Ohio Accelerated Pavement Loading Facility

Ohio Accelerated Pavement Loading Facility

- Owner/Operator: Ohio University
- Location: Lancaster, Ohio, USA
- Constructed 1996-1997
- Enclosed Chamber with Controlled Loading, Air Temperature and Subgrade Moisture
- -10°F to 140° F
- Test Pit: (41 ft x 35 ft x 15 ft) 13.7 m x 11.6 m x 2.4 m deep

Ohio Accelerated Pavement Loading Facility

Ohio Accelerated Pavement Loading Facility

Paving at APLF

Sensor Installation

Performance of Shallow Cover Thermoplastic Pipes Subject to Temperature Change

Billy Jones

Presentation Overview

- Facility and Project Information
- Project Construction
- Instrumentation & Sample Data
- Summary

Ohio University APLF Facility

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Shallow Cover Experiment

- Tests were done in Accelerate Pavement Loading Facility (APLF)
  - Temperature controlled
  - Fitted with Accelerated Pavement Testing Machine (APTM)
- APTM capable of exerting 30,000 lb dual tire load
- 3 high density polyethylene (HDPE), and 2 polypropylene (PP) pipes buried in testing pit
- 48-inch diameter pipes – Ohio DOT Item 304
- 36-inch diameter pipes – #57 Gravel
- All pipes subject to same cover conditions

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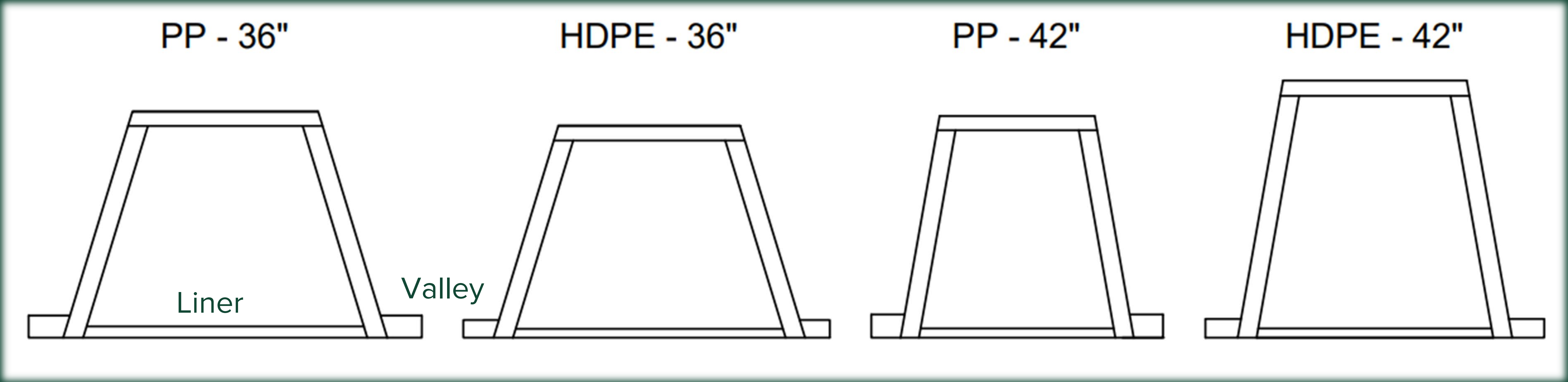
Pipe Material Information



Pipe Material	Young's Moc (Short-terr	lodulus erm)	Utimate Stress Limit (Long-term)
PP	175000	)0	1000
HDPE	110000	0	900

Pipe Materiala	Nominal Diameter (in)	Effective Area (in^2)	MOI (in^4)
PP	36	0.302	0.3703
	42	0.34	0.3786
HDPE	36	0.268	0.3299
	42	0.28	0.5295

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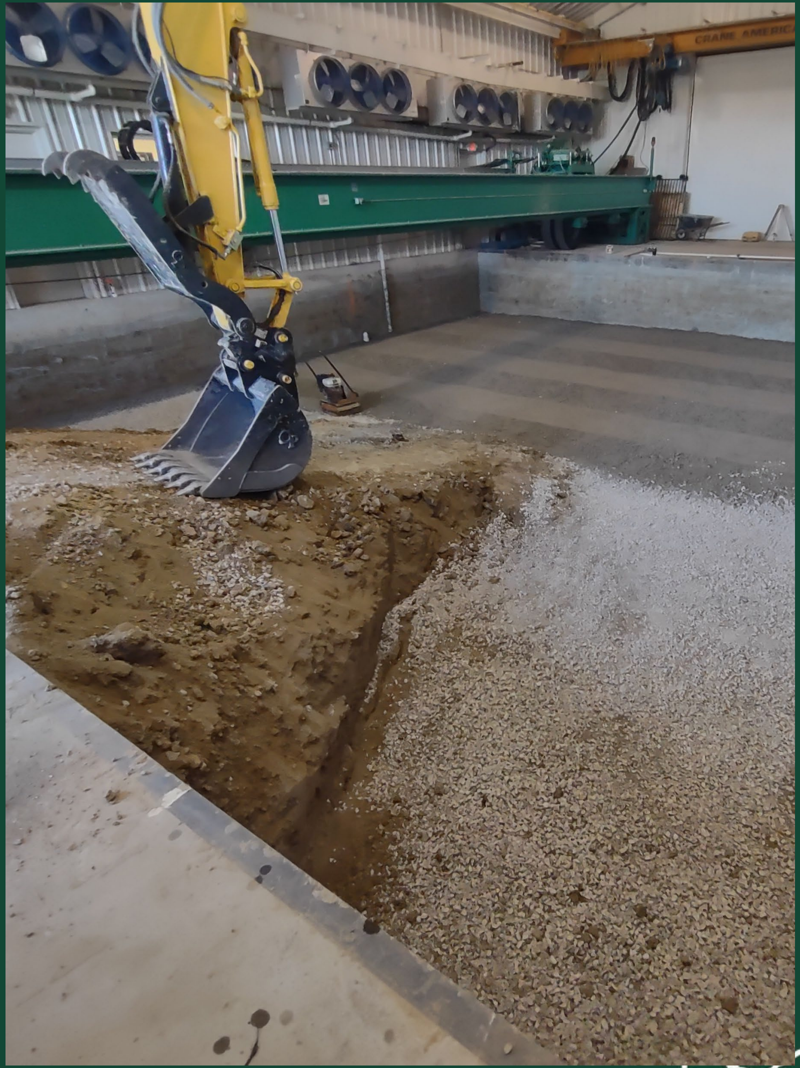
Pre-Construction Demolition



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Pipe Installation

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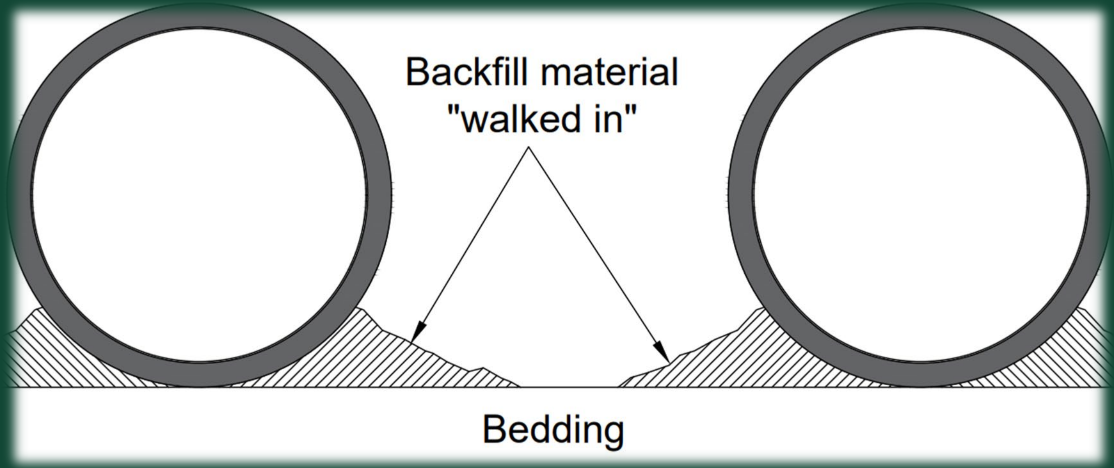
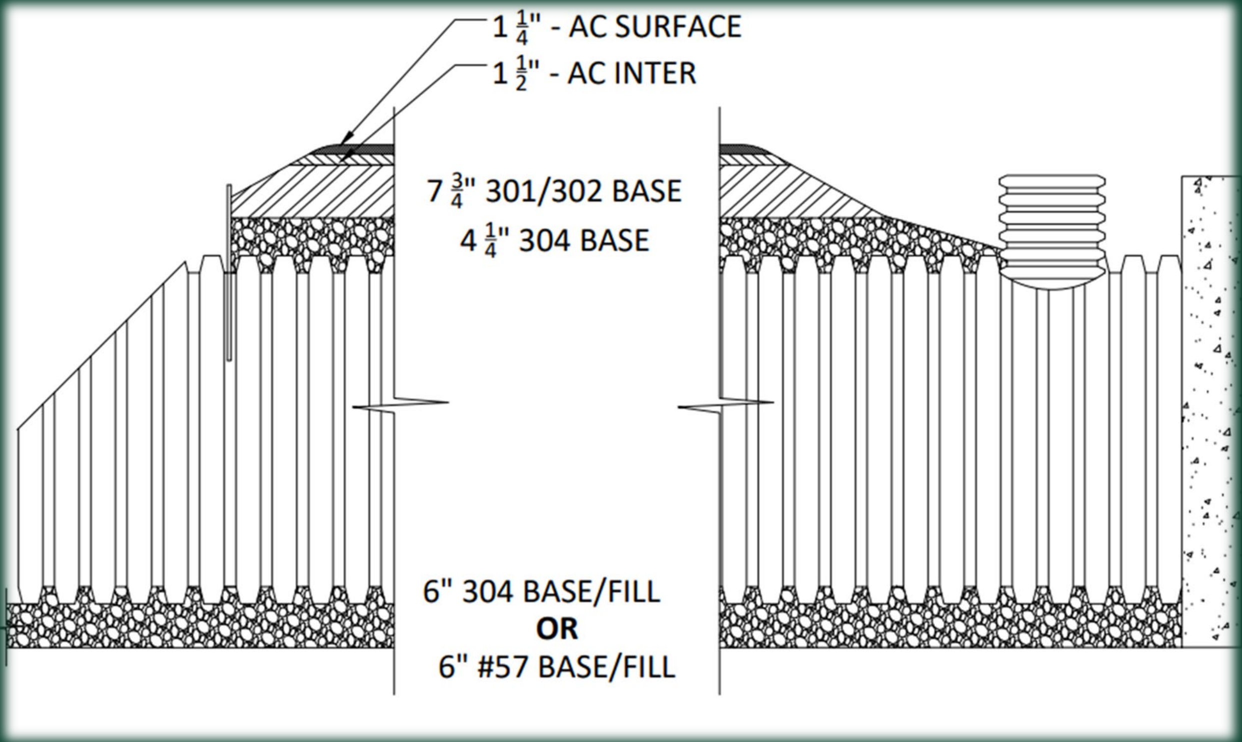
Embedment Construction Details

- ASTM F1668 Construction Procedures for Buried Plastic Pipe
- 36” - uncompacted #57 gravel
- 48” – 304, compacted 4-inch lifts
- 4 ¼” layer of compacted 304 overtop





Embedment Materials - #57 vs 304

ODOT Item 304

AASHTO #57 Gravel

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Embedment Material Soil Testing

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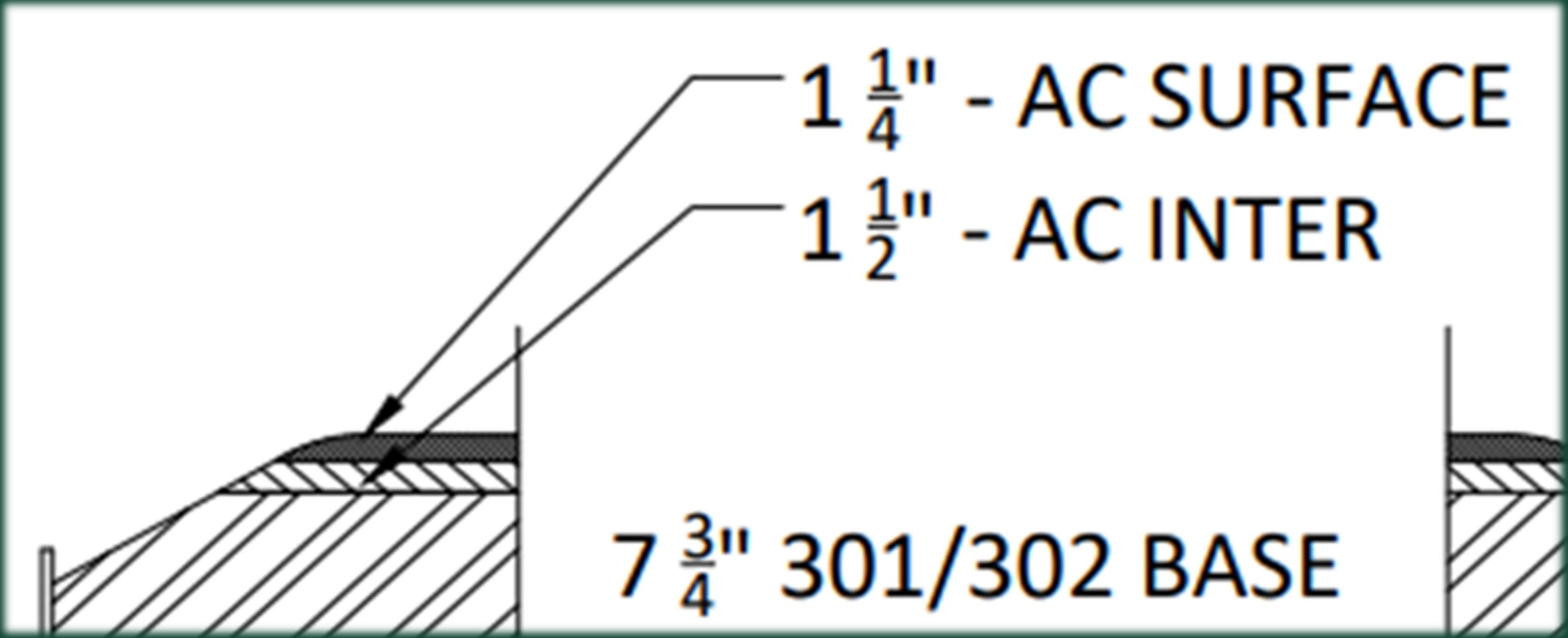
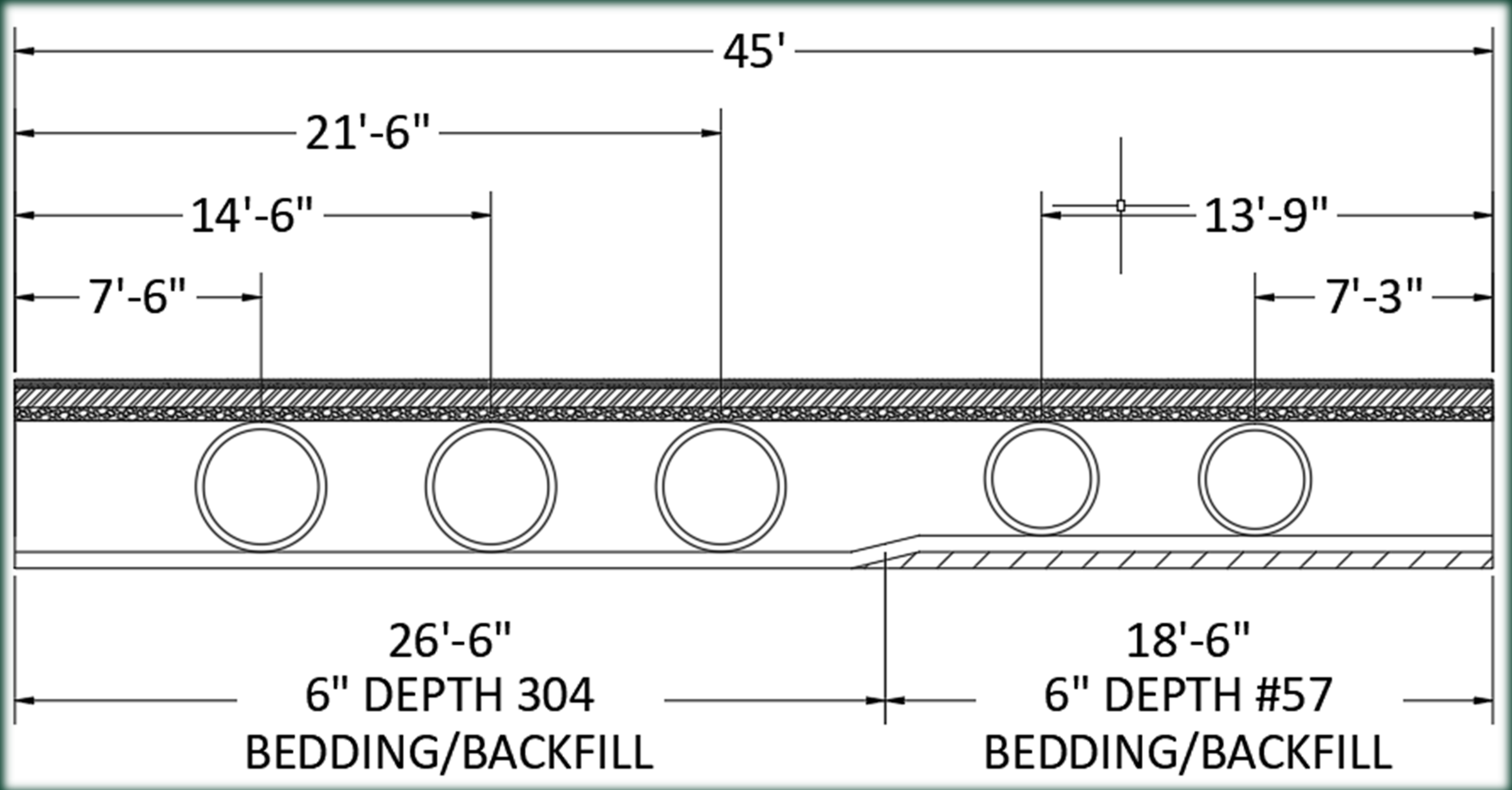
Embedment Construction

Asphalt Construction Details



Construction Details – Plan View



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Instrumentation and Data Collection

Data Collection Intervals

ROOM
PIPE TEMP - (60-75F)
AC TEMP - (65-85F)

COLD
PIPE TEMP - (<60 F)
AC TEMP - (<65 F)

WARM/HOT
PIPE TEMP - (>75F)
AC TEMP - (>85 F)

0-10K → 10K-30K → 30K-50K → 50K-80K

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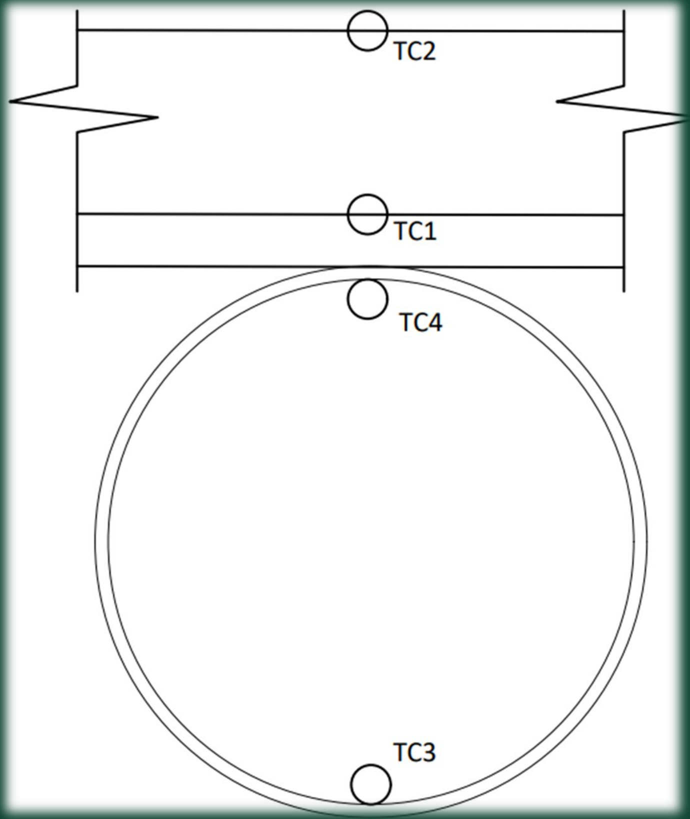
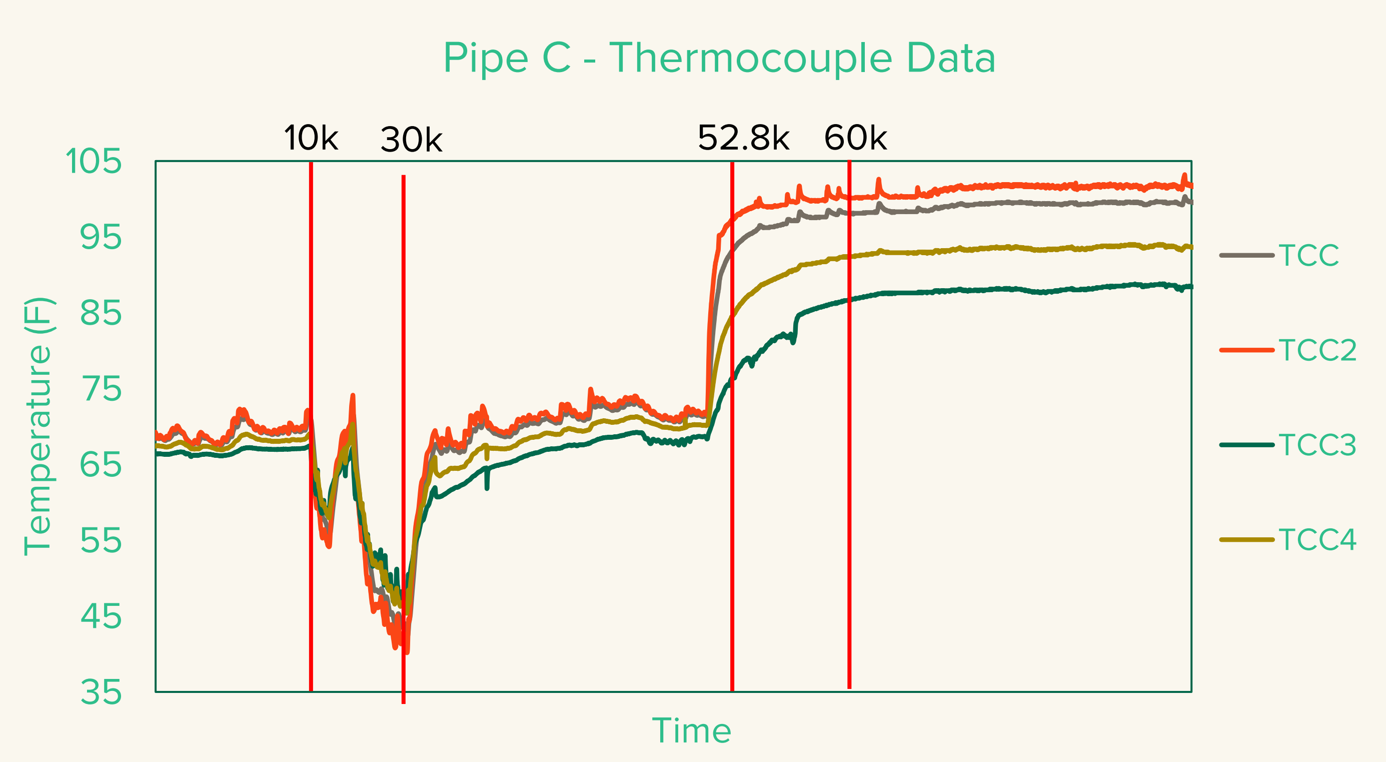
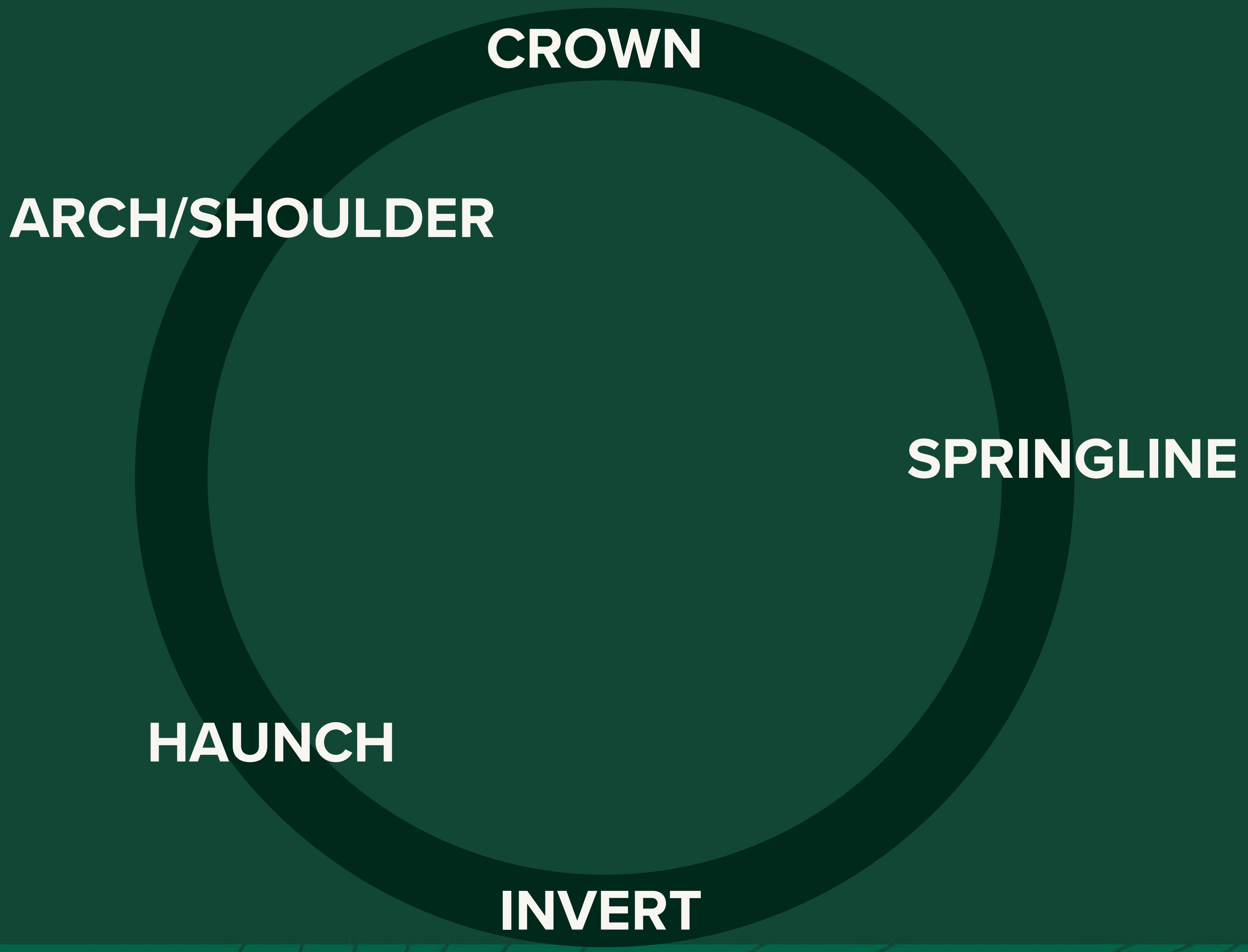
Temperature Data

Temperature Classification	Load Cycles	Asphalt Temperature		Pipe Temperature	
		(top AC base)	(bott. AC base)	Invert	Crown
		TCC	**TCC2**	**TCC3**	**TCC4**
ROOM	10k	71.7	70.0	67.2	68.5
COLD	30k	43.1	43.3	46.5	45.1
WARM	52.8K	96.0	89.6	73.4	79.9
HOT	60K	100.3	99.0	86.7	92.7

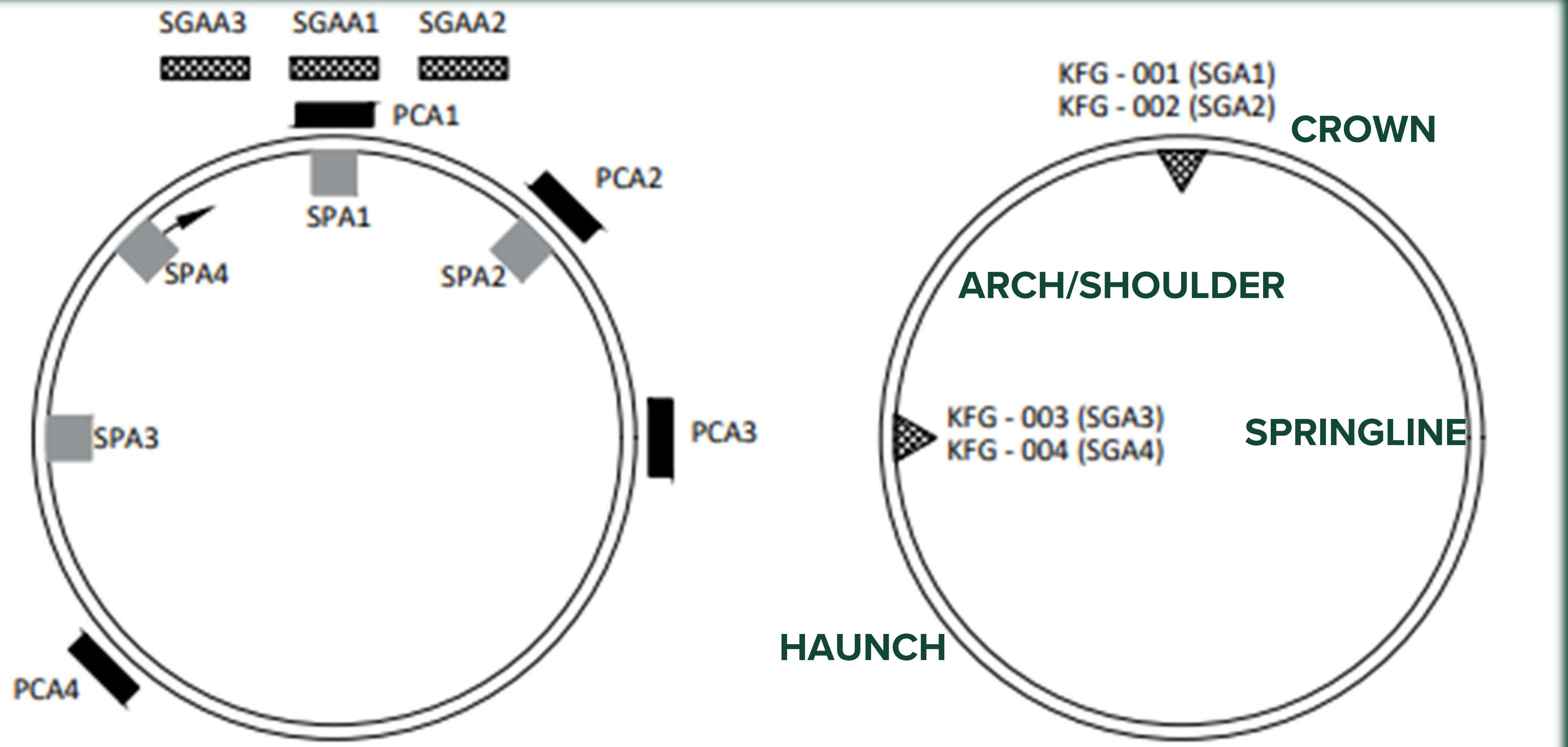




Pipe Nomeclature

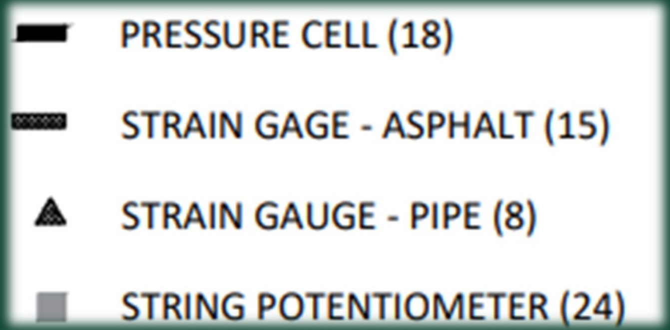


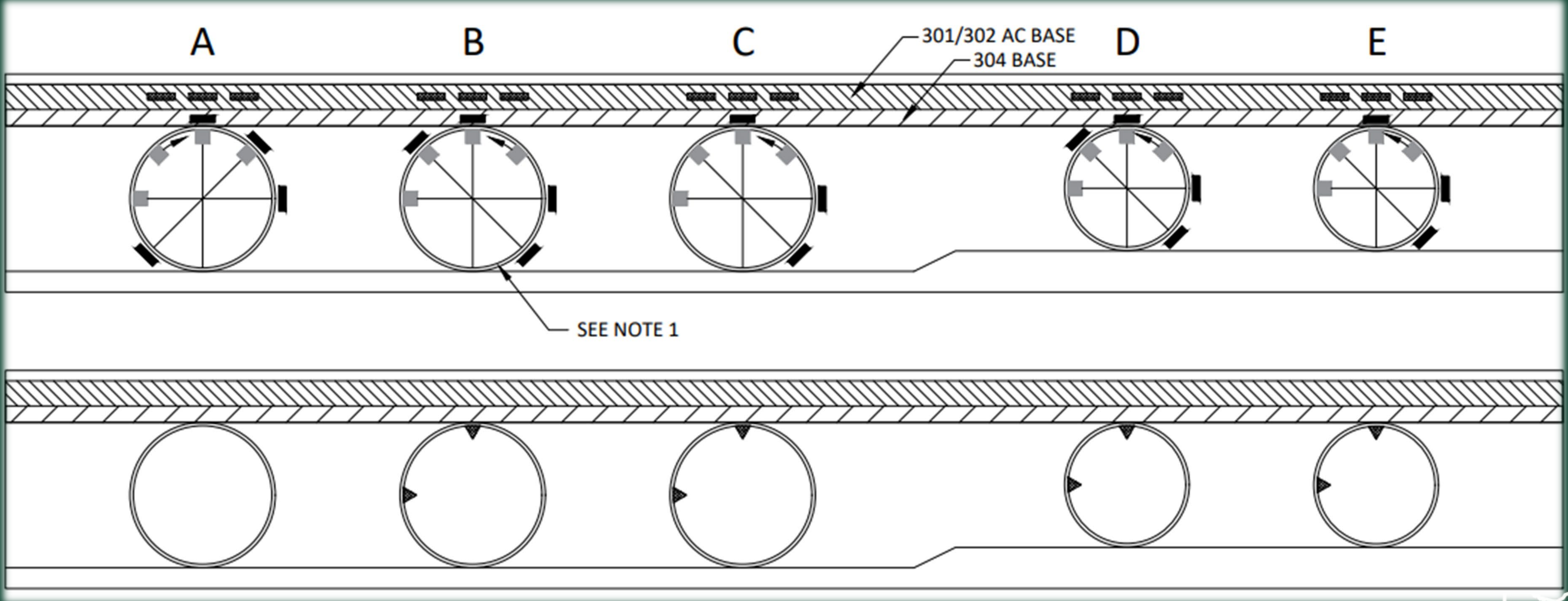
Instrumentation - Typical Layout



TYPICAL INSTRUMENTATION LABELING SCHEME

Instrumentation Location Plan

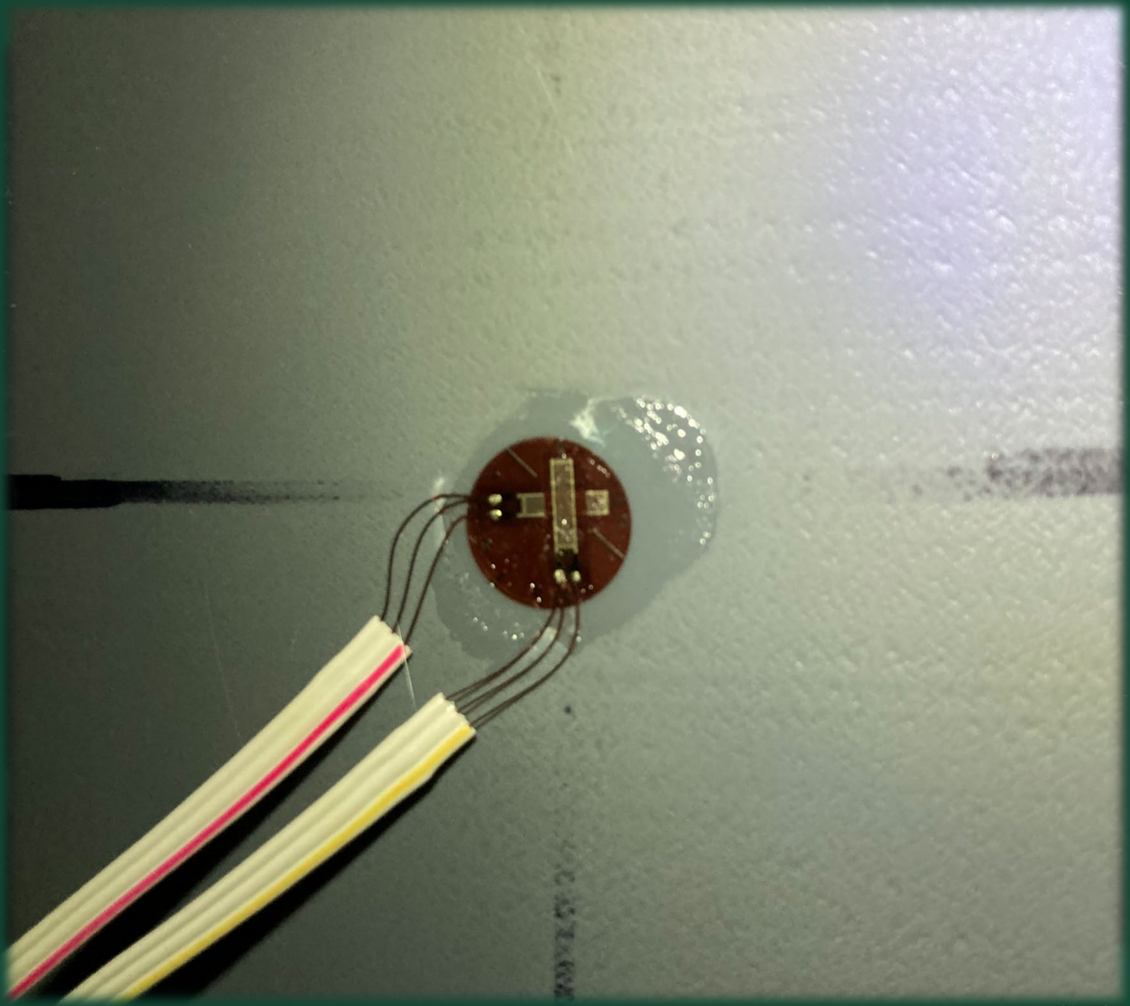




Pipe Instrumentation

Strain Gages (SG)

- Biaxial gages placed at crown and springline on interior pipes
- Placed on corrugation valley to prevent liner interference



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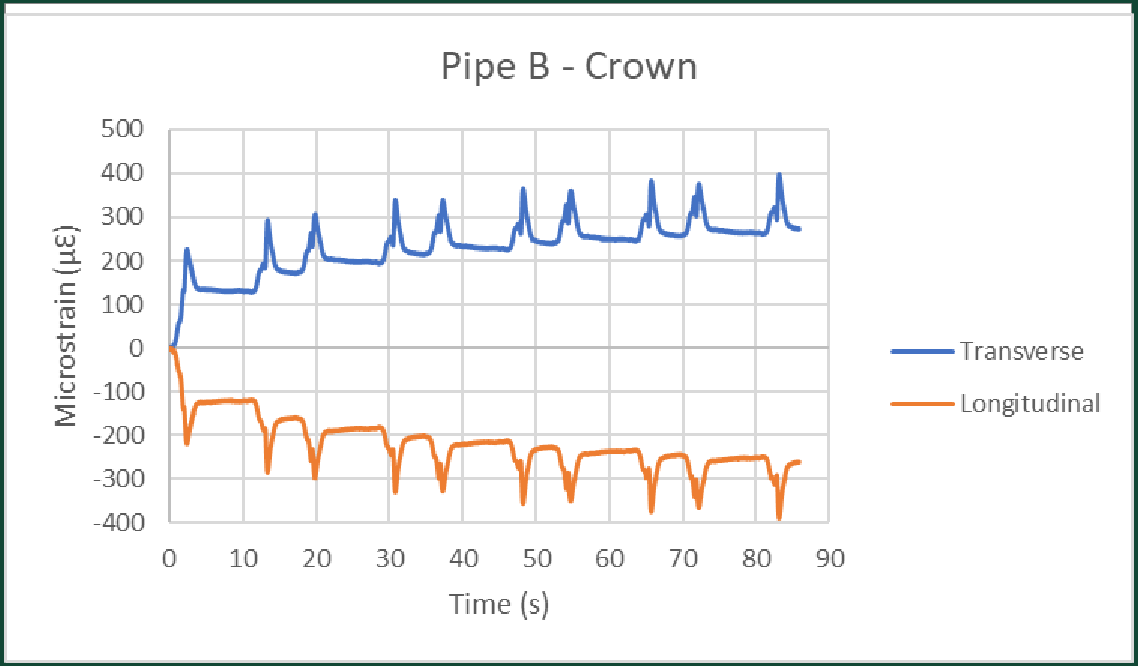
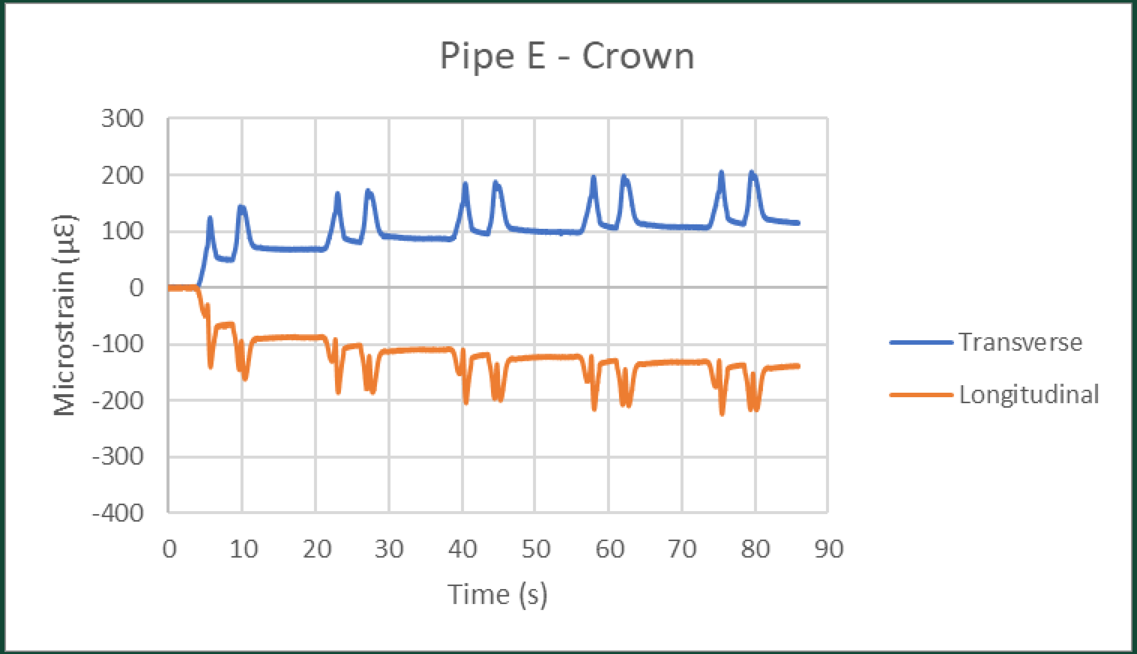
Early Strain Behavior

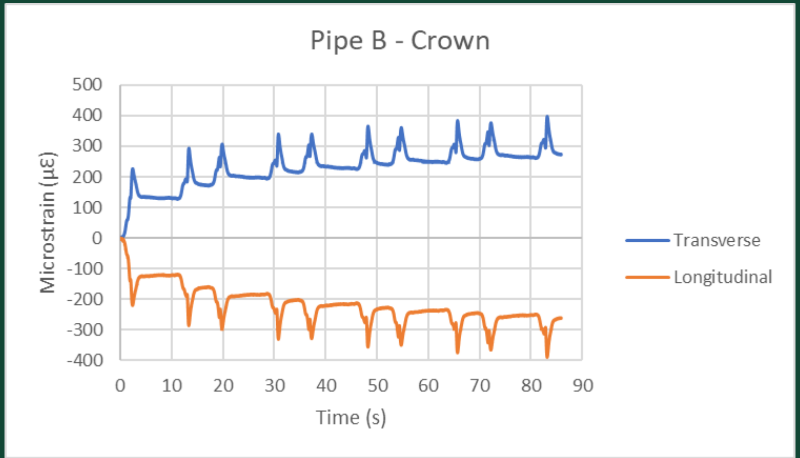
304 vs. #57

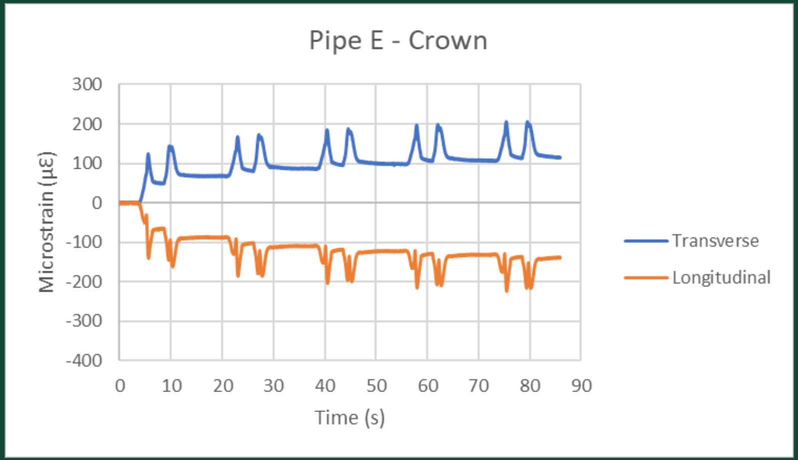


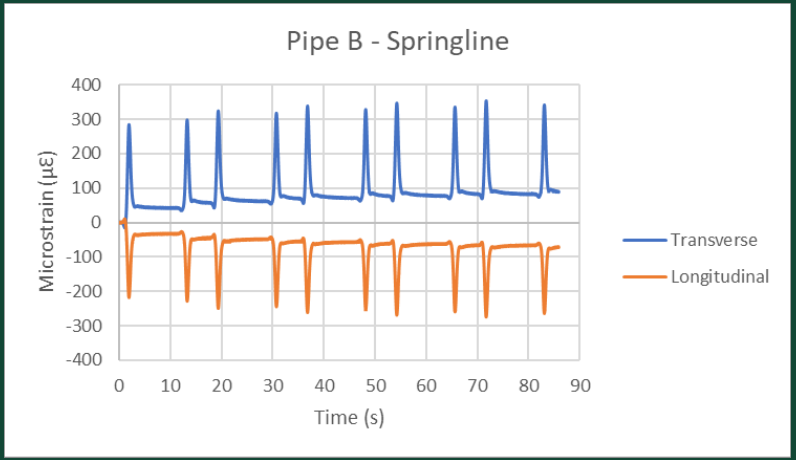


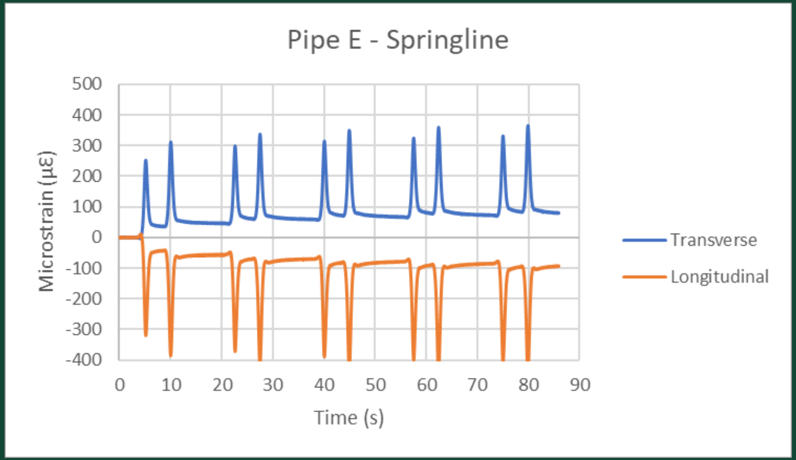
Early Strain Behavior → Equillibrium

304 vs. #57



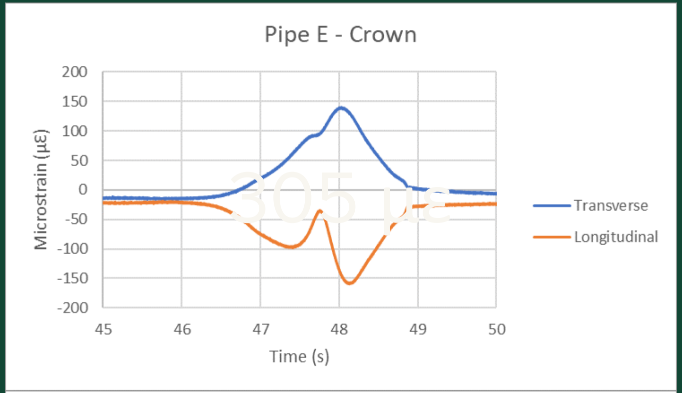


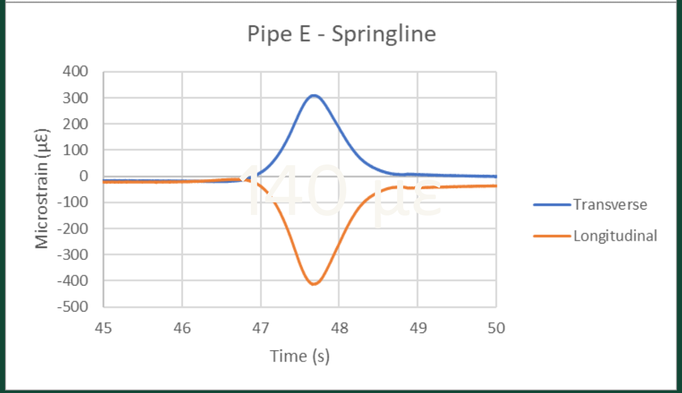




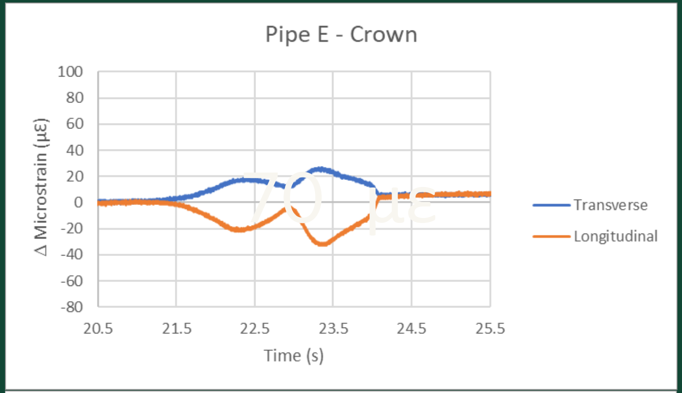
Temperature Response – Pipe Strain

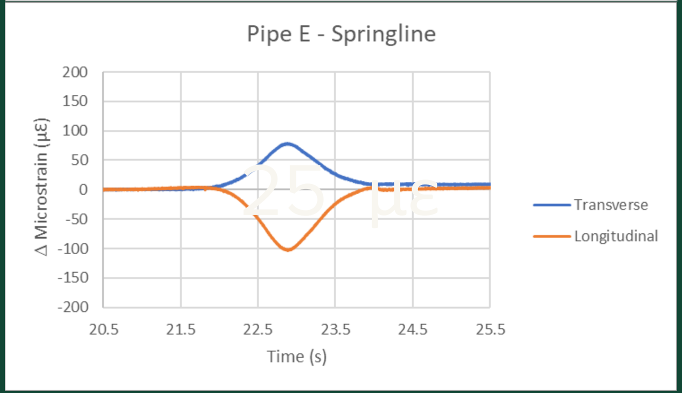
10k - ROOM



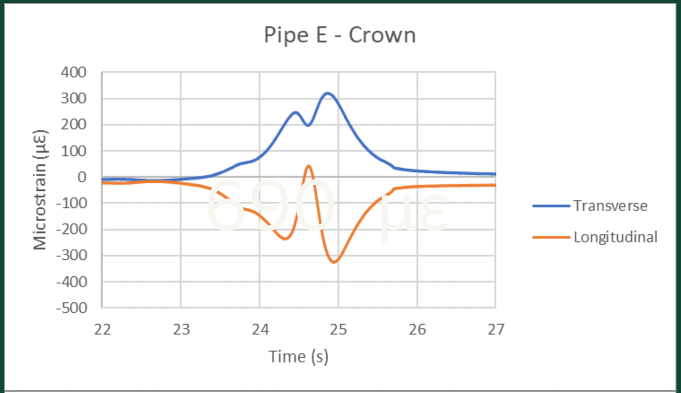


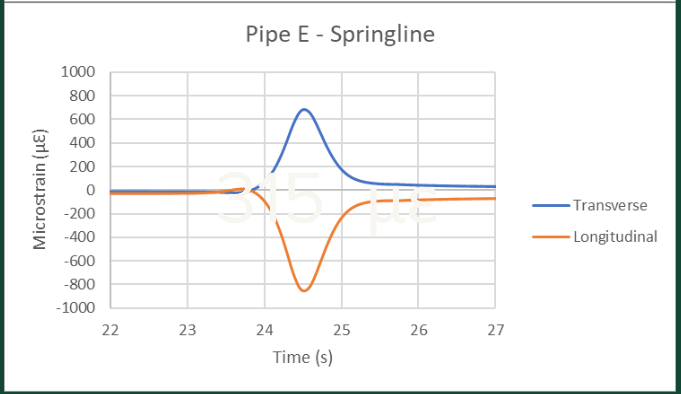
30k - COLD





80k - HOT





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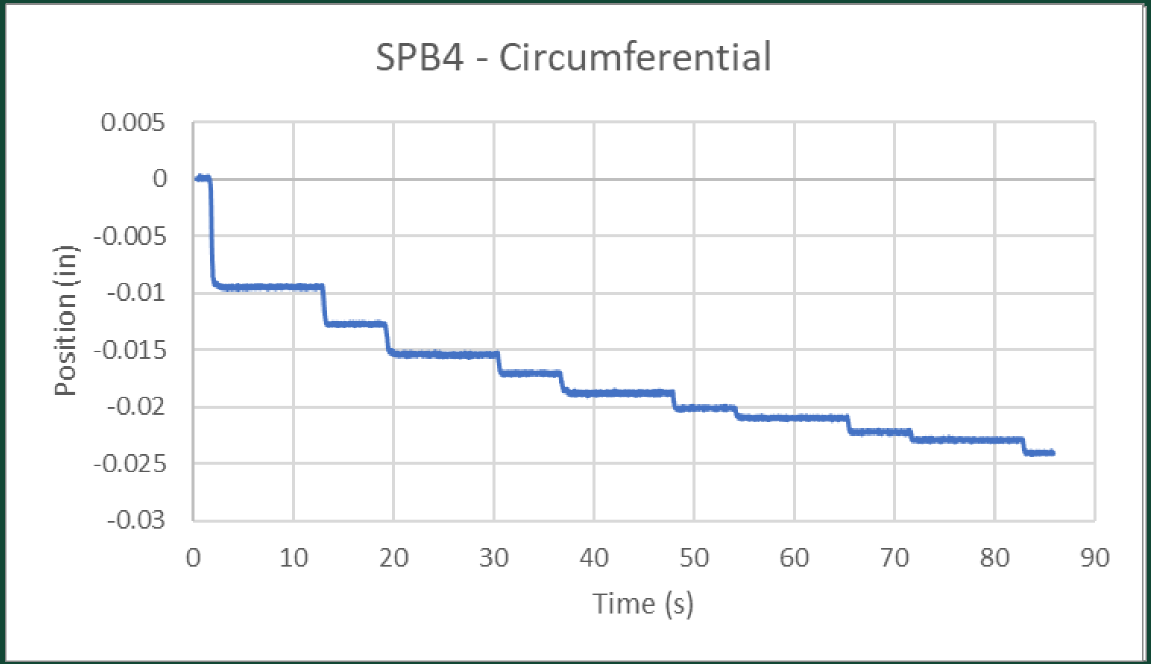
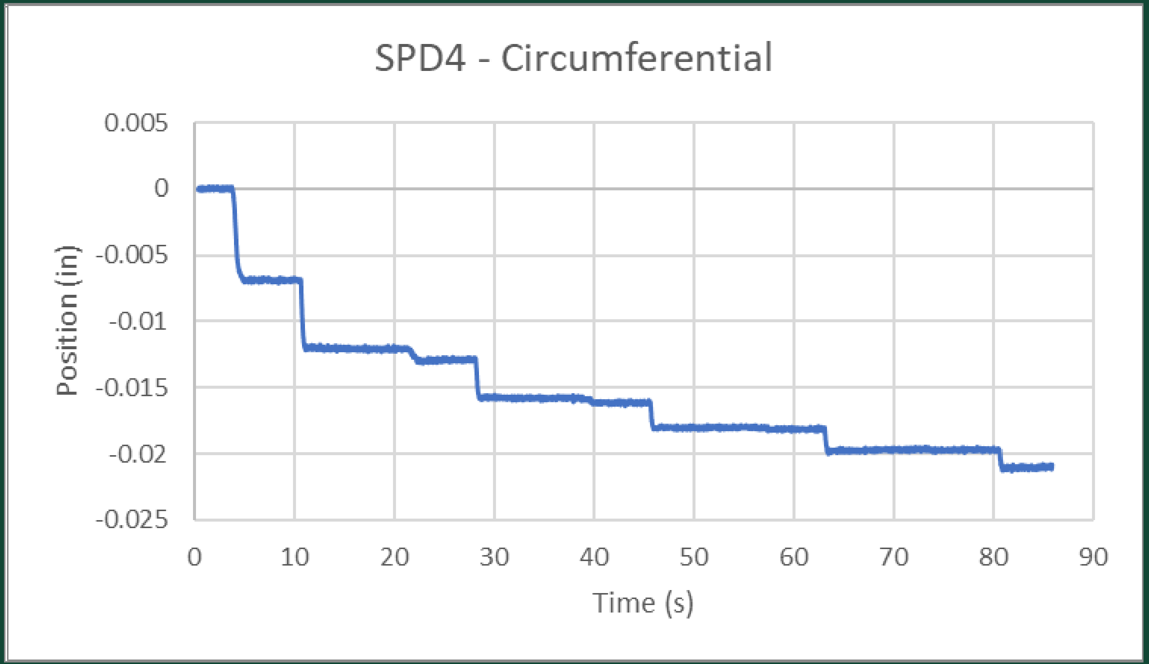
Pipe Instrumentation

- String Potentiometers (SP)
  - 4.7 inch range potentiometers placed at crown, arch/haunch, springline and circumferential locations
  - Fixed to corrugation valley
- Thermocouples (TC)
  - Placed and invert and crown locations

Early Deflection Behavior – 100 Load Cycles

304 vs. #57

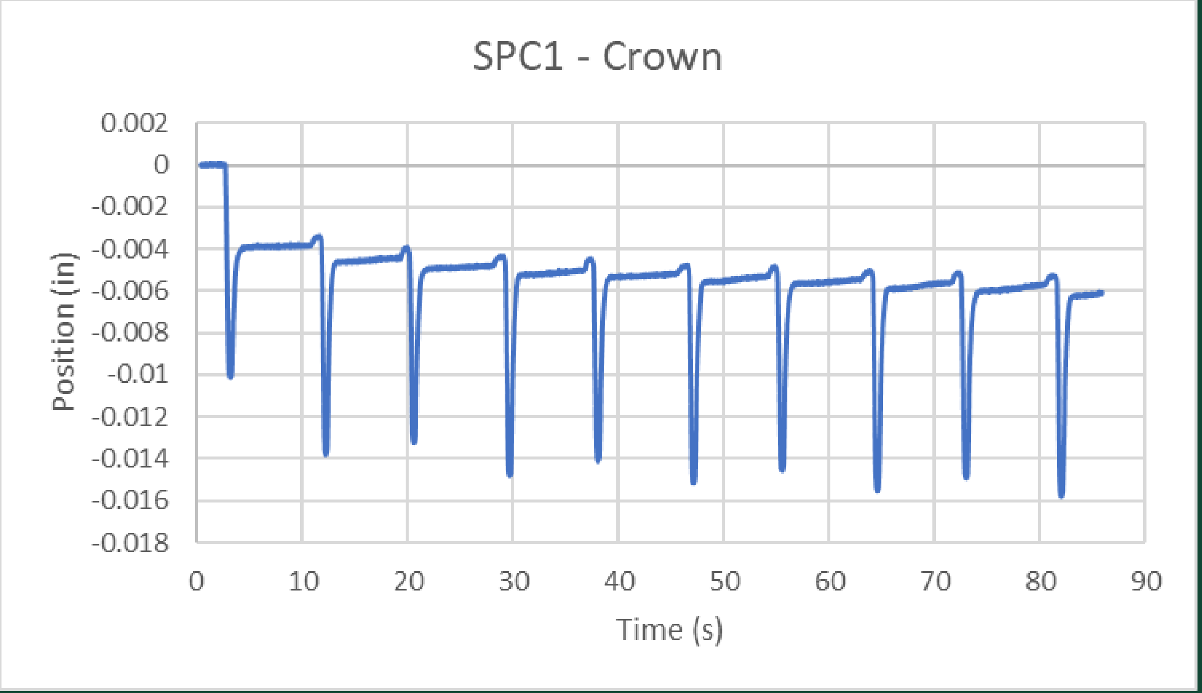




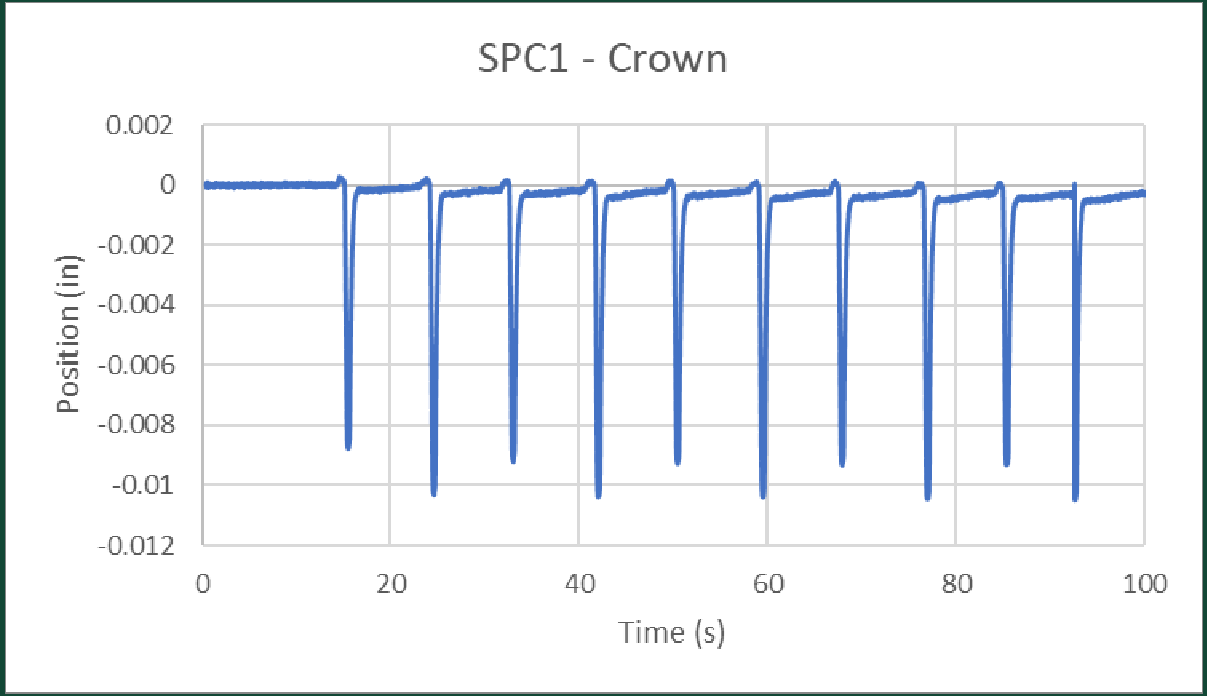
ALL VALUES VERY SMALL

Early Deflection Behavior → Equilibrium

100 load cycles



1,000 load cycles

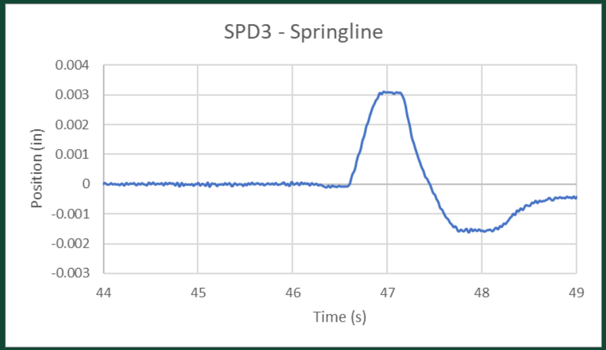


Temperature Response – Deflection

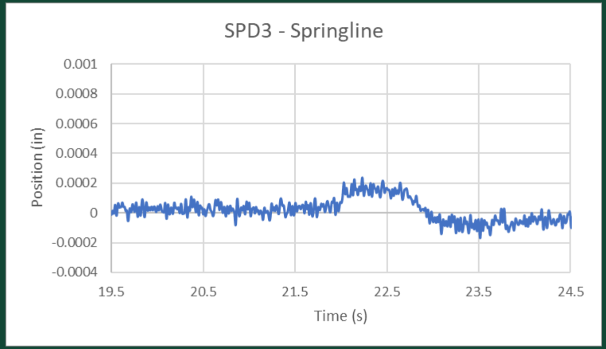
10k
ROOM

0.0015 in.

0.011 in. 0.003 in.



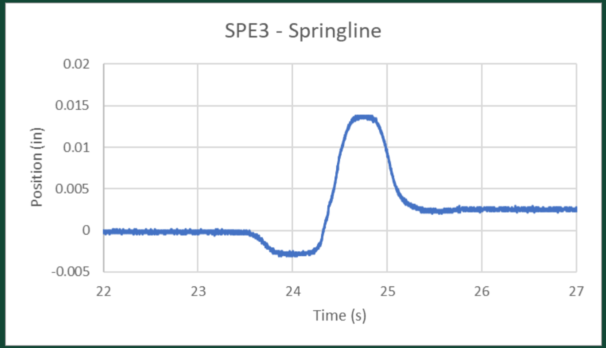
30k
COLD



80k
HOT

0.015 in.

0.04 in. 0.015in.



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Embedment & Asphalt Instrumentation

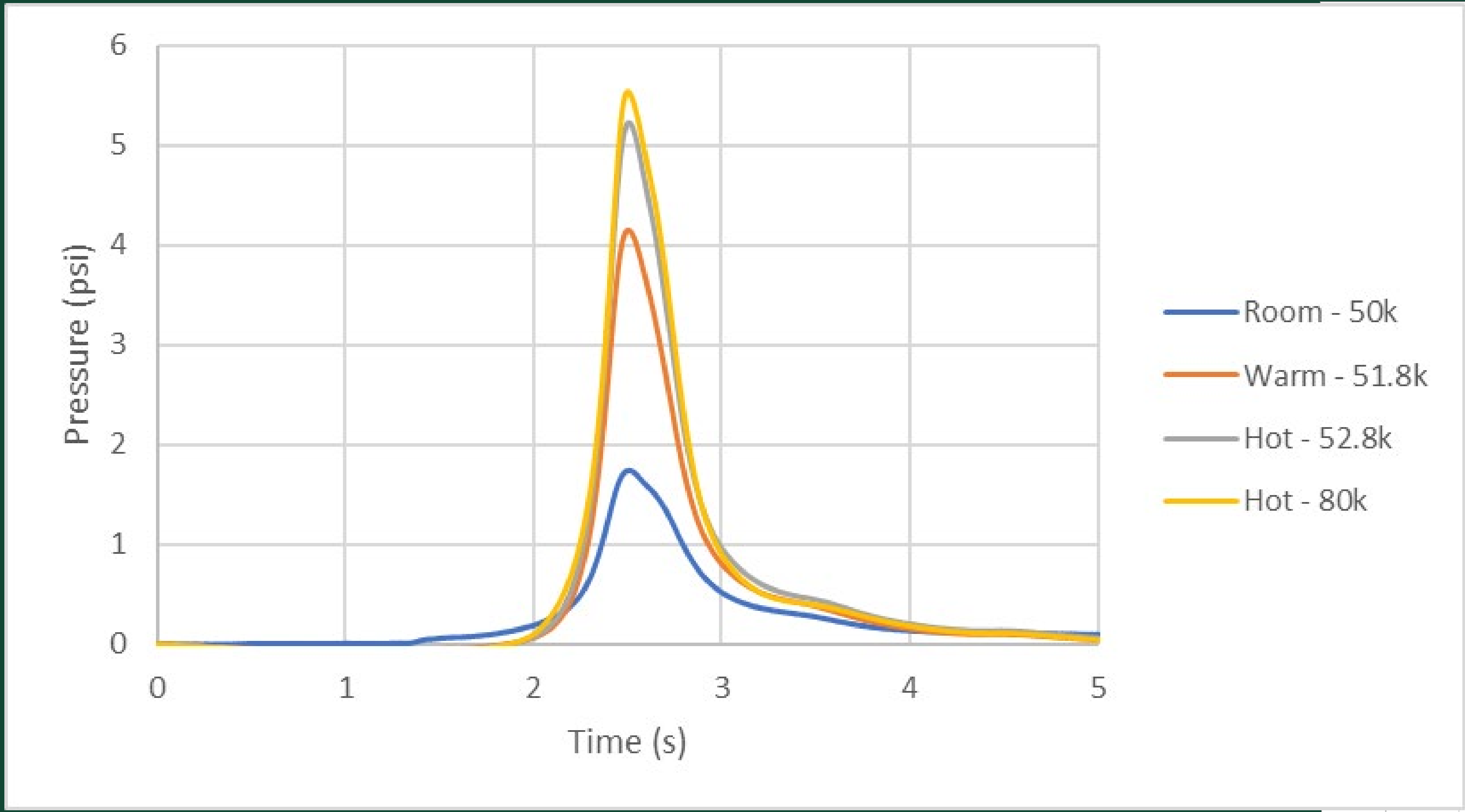
- Pressure Cells (PC)
  - In embedment material at crown, springline, haunch and arch locations
  - Placed in thin layer of sand to avoid potential load concentrations
- Asphalt Strain Gages (SGA)
  - Bottom of asphalt base layer, on top of compacted 304 layer
  - Longitudinal, above pipe crown
- Thermocouples (TC)
  - Bottom and top of asphalt base

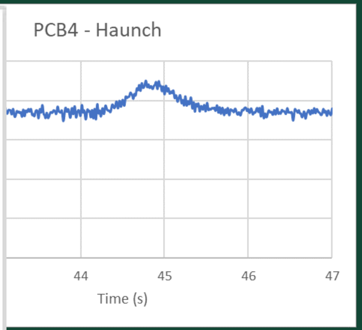
Temperature Response – Pressure

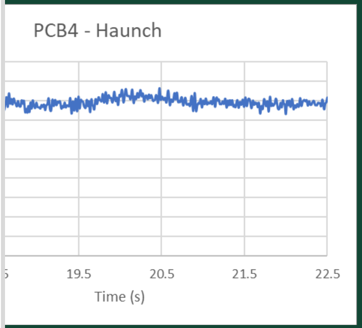
10k
ROOM

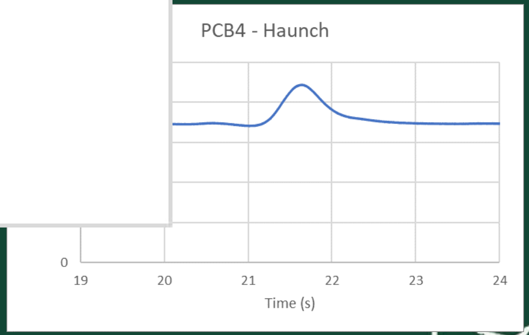
30k
COLD

80k
HOT



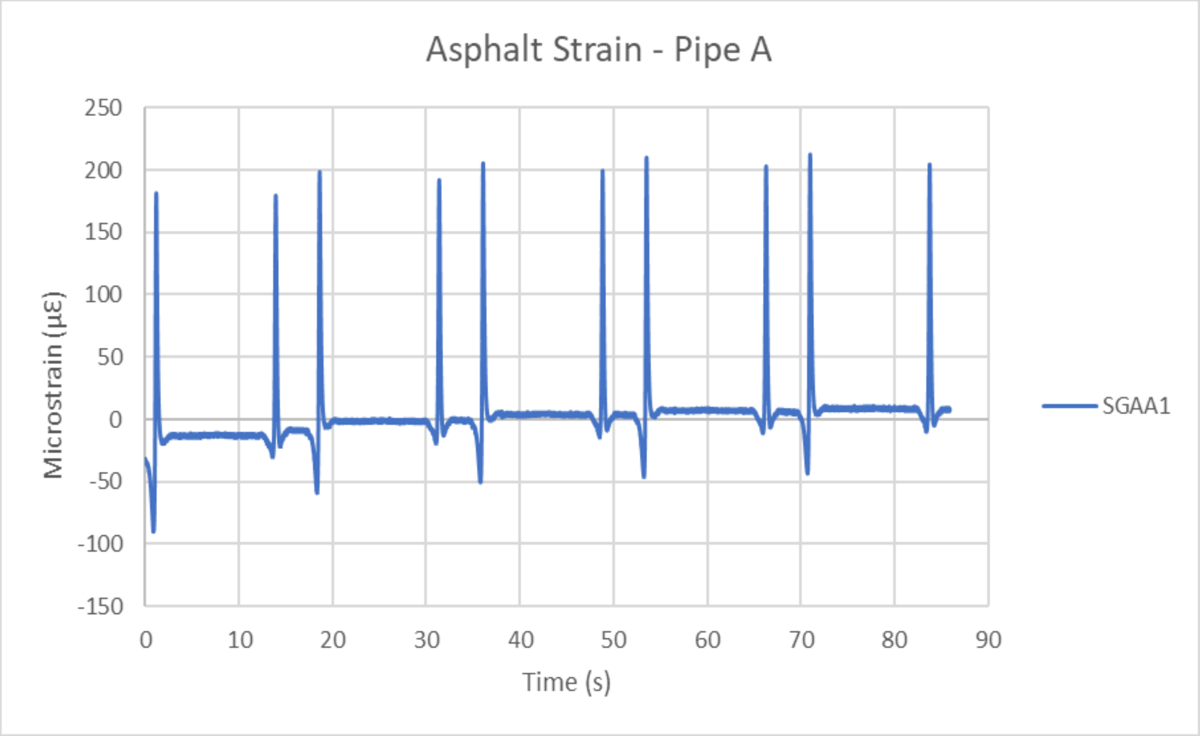


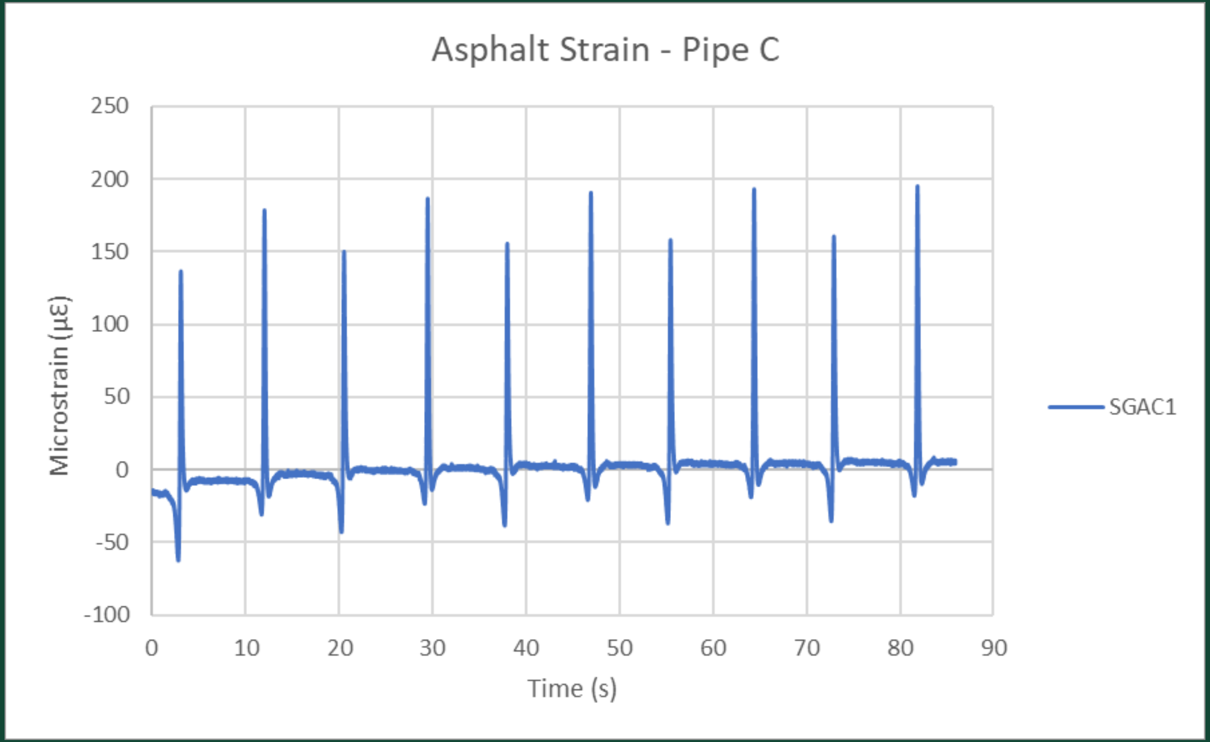




Early Asphalt Strain Behavior

304 vs. #57



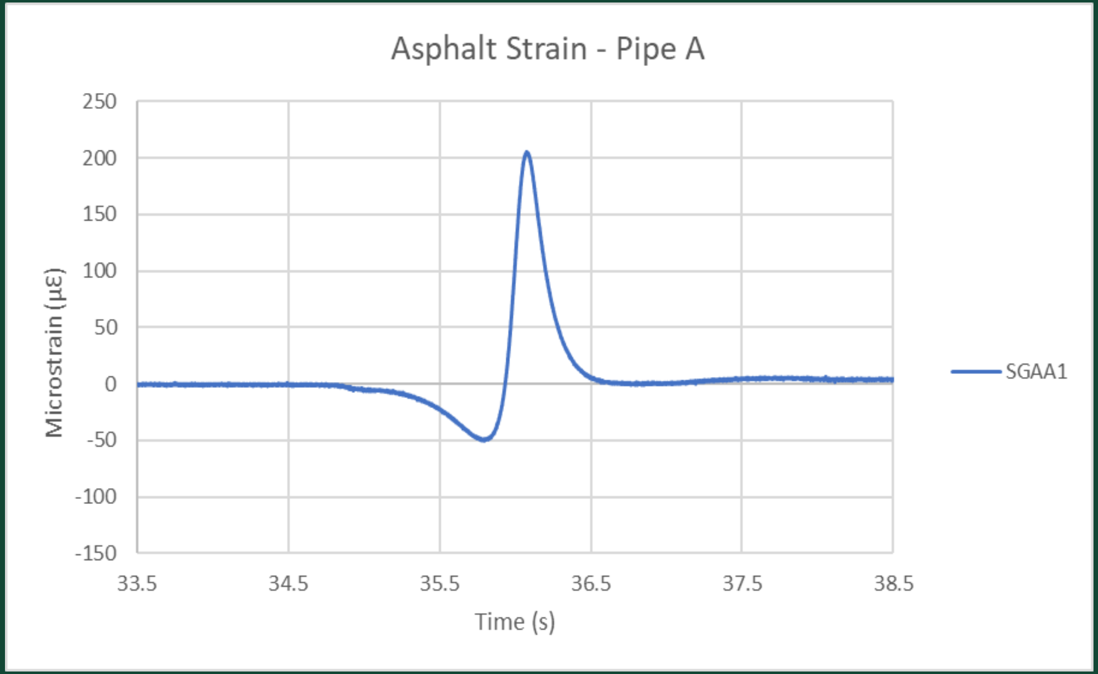


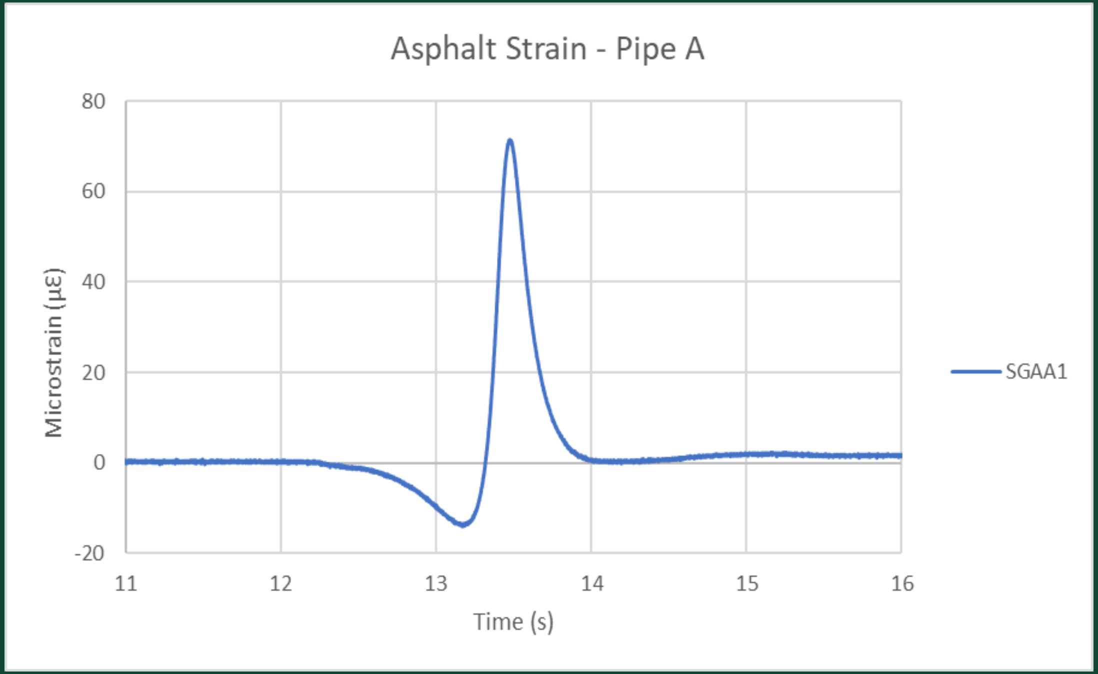
Early Asphalt Strain Behavior ➔ Equilibrium

100 Load Cycles
200με

60% + DROP

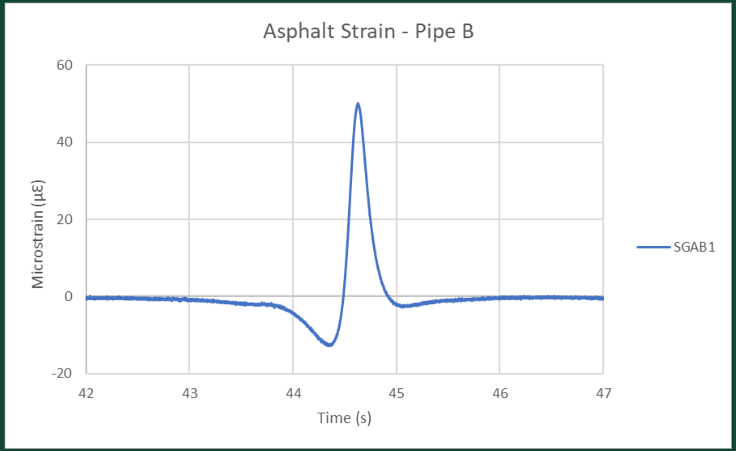
1000 Load Cycles
75με





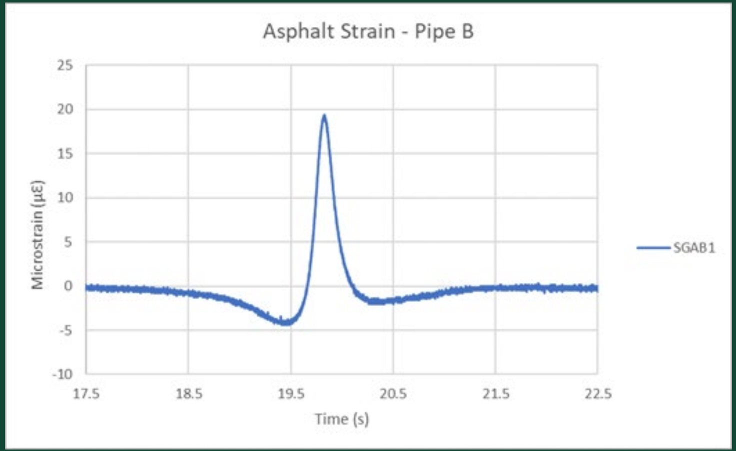
Temperature Response – Asphalt Strain

10k - ROOM



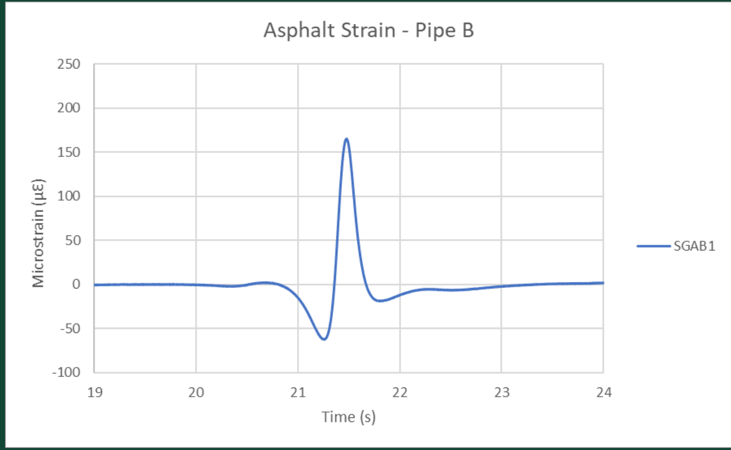
50 με

30k - COLD



20 με

80k - HOT



160 με

Embedment & Asphalt Instrumentation

- Pressure Cells (PC)
  - In embedment material at crown, springline, haunch and arch locations
  - Placed in thin layer of sand to avoid potential load concentrations

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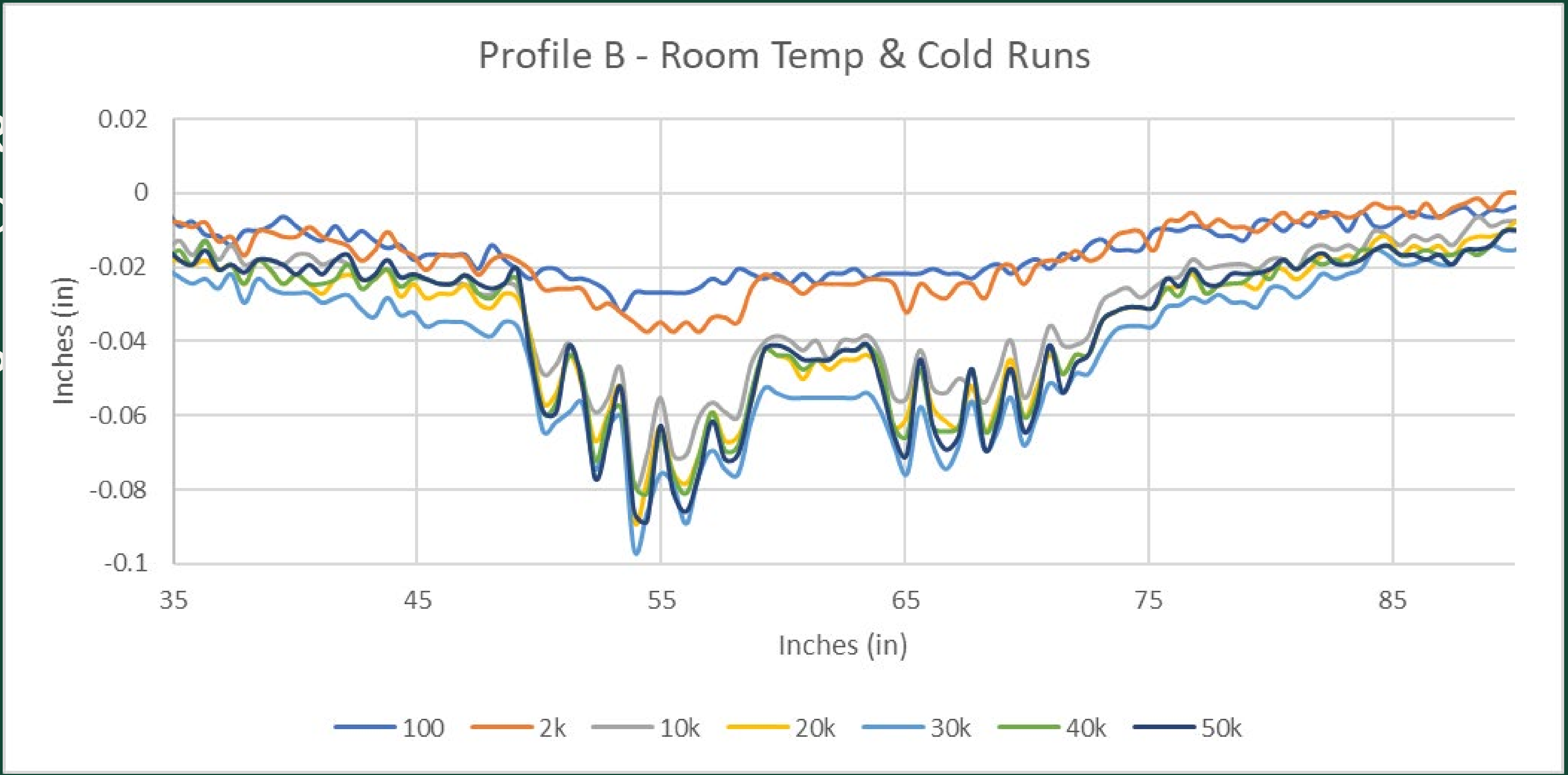
Asph

- Measurem
  midpoints
- Carriage t
- Onboard c
  elevations
- Elevation r

Asphalt Profile Results

- R
- D
- P



Summary

- No major differences between embedment materials
- No large differences in behavior between two pipe materials, across the temperature range tested
- Despite not achieving 2ft of cover requirement (AASHTO LRFD), all pipes performed very well
- Never approached anywhere near 5% deflection limit, even under most extreme temperatures (0.05” MAX)

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Thermoplastic Pipes Performance at High and Ambient Temperatures Under Shallow Cover

Presenter:
Abdul Basit Dahar
PhD Student
Ohio University

Civil and Environmental Engineering Department

May 9, 2024

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Presentation Layout

- Introduction
- Literature Review
- Research Gap
- Objectives
- Materials and Methods
- Results

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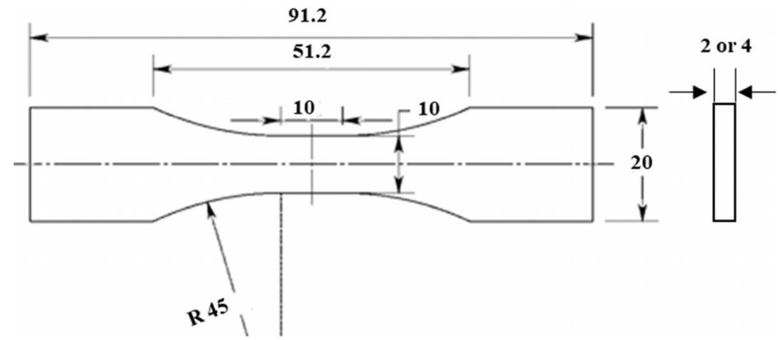
Background

- Recent Wildfire Devastation: California's wildfires have intensified in recent years, causing extensive damage to both forests and developed regions.
- Historic Scale of Destruction: Since 2015, the state has witnessed 15 of its 20 most destructive fires, leading to widespread annihilation of homes and buildings across diverse landscapes, from the Sierra Nevada foothills to the Coast Range.
- Intersection of Human Habitation and Fire Zones: The fires are increasingly occurring in populated areas—or conversely, more people are settling in fire-prone regions—introducing new risks for health and infrastructure.
- Post-Fire Hazards: Among the various dangers that follow in the aftermath of these fires are buried infrastructure, including HDPE (High-Density Polyethylene) and PP (Polypropylene) pipes. These materials are commonly used for utilities and are at risk of damage.
- Infrastructure at Risk: These buried pipes face threats from both static and moving loads beneath pavements, which can be compromised or weakened by the intense heat and subsequent environmental changes caused by the fires.

Literature Review

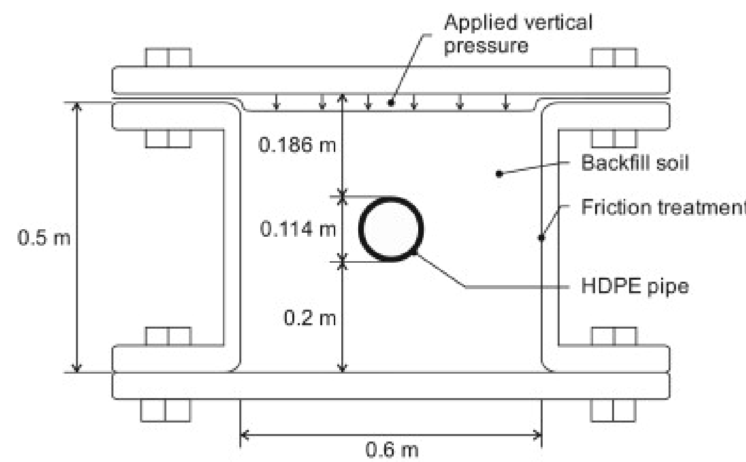
Material-Level Testing

- Povolo et al., 1996
- R.W. Bonds, 2000
- Merah et al., 2003
- Amjadi & Fatemi, 2021



System-Level Testing

- Krushelnitzky & Brachman, 2013
- Zhang et al., 2022



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Literature Review

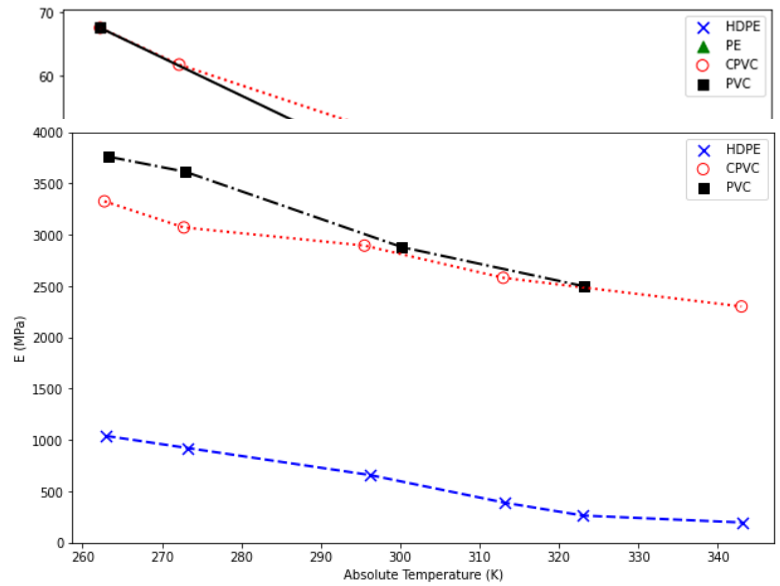
- Yield stress decreases linearly with temperature increase from 32 MPa at -10 ℃ (263.15 K) to 9 MPa at 70 ℃ (343.15 K).
- Ductile fracture is the predominant failure mechanism, with notable necking at room and higher temperatures.
- Linear correlation between yield strength of HDPE and temperature:
- Formula:

$_{ys}$ = 112.85 - 0.305T   263K T 343K

- Theoretical support from Eyring's theory of viscosity.

$_{ys}$ = H/V + R/V ln(/A)T

* Reference: Adapted from Merah et al., 2003; R.W. Bonds, 2000; Povolo et al., 1996.



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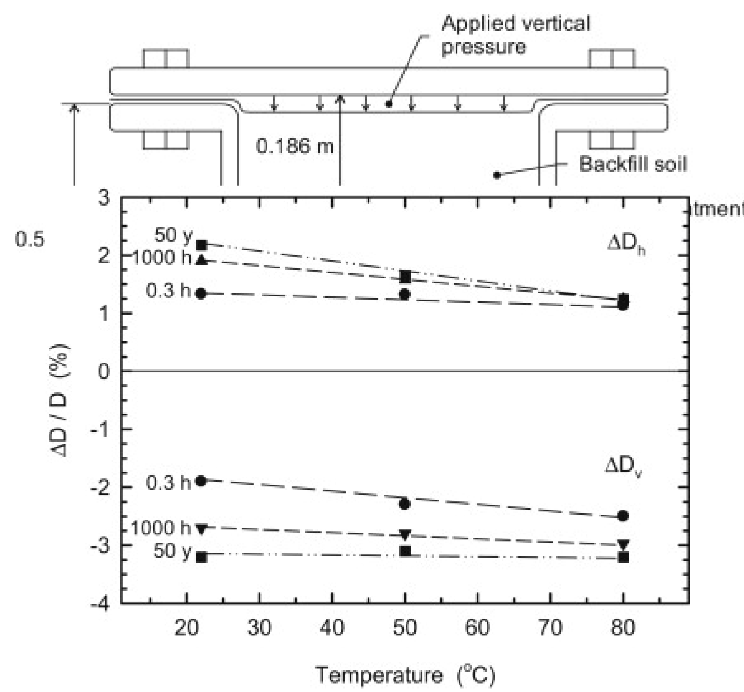
Literature Review

Krushelnitzky & Brachman, 2013

- Significant findings indicate HDPE pipe deflections increase with temperature.
- The study observed vertical deflections in sand-backfilled HDPE pipes increase by 1.3 times when temperature rose from 22°C to 80°C.
- This increase in deflection is attributed to greater circumferential compression at higher temperatures.
- Even under prolonged pressure for 1000 hours, vertical pipe deflections continued to rise, although at a slower rate.



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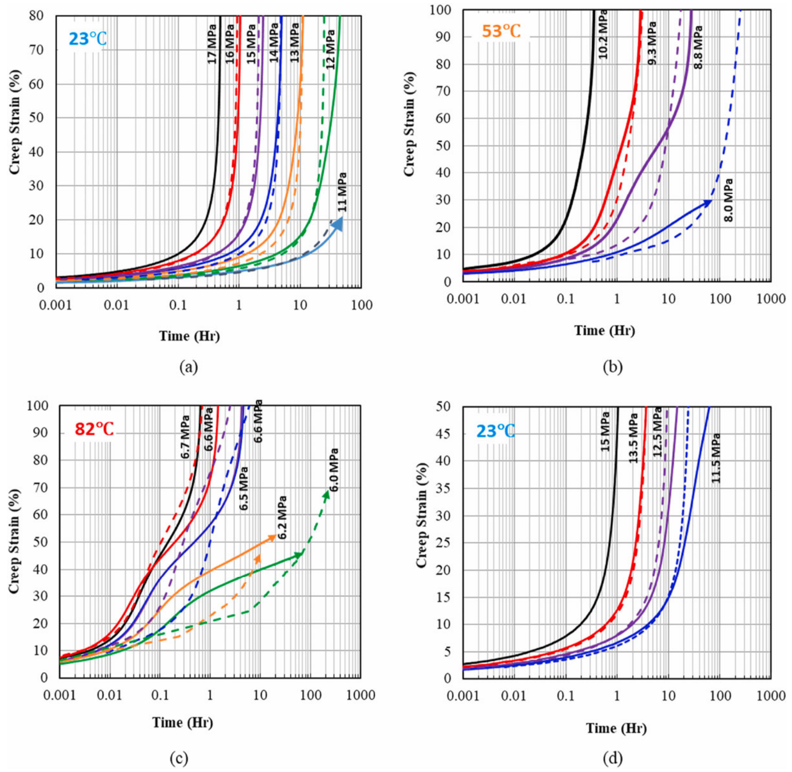
Literature Review

Amjadi & Fatemi, 2021

- The study revealed a decrease in creep strength and an increase in both creep strain and strain rate with rising temperature.
- The Larson-Miller parameter, typically used for metals, effectively correlated the time to rupture, stress, and temperature data for HDPE.
- The Monkman-Grant relation and the Findley power law were successfully applied to model the HDPE's creep behavior.
- The research also included longer-term creep tests at room temperature, validating the extrapolation accuracy of short-term creep results to predict longer-term creep life.



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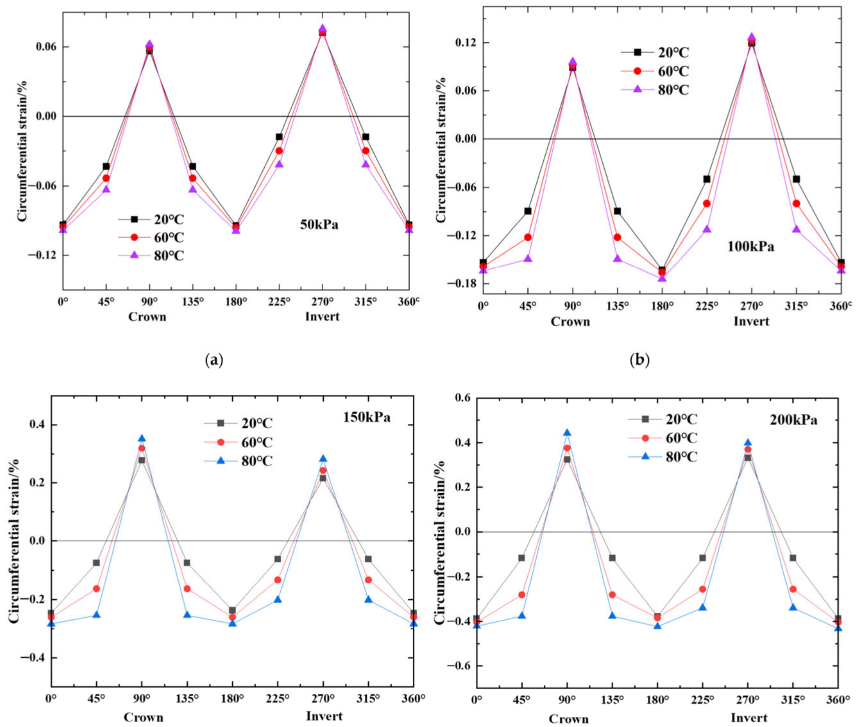
Literature Review

Zhang et al., 2022

- Sequential pressure and temperature variations impact deformation and strain in HDPE pipes.
- Findings suggest alterations in pipe deformation and strain distribution under environmental stress.
- Emphasizes the importance of understanding soil stiffness around HDPE pipes.



(a) (b) (c) (d)

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Research Gap

- Limited data of HDPE and PP pipes' mechanical properties during and after exposure to elevated temperatures.
- Limited research on HDPE and PP pipes under shallow covers with static and dynamic loads after exposure to high temperatures.
- Lack of design equations for HDPE and PP pipes considering elevated temperatures.
- Need for guidelines on the thermal interaction between adjacent HDPE and PP pipes.

Objectives

- To investigate the mechanical properties of HDPE and PP pipes across a range of temperatures.
- To examine the response of HDPE and PP pipes under varying loads when installed under shallow cover.
- To develop and validate a full-scale finite element model for HDPE and PP pipes under shallow cover, incorporating a parametric study with traffic load simulations.
- To develop design equations for HDPE and PP pipes that factor in elevated temperatures.
- To establish guidelines for the thermal interaction between closely installed HDPE and PP pipes.

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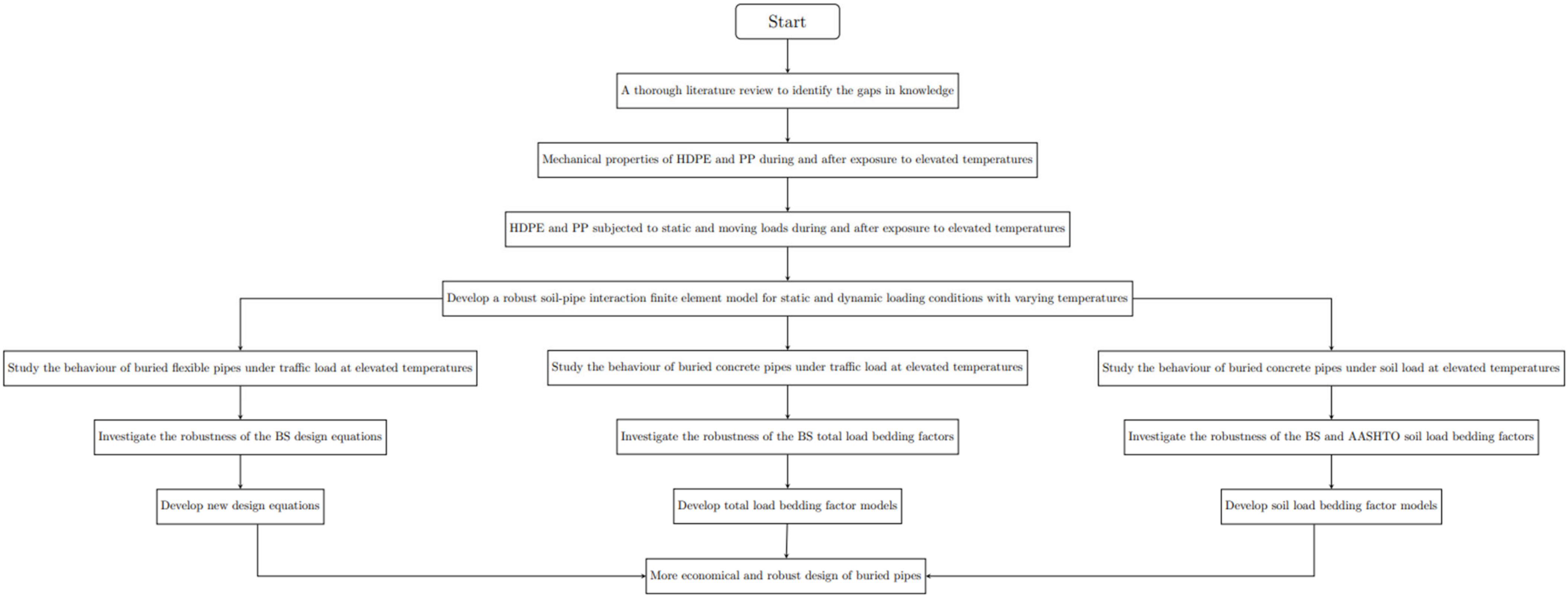

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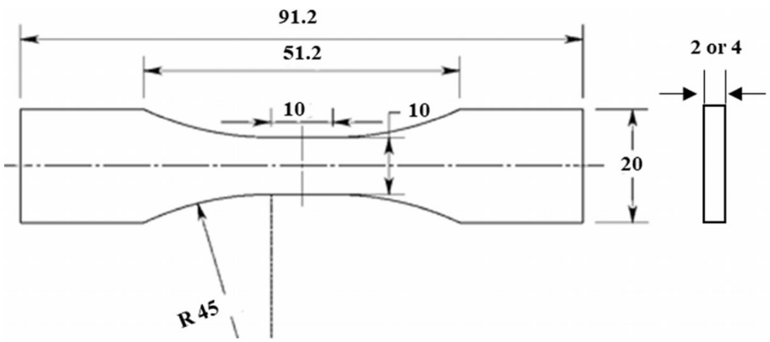
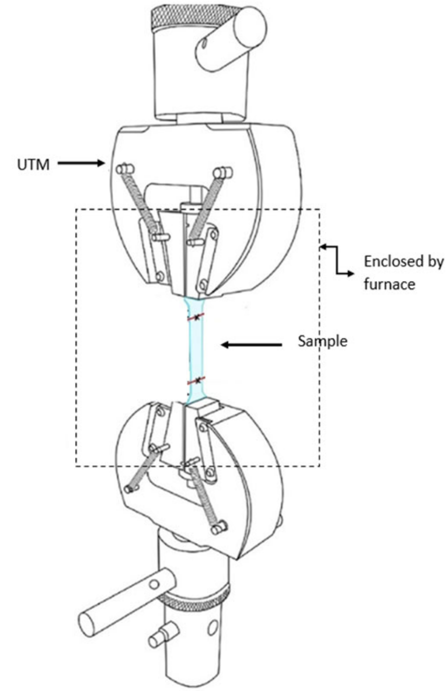
Materials and Methods

1-Material-Level Testing

- Coupons will be subjected to tensile testing while being heated.
- Coupons will undergo tensile testing after cooling from elevated temperatures.





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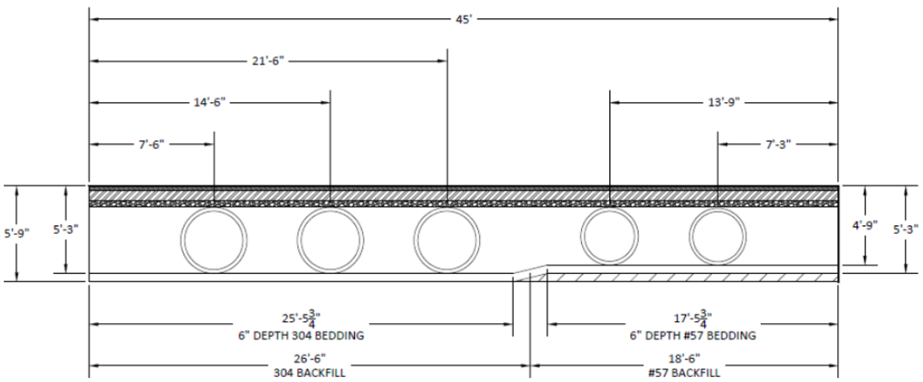
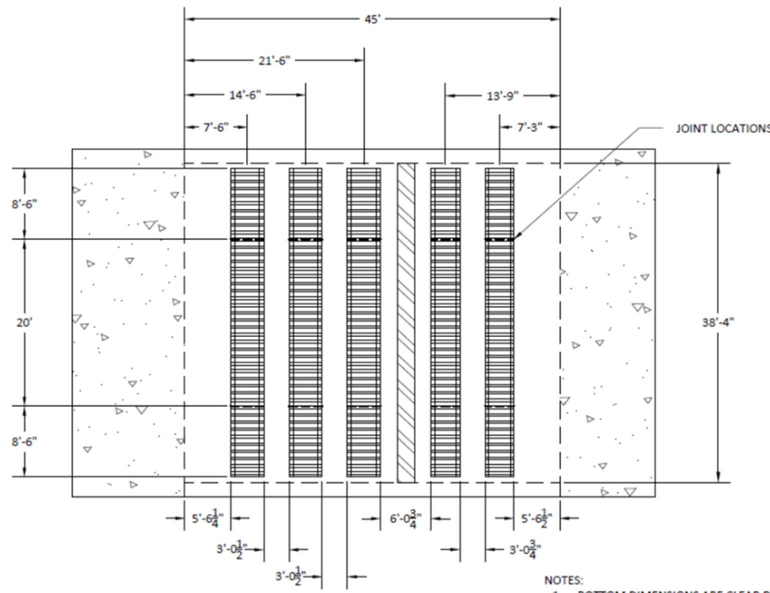
Materials and Methods

2-System-Level Testing at the APLF Facility of Ohio University, Lancaster Campus

PIPE INFORMATION				
Pipe	Pipe type	Pipe material	Outer diameter (in)	Bedding material
A	N12	HDPE	42	ODOT Item 304
B	N12	HDPE	42	ODOT Item 304
C	HP Storm	Polypropylene	42	ODOT Item 304
D	N12	HDPE	36	AASHTO #57
E	HP Storm	Polypropylene	36	AASHTO #57



NOTES:
1. 1:4 BEDDING SLOPE PICTURED, BASED ON 2-0" CLEAR DISTANCE TO PIPES.
2. TOP OF ASPHALT TO BE LEVEL WITH CONCRETE SLAB ON PIT WALLS.
3. HATCHED BEDDING REPRESENTS EXISTING SOIL



NOTES:
1. BOTTOM DIMENSIONS ARE CLEAR DISTANCE B/W EXTERIOR CORRUGATION WALL.
2. PIPE LENGTH DIMENSIONS BASED ON 8" CLEAR DISTANCE TO WALL. ADJUST AS NEEDED.
3. SLOPED AREA INDICATED BY CROSS-HATCH.

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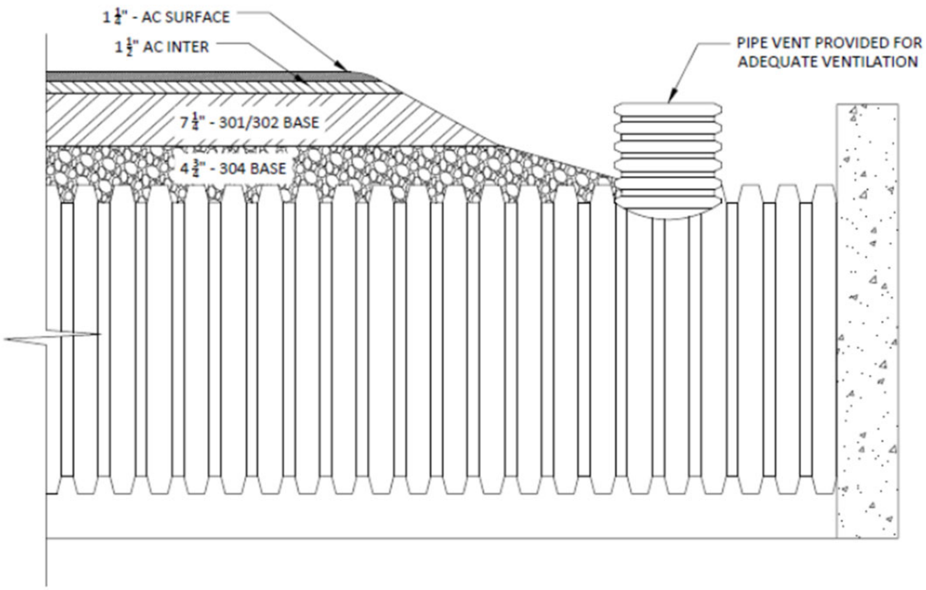
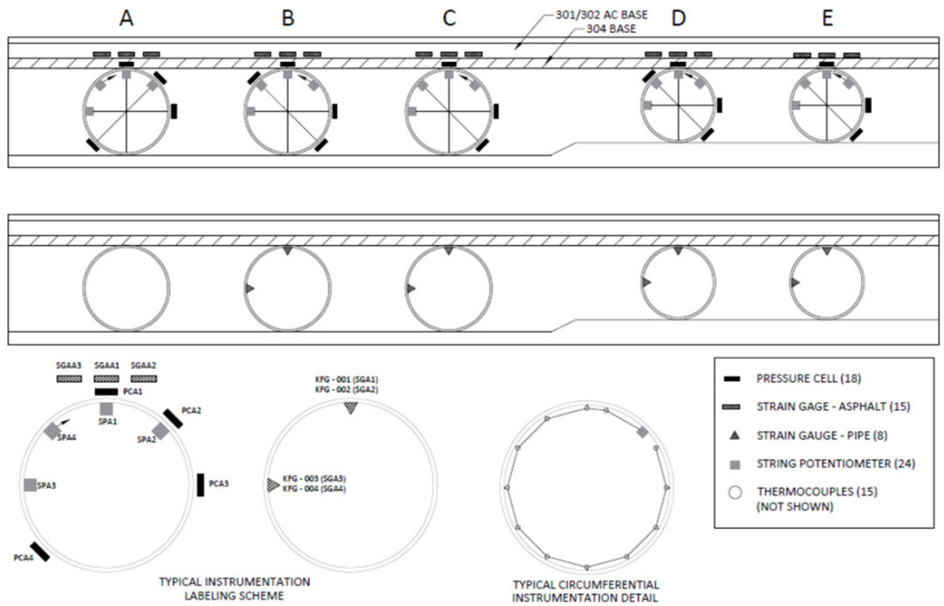
Materials and Methods





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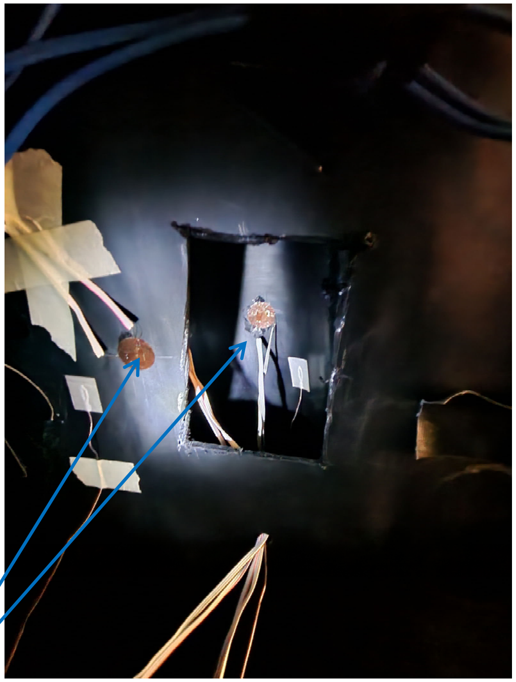
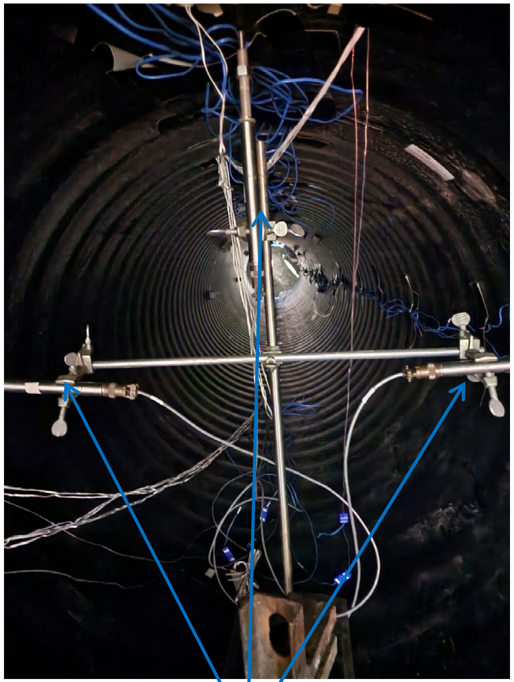
Instrumentation Setup





Propane Gas Heater

Strain Gauges

LVDTs

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Materials and Methods

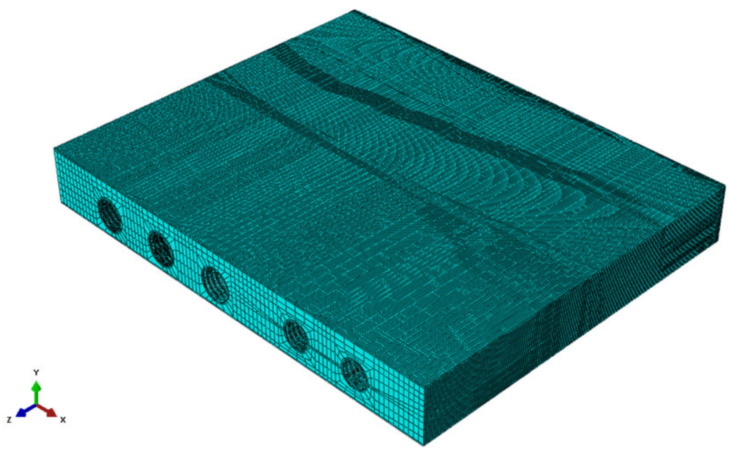
No.	Layer	Material	Parameter: Unit weight (kg/m^3)	Elastic modulus (MPa)	Poisson's ratio	Damping ratio, $\zeta = 0.05$: α	β
1	AC surface course	SMA13	2,400	Viscoelastic[a]	0.30	0.342	0.0069
2	AC middle course	SBS-AC20	2,400	Viscoelastic[a]	0.30	0.342	0.0069
3	AC bottom course	HE-AC5	2,300	Viscoelastic[a]	0.35	0.342	0.0069
4	Semi-rigid base	CTB	2,100	14,000	0.25	0.342	0.0069
5	Semi-rigid subbase	CTB	2,100	14,000	0.25	0.342	0.0069
6	Cement-stabilized subgrade	CS	1,900	6,000	0.35	0.342	0.0069
7	Natural soil	In-place soil	1,800	120	0.40	0.342	0.0069

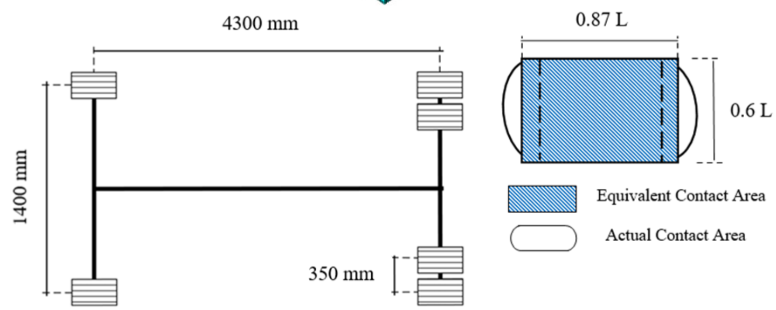
Inputs parameters for defining viscoelastic behavior of each asphaltic layer at 10°C

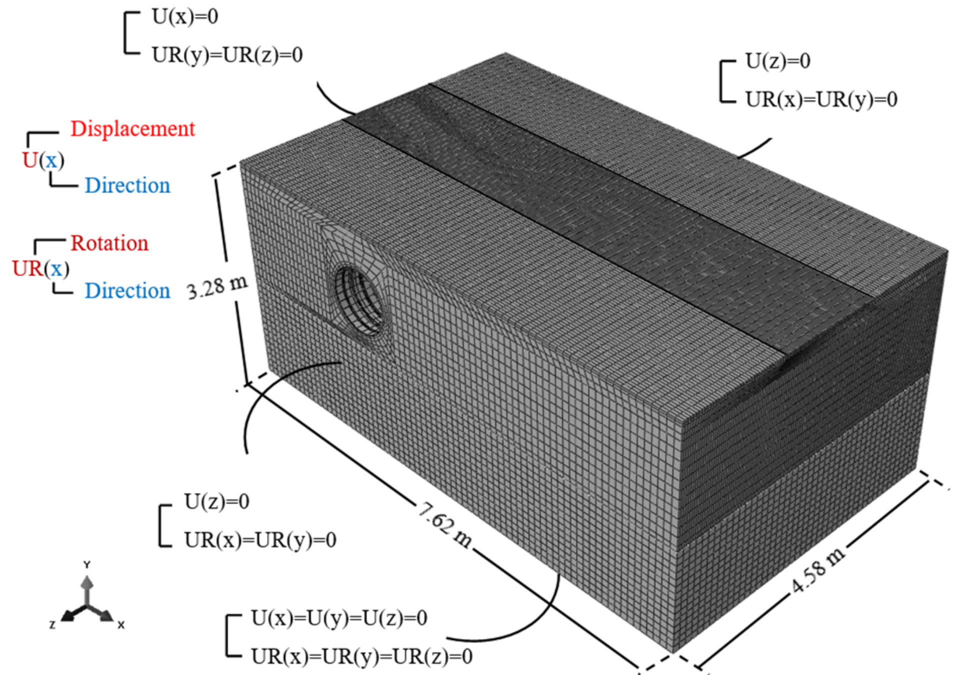
No.	SMA13 τ_i	SMA13 G_i	SBS-AC20 τ_i	SBS-AC20 G_i	HE-AC5 τ_i	HE-AC5 G_i
	Prony–Dirichlet series for generalized Maxwell model					
1	1.947×10^{-5}	1.593×10^{-1}	1.003×10^{-4}	1.519×10^{-1}	2.921×10^{-5}	2.019×10^{-1}
2	7.661×10^{-4}	1.681×10^{-1}	3.440×10^{-3}	1.326×10^{-1}	9.227×10^{-4}	2.113×10^{-1}
3	3.968×10^{-2}	2.089×10^{-1}	1.651×10^{-1}	1.884×10^{-1}	3.689×10^{-2}	1.775×10^{-1}
4	1.004×10^{0}	2.022×10^{-1}	2.472×10^{0}	2.603×10^{-1}	1.248×10^{0}	1.797×10^{-1}
5	2.267×10^{1}	1.776×10^{-1}	4.009×10^{1}	1.789×10^{-1}	6.323×10^{1}	1.499×10^{-1}
6	1.279×10^{3}	8.091×10^{2}	2.857×10^{3}	6.813×10^{-2}	3.399×10^{3}	7.165×10^{-2}
	Elastic modulus for viscoelasticity (moduli time scale is instantaneous)					
	10,000		15,000		6,500	
	Williams–Landel–Ferry equation constants					
C1	23.74		27.061		25.44	
C2	177.80		222.90		198.80	
RMSE	0.11		0.02		0.07	

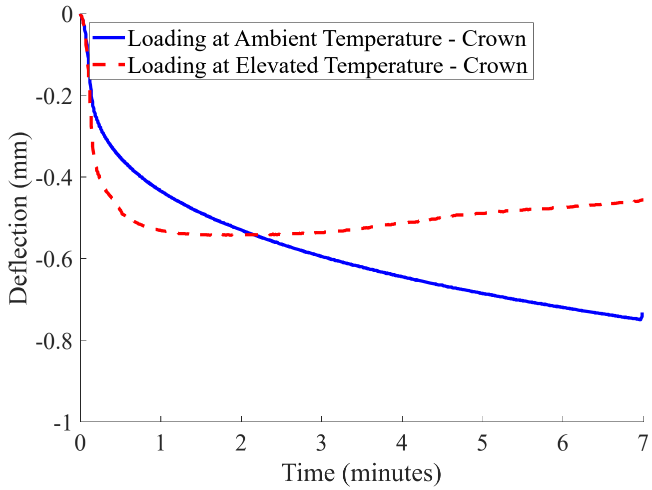
Note: No. = number of Prony–Series; τ = relaxation time; and G = dimensionless relaxation modulus.

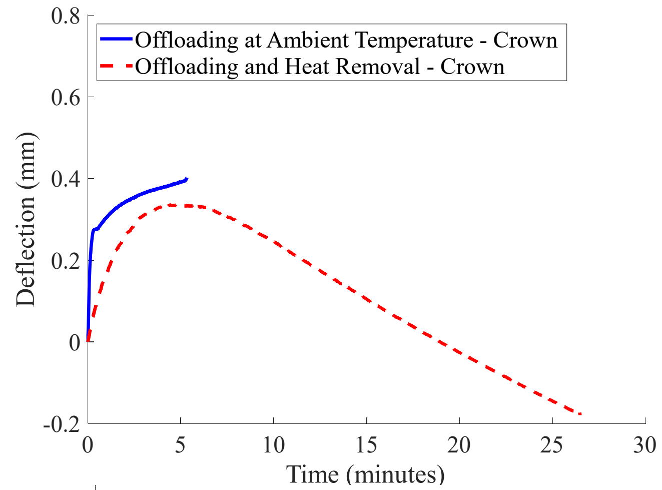
Finite Element Modeling

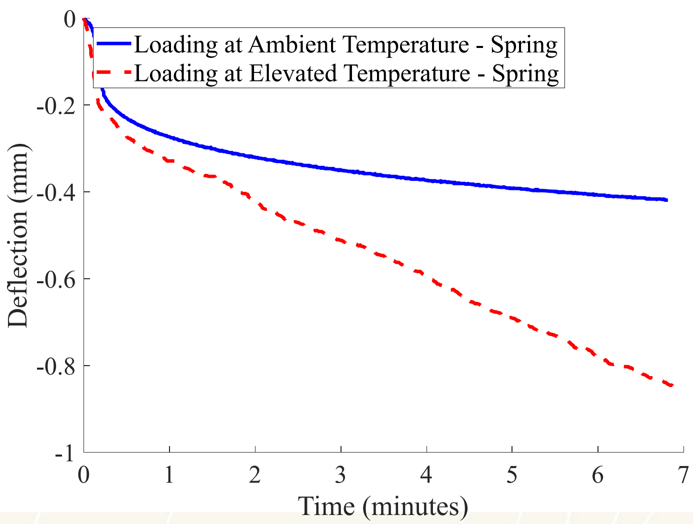


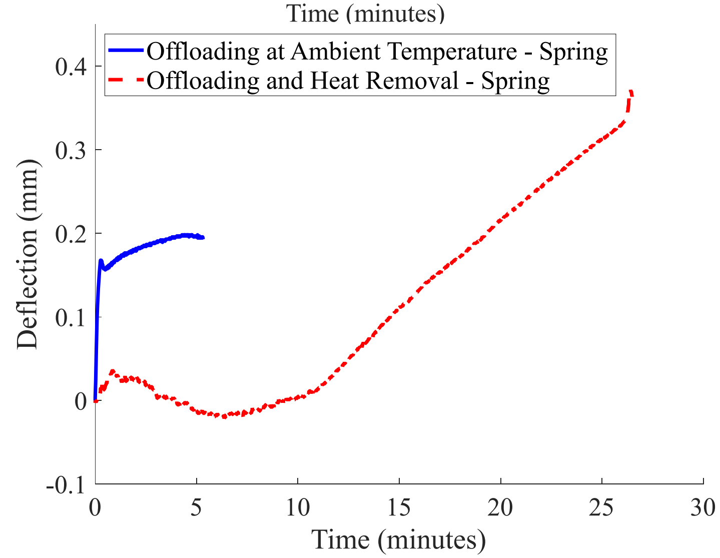




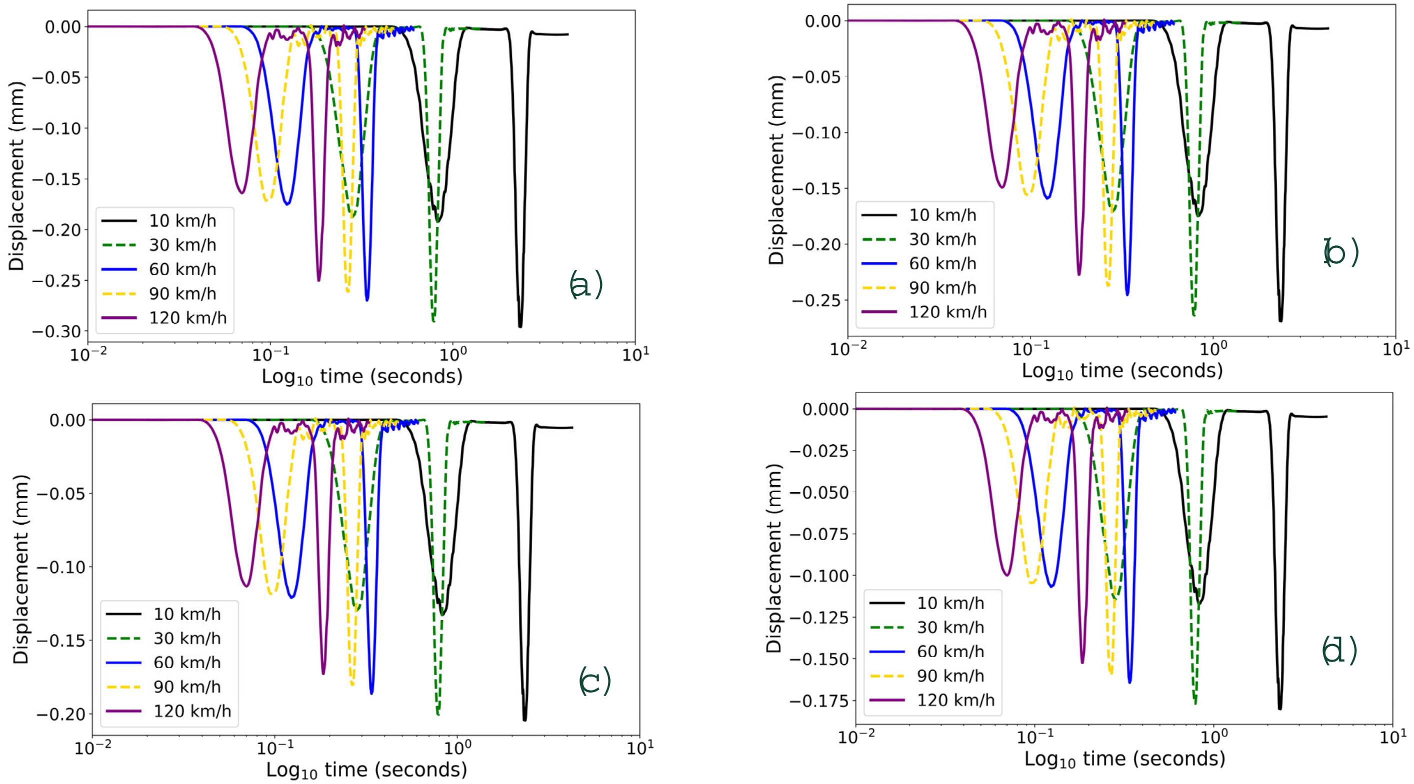

Loading at Ambient Temperature - Crown
Loading at Elevated Temperature - Crown
Deflection (mm)
Time (minutes)
0
-0.2
-0.4
-0.6
-0.8
-1
0 1 2 3 4 5 6 7


Offloading at Ambient Temperature - Crown
Offloading and Heat Removal - Crown
Deflection (mm)
Time (minutes)
0.8
0.6
0.4
0.2
0
-0.2
0 5 10 15 20 25 30


Loading at Ambient Temperature - Spring
Loading at Elevated Temperature - Spring
Deflection (mm)
Time (minutes)
0
-0.2
-0.4
-0.6
-0.8
-1
0 1 2 3 4 5 6 7


Offloading at Ambient Temperature - Spring
Offloading and Heat Removal - Spring
Deflection (mm)
Time (minutes)
0.4
0.3
0.2
0.1
0
-0.1
0 5 10 15 20 25 30

Ambient Temperature



Crown displacement versus time response under a moving truck with different truck speeds for (a) very flexible pipe (10 KN/m) (b) flexible pipe (30 KN/m) (c) semi-rigid pipe (100 KN/m) (d) rigid pipe (1000 KN/m)

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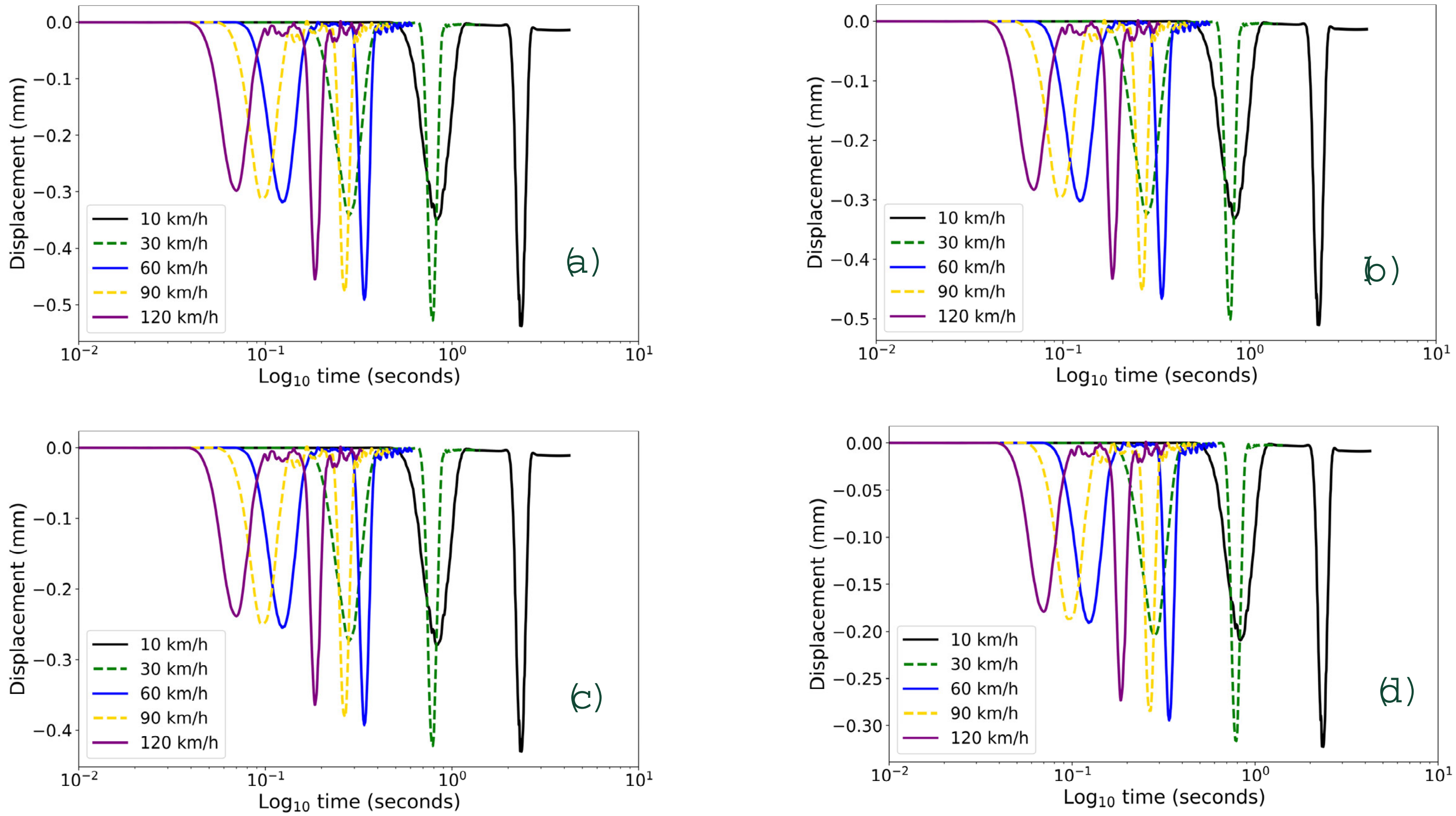
Elevated Temperature



Crown displacement versus time response at elevated temperatures under a moving truck with different truck speeds for (a) very flexible pipe (10 KN/m), (b) flexible pipe (30 KN/m), (c) semi-rigid pipe (100 KN/m), (d) rigid pipe (1000 KN/m).

Thank You!