Shot 20	State II	20	-4.5	0.69	17.55	25.71	1.01	0.84	17.50%	Indirect Measure - Axial	Yes	Moderate	Yes	714,767	14,912	1 SD less than average
Shot 20	State II	20	-4.5	0.84	21.21											
Shot 20-LT	State II	9	0	0.50	12.62											
Shot 20-LT	State II	9	0	0.60	15.27											
Shot 21	State II	20	-4.5	0.70	17.73	30.37	1.20	0.84	30.16%	Direct Measure	Yes	Moderate	Yes	702,000	10,900	Actual
Shot 21	State II	20	-4.5	0.84	21.21											
Shot 21-LT	State II	11.3	0	0.55	14.05											
Shot 21-LT	State II	11.3	0	0.66	16.84											
Shot 22	State II	20	-4.5	0.75	18.97	27.97	1.10	0.88	20.16%	Indirect Measure - Axial	Yes	Moderate	Yes	595,911	12,200	1 SD less than average
Shot 22	State II	20	-4.5	0.88	22.33											
Shot 22-LT	State II	9	0	0.54	13.64											
Shot 22-LT	State II	9	0	0.64	16.18											
Shot 23	State II	20	-4.5	0.71	18.08	26.64	1.05	0.85	18.75%	Indirect Measure - Tensile	Yes	Moderate	Yes	675,000	11,026	1 SD less than average
Shot 23	State II	20	-4.5	0.85	21.64											
Shot 23-LT	State II	9	0	0.51	13.00											
Shot 23-LT	State II	9	0	0.80	20.40											
Shot 24	State II	20	-4.5	0.71	18.08	25.90	1.02	0.85	16.44%	Indirect Measure - Tensile	Yes	Excellent	N/A	675,000	10,181	1 SD less than average
Shot 24	State II	20	-4.5	0.85	21.64											
Shot 24-LT	State II	17.6	0	0.67	17.02											
Shot 24-LT	State II	17.6	0	0.80	20.19											
Shot 26	State II	20	-4.5	0.71	18.08	26.47	1.04	0.85	18.25%	Indirect Measure - Tensile	Yes	Excellent	Yes	675,000	10,275	1 SD less than average
Shot 26	State II	20	-4.5	0.85	21.64											
Shot 26-LT	State II	17.6	0	0.67	17.02											
Shot 26-LT	State II	17.6	0	0.80	20.19											
Shot 27	State II	20	-4.5	0.71	18.08	25.36	1.00	0.85	14.66%	Indirect Measure - Axial	Yes	Moderate	Yes	664,294	15,472	1 SD less than average
Shot 27	State II	20	-4.5	0.85	21.64											
Shot 27-LT	State II	7.1	0	0.47	11.86											
Shot 27-LT	State II	7.1	0	0.56	14.20											
Shot 28	State II	20	-4.5	0.55	13.89	21.22	0.84	0.73	12.24%	Direct Measure	Yes	Moderate	Yes	747,000	14,200	Actual
Shot 28	State II	20	-4.5	0.73	18.62											
Shot 28-LT	State II	19	0	0.53	13.51											
Shot 28-LT	State II	19	0	0.71	17.91											
Shot 29	State II	20	-4.5	0.55	13.89	19.85	0.78	0.73	6.22%	Direct Measure	Yes	Moderate	Yes	748,000	12,700	Actual
Shot 29	State II	20	-4.5	0.73	18.62											
Shot 29-LT	State II	20	0	0.54	13.77											
Shot 29-LT	State II	20	0	0.72	18.26											
Shot 30	State II	20	-4.5	0.73	18.44	22.24	0.88	0.82	6.48%	Direct Measure	Yes	Poor	Yes	646,000	15,200	Actual
Shot 30	State II	20	-4.5	0.82	20.80											
Shot 30-LT	State II	9	0	0.52	13.26											
Shot 30-LT	State II	9	0	0.60	15.11											
Shot 31	State II	20	-4.5	0.57	14.35	21.53	0.85	0.76	10.93%	Indirect Measure - Axial	Yes	Poor	Yes	682,204	11,171	1 SD less than average
Shot 31	State II	20	-4.5	0.76	19.18											
Shot 31-LT	State II	15	0	0.50	12.75											
Shot 31-LT	State II	15	0	0.67	17.02											



Design Reconciliation Summary – 110 Load Cases for 28 Shots

- 14 shots were able to be assessed in a conventional manner by Direct Measurement method
- 13 shots were assessed for structural adequacy using Indirect Measures in a conservative manner
- 1 shot, Shot 6, needed to estimate mechanical properties minimum properties for the project
- Multiple values were available to interpret thickness, stiffness and strength for most samples.
    - Where multiple valid values were available, the lowest value was used for the Design Reconciliation Assessment.

Actual Wall Thickness (mm)	Actual Wall Thickness (in)	Governing Required Thickness (in)	Actual to Governing with full LRFD Values (%)	Mechnical Properties	Wet out compliance	Cure Rating	Resolved by Increased Cure Time	Flexural Modulus (psi)	Flexural Strength (psi)	Basis of Estimate
19.80	0.78	0.44	75.96%	Direct Measure	Yes	Excellent	N/A	415,000	4,230	Actual
20.41	0.80	0.77	4.22%	Direct Measure	Yes	Excellent	N/A	635,000	18,300	Actual
21.73	0.86	0.73	16.70%	Direct Measure	Yes	Excellent	N/A	743,000	16,000	Actual
22.98	0.90	0.85	6.19%	Direct Measure	Yes	Excellent	N/A	757,000	10,400	Actual
22.28	0.88	0.87	0.84%	Estimated	Yes	Excellent	N/A	675,000	11,742	1 SD less than average
20.80	0.82	0.75	9.64%	Direct Measure	Yes	Moderate	N/A	708,000	14,900	Actual
23.17	0.91	0.73	24.44%	Direct Measure	Yes	Excellent	N/A	730,000	12,600	Actual
21.92	0.86	0.73	18.89%	Indirect Measure - Axial	Yes	Moderate	N/A	753,843	13,563	1 SD less than average

Summary

- PROJECT ACHIEVEMENTS:
  - Structurally Rehabilitate 111 yr. old interceptor (100-year design life)
  - Minimal excavation and impacts - 725,000 pounds of resin in 28 shots (27 of those, the complex “box” from 1911!)
  - Constructed without a single OTH Wet-out
  - Design Objectives Fully Verified in Construction Phase
  - Meet requirements of EPA Partial Consent Decree
- COST & SCHEDULE:
  - Contract Start – August 2022
  - Substantial Completion – September 2023
  - 1-year Warranty Inspections – fall 2024
  - Awarded to Insituform for $17MM, $18.4MM final (PV Pro-Fi loan)

Queries

Chris Macey – AECOM - chris.macey@aecom.com
Andrew Costa – Azuria - acosta@azuria.com

Before

After