ASCE

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Evaluation of Corrugated HDPE Pipes Manufactured with Recycled Content Underneath Railroads

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Recent Advances in Underground Pipeline Engineering & Construction

Outline

- Background information
- Field test summary and results
- Lab test summary and results
- Conclusions



Benefits of Incorporating Recycled Materials into Corrugated HDPE Pipe

- Environmental benefits
  - Cradle to grave analysis shows the largest environmental impact for pipe systems occurs during production of raw materials
- Economic benefits
  - Post-Consumer Recycled materials typically result in cost savings of up to 20% over virgin materials

Concerns with HDPE Pipe Made with Recycled Content

- Potential for compromised service life due to:
  - Variability in material stream
  - Contamination
    - Polypropylene, Rubbers, Paper labels, etc.
- Concerns with potential for fatigue related failures due to live loads



Background Information



Background Information

Dirty mixed color PCR flake

Background Information

Washed mixed color PCR flake

Background Information

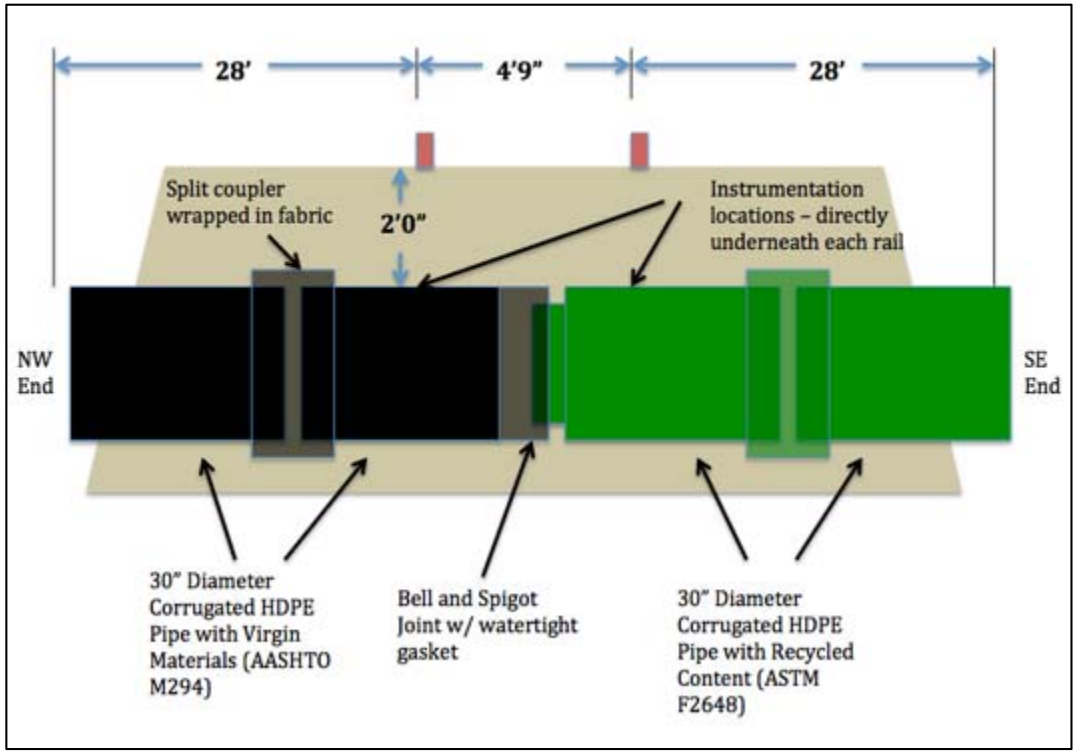
Reprocessed mixed color PCR

– this was the material used in our research project

Overview and Description of Test Protocol for Fatigue Evaluation

- Field installation underneath live railroad
  - Southeastern Pennsylvania Transportation Authority (SEPTA) regional commuter rail line
- Accelerated laboratory fatigue test on finished pipe samples

Live Load Testing under Railroads



- Both virgin and recycled 30" diameter pipes installed under SEPTA regional commuter rail
- 2.5 feet of cover to bottom of tie
- Pipes instrumented with strain gages and extensometers

Properties of Test Pipes

Property	Test Method	AASHTO M294 Pipe (Virgin)	ASTM F2648 Pipe (recycled)
Pipe plaque density	ASTM D 1505	0.963 g/cm^3	0.966 g/cm^3
Melt index	ASTM D 1238	0.12 g	0.30 g
Carbon Black %	ASTM D 1603	2.15 %	2.57 %
Flexural Modulus	ASTM D 790	152,755 psi	146,322 psi
Yield Strength	ASTM D 638	4,050 psi	4,062 psi
Pipe liner NCLS	ASTM F 2136	87.9 hrs	18.4 hrs
Pipe plaque NCLS	ASTM F 2136	106.1 hrs	13.7 hrs
Pipe Stiffness	ASTM D 2412	35.0 lb/in/in	34.28 lb/in/in
Pipe Flattening	ASTM D 2412	> 20%	> 20%
Brittleness Test	ASTM D 2444	Pass	Pass
Pipe Plaque UCTL	TRI Method	> 800 hours	99 hours
Recycled Content	TRI Method	-	49%



Live Load Testing under Railroads

Villanova University partnered with SEPTA to install some pipes as a test installation underneath one of their lines; SEPTA and NCHRP covered the installation costs, materials for the project were donated by industry

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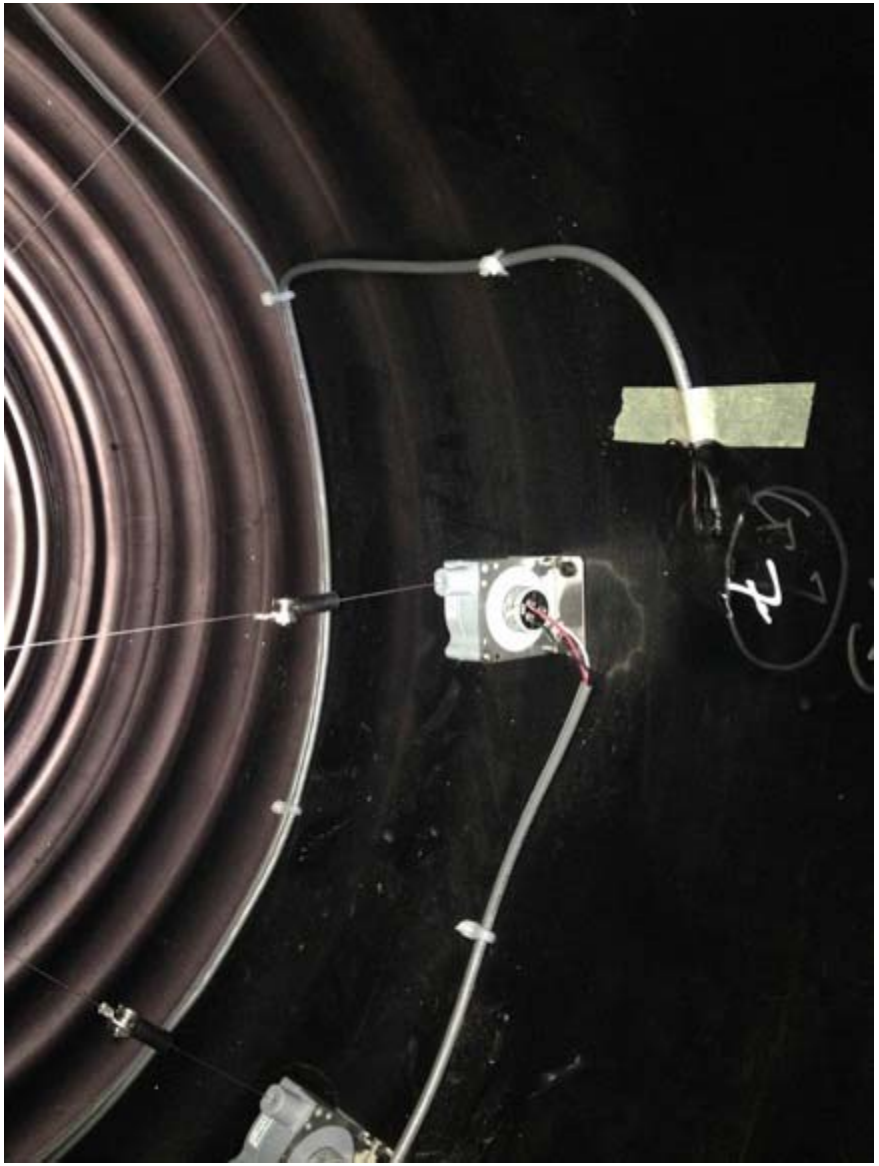

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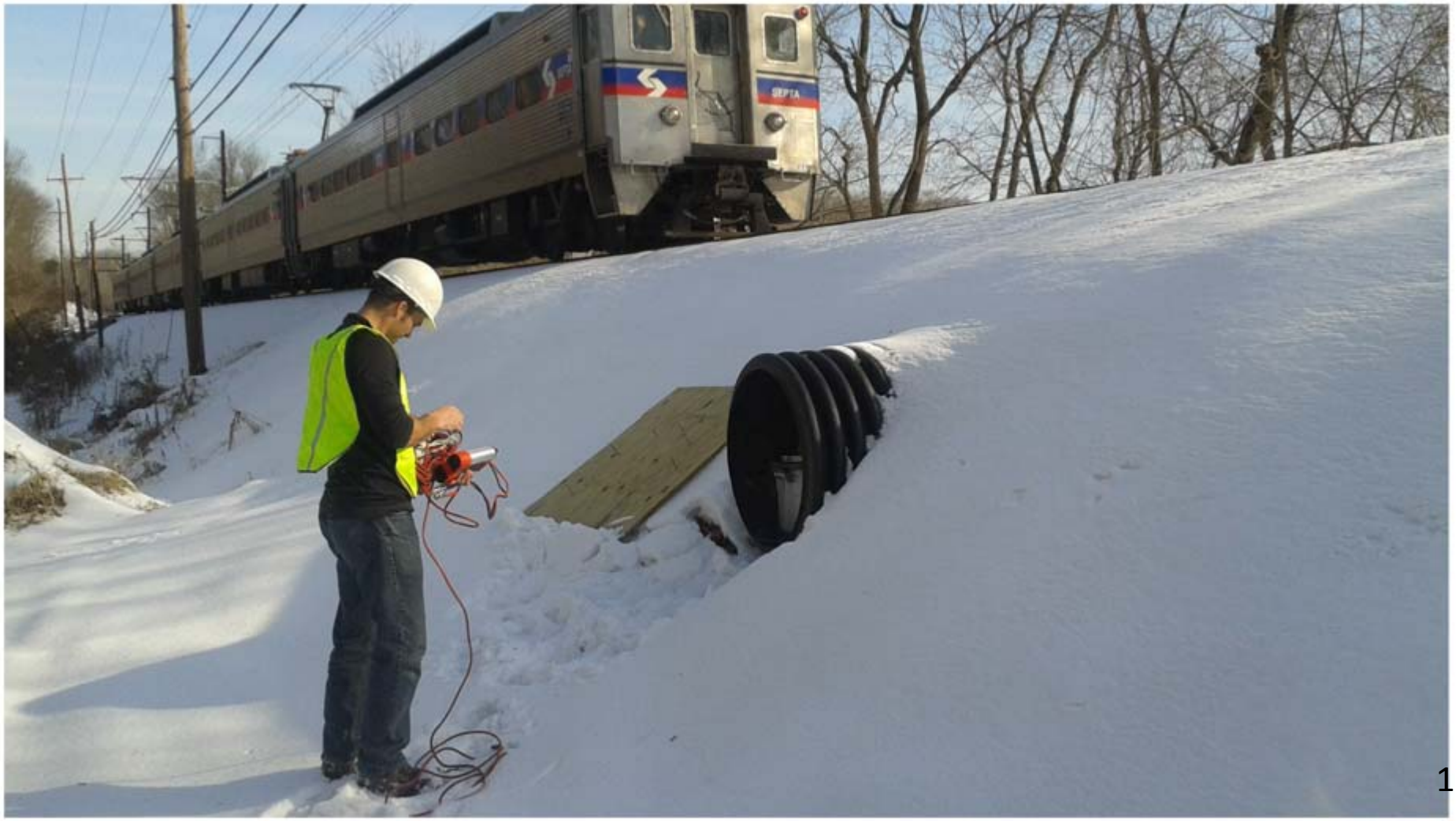

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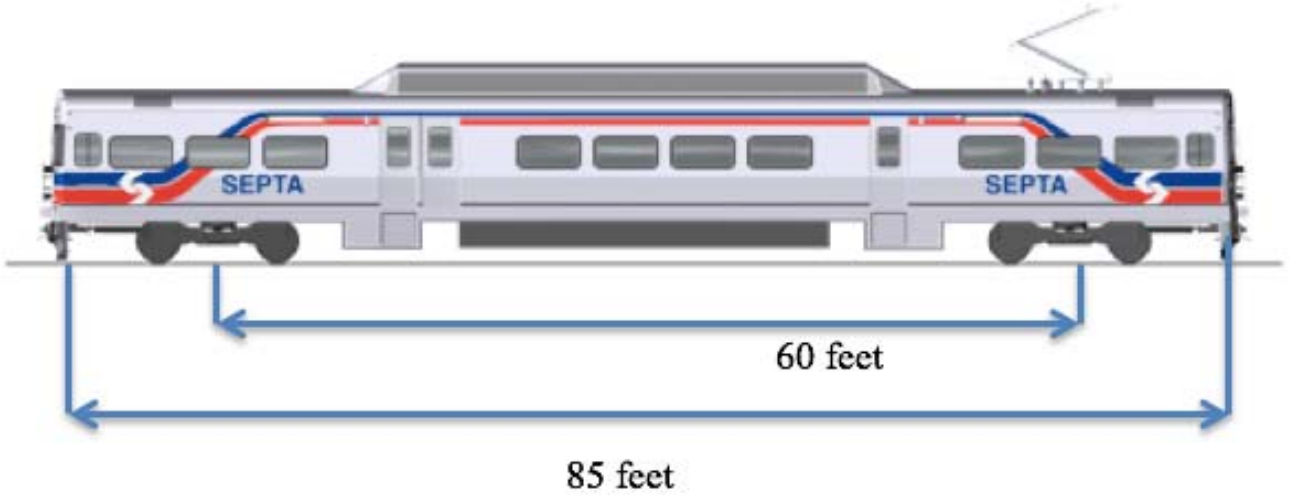
Loading Conditions

- Typical SEPTA passenger car – 109 passengers
  - 4 axles, 150,000 lb
  - Speed ~ 50 mph
- 1 - 2 trains per hour over pipe
- 3 – 6 cars per train

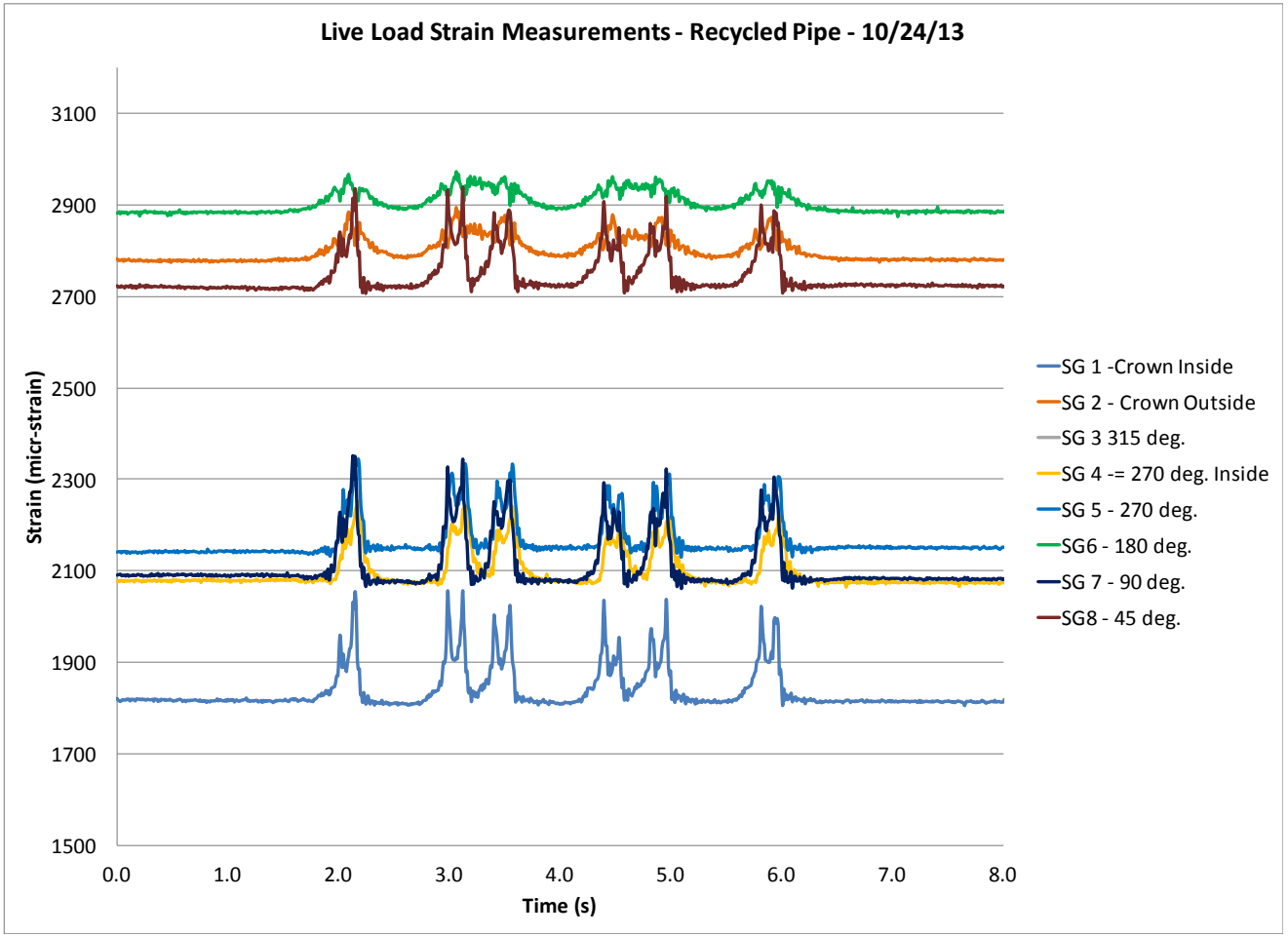




Field Test Data

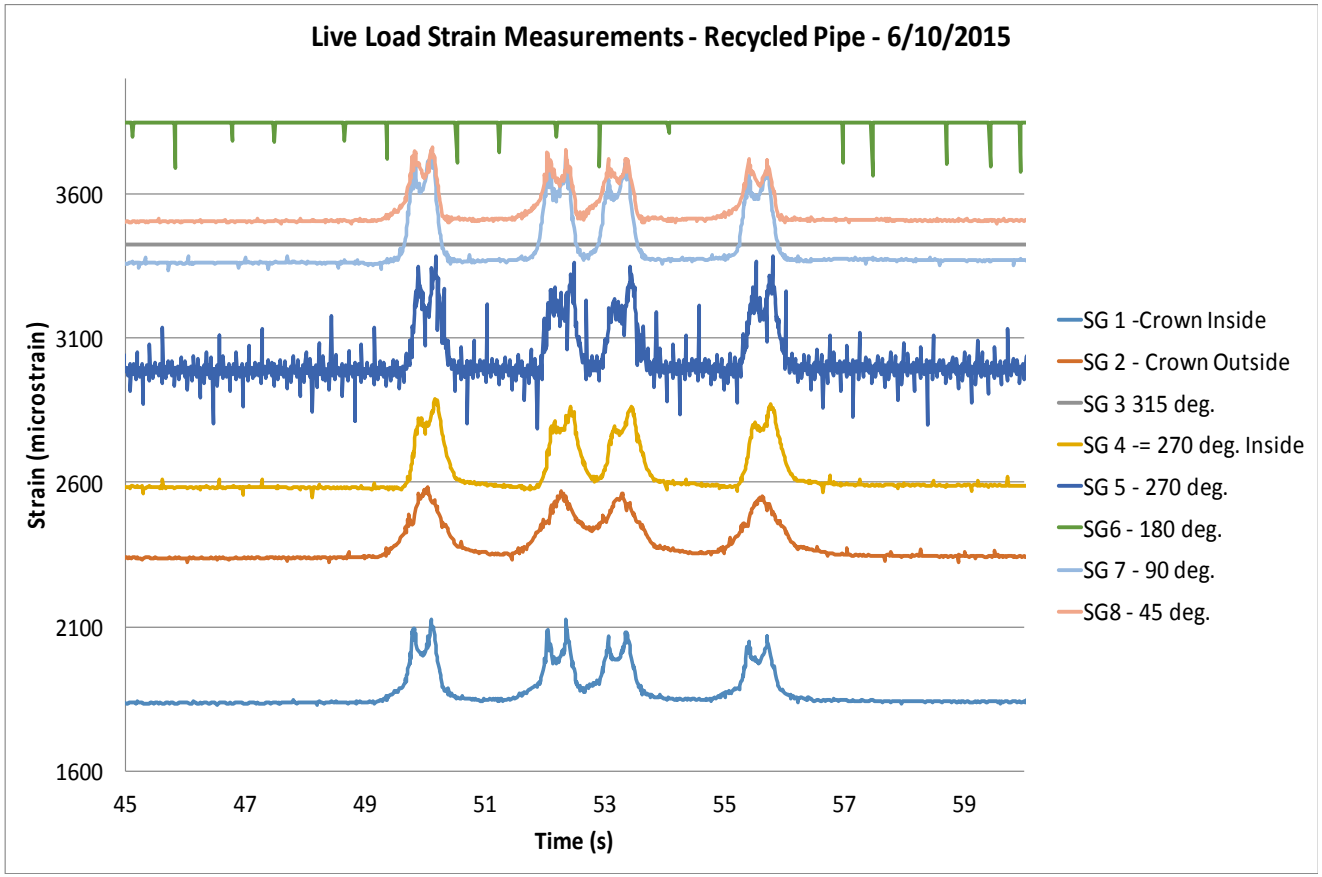
Property	AASHTO M294 Pipe (100% Virgin)		ASTM F2648 Pipe (Recycled Content)	
Initial ID (in.)	30.1		30.1	
Installed Deflection (in)	V: 30.3	H: 29.9	V: 30.3	H: 29.9
6-month Deflection (in)	V: 29.9	H: 29.8	V: 30.2	H: 29.8
1-yr Deflection (in)	V: 29.9	H: 29.8	V: 30.3	H: 29.8
Max. Peak-Peak Dynamic Defl. (in)	< 0.0200 (0.5 mm)		< 0.0200 (0.5 mm)	
Max. Peak-Peak Dynamic Strain	500 μstrain		500 μstrain	

Field Test Data – Recycled Pipe



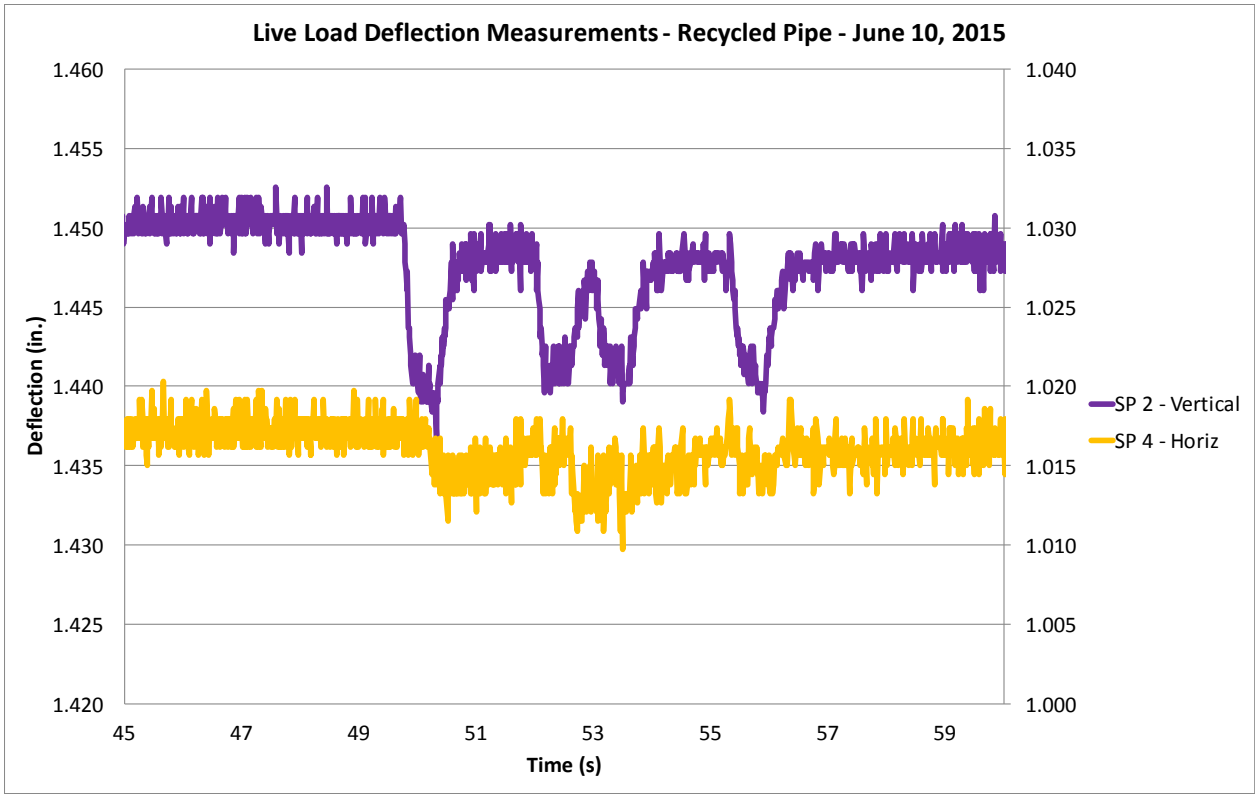
- Typical trace from 3-car train (6 trucks, 12 axles)
- Recycled Pipe
- 1 month after install
- Sampling rate = 50 Hz
- Train speed ~ 73 fps (50 mph)

Field Test Data – Recycled Pipe



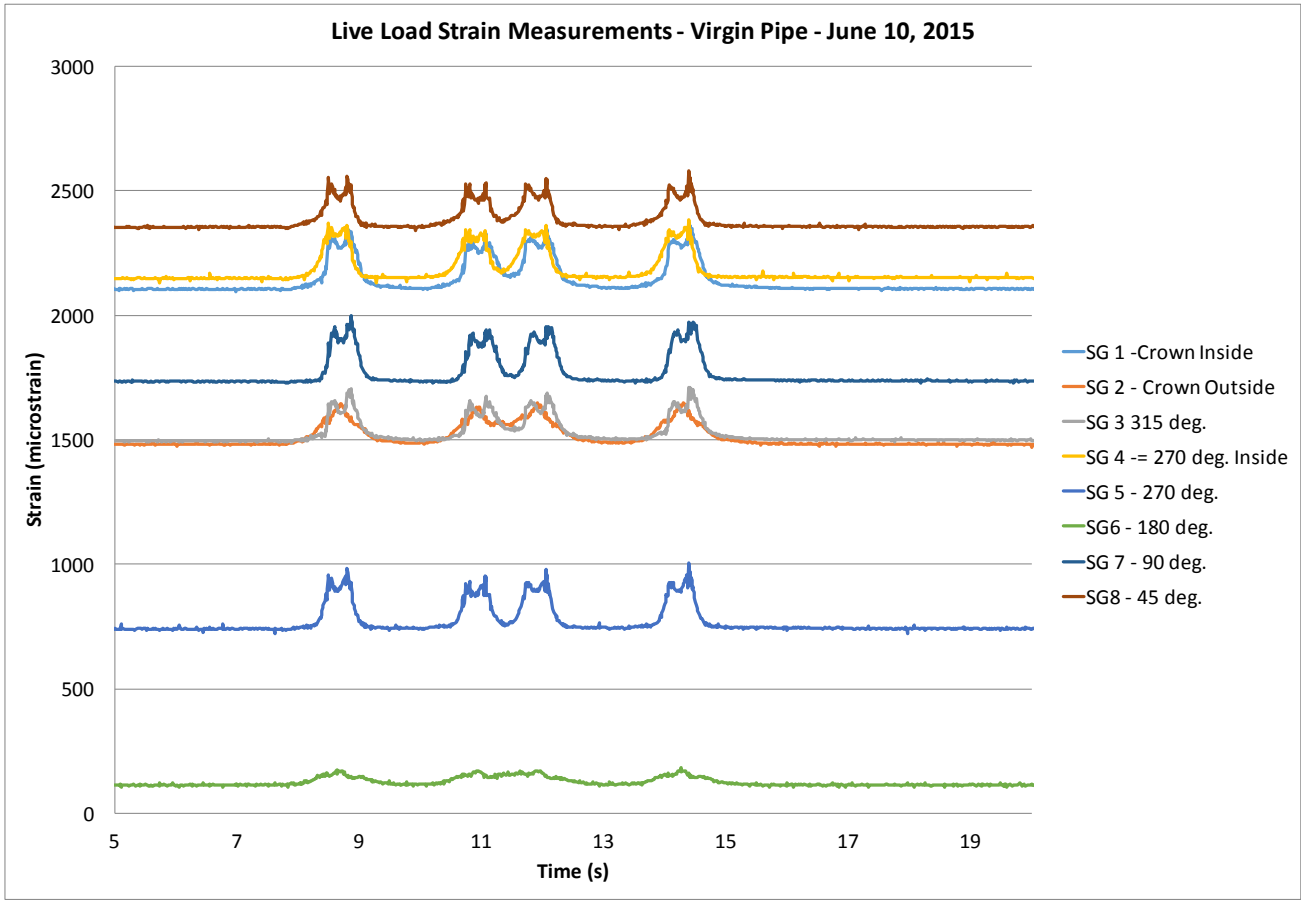
- Trace from 2-car train
- 20 months after install
- Sampling rate = 50 Hz
- Train speed ~ 50 fps (30 mph)
- No change from previous strain levels

Field Test Data – Recycled Pipe



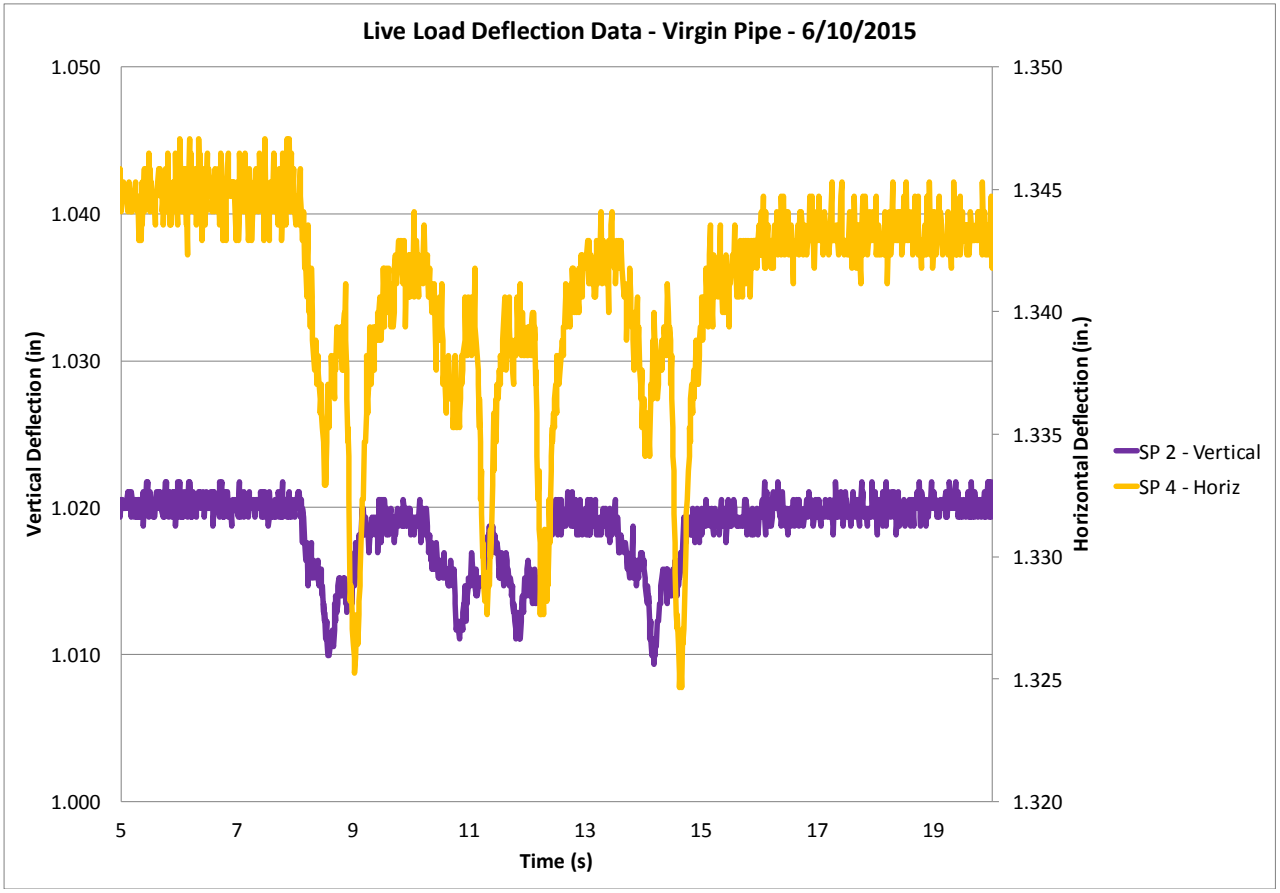
- Trace from 2-car train
- 20 months after install
- Sampling rate = 50 Hz
- Train speed ~ 50 fps (30 mph)
- No change from previous deflection levels

Field Test Data – Virgin Pipe



- Trace from 2-car train
- 20 months after install
- Sampling rate = 50 Hz
- Train speed ~ 50 fps (30 mph)
- No change from previous strain levels

Field Test Data – Virgin Pipe



- Trace from 2-car train
- 20 months after install
- Sampling rate = 50 Hz
- Train speed ~ 50 fps (30 mph)
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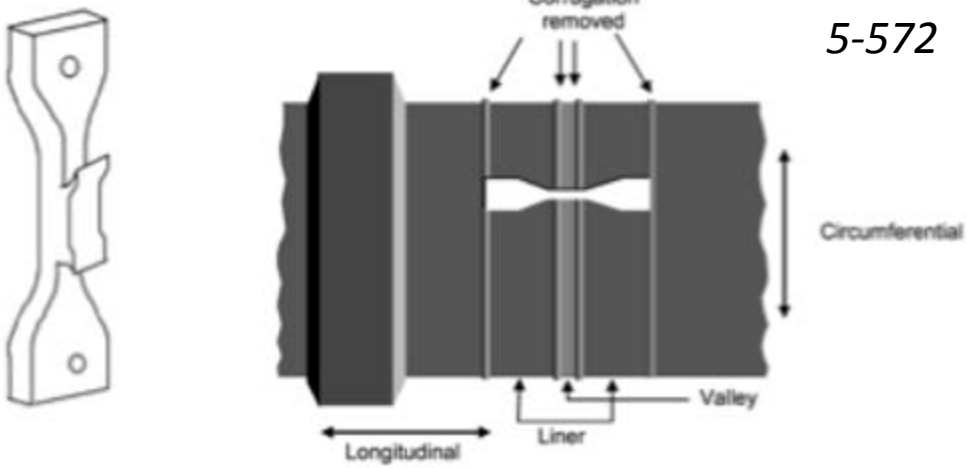
Accelerated Testing: Laboratory Study

- Development of a simplified laboratory fatigue test on finished pipe specimens
- Testing conducted on specimens taken directly from the pipe wall
- Loads and strains on pipe specimens designed to match those observed in the field study



Florida DOT (FDOT) Junction Specimens

- Used standard FDOT junction test specimens for cyclical test

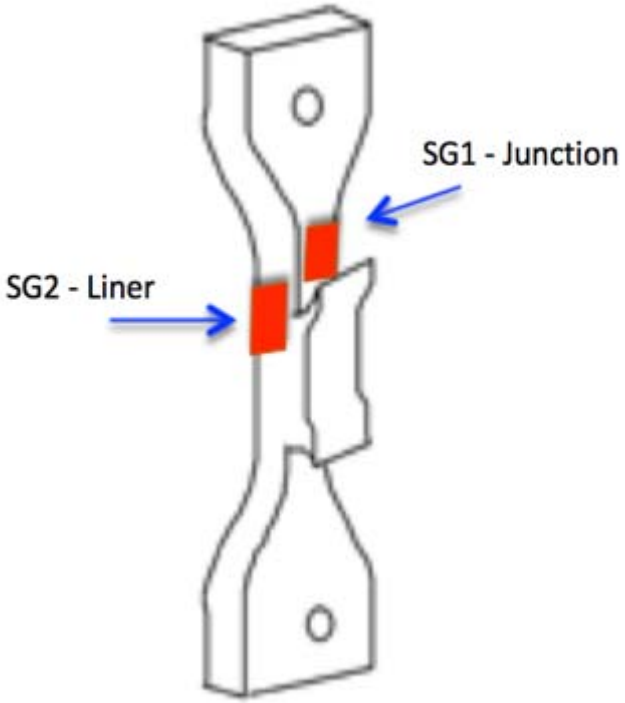


Source: FDOT FM 5-572

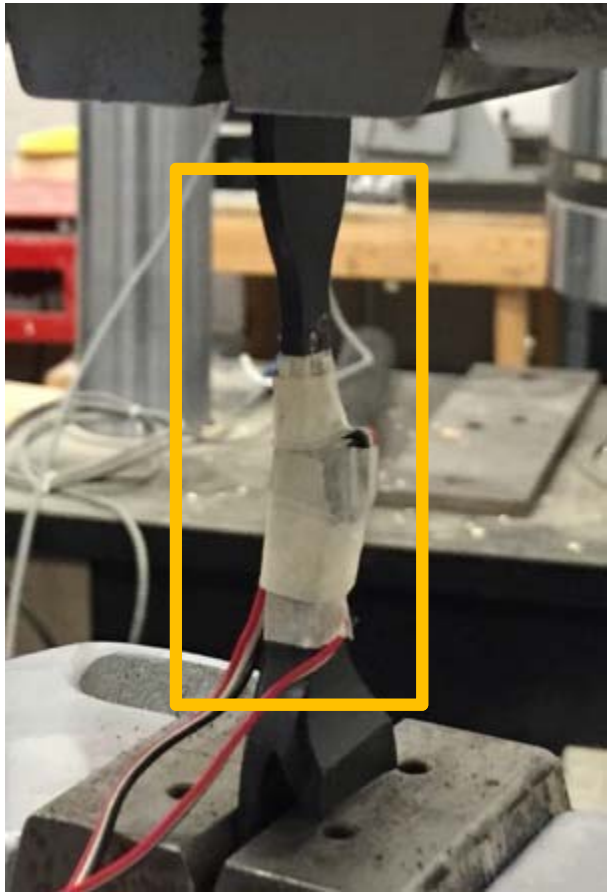


FDOT Junction Test Specimens (FM 5-572)

Villanova University Fatigue Test

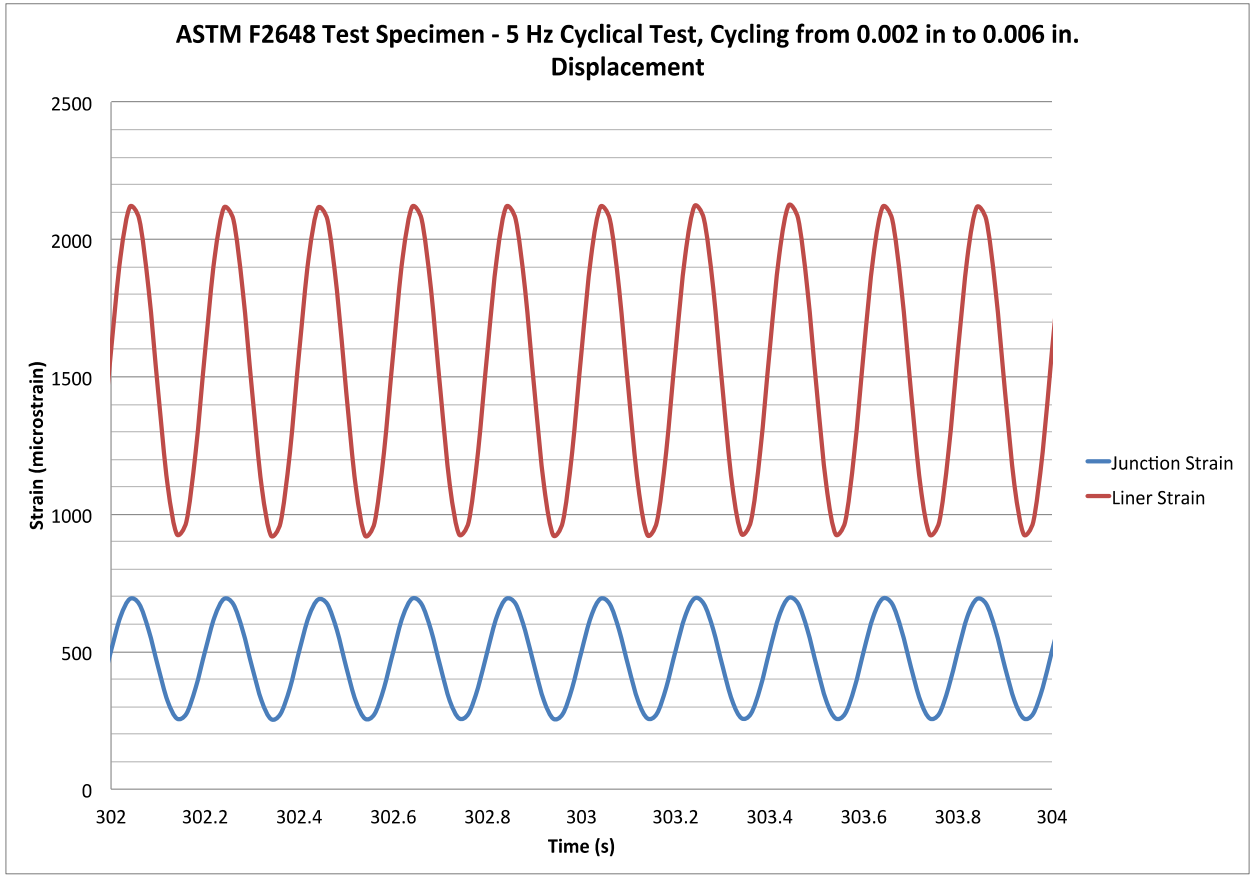


Fatigue Test Protocol



- Cycled specimens in MTS tester at a loading frequency of 5 Hz
  - Complete 1 million cycles in 2.5 days
  - Approximates 10 years service
  - Field frequency during train event:
    - ~ 1.5 Hz between trucks,
    - ~ 10 Hz between individual axles
- Displacement controlled test to match field-measured strains
- Observe specimens for macro cracking and micro cracking

Lab Test Data



- Measured strains on lab specimens <u>tested to twice</u> those measured in field pipe
- 0.004 inch displacement = 1200 microstrain
- Max Peak – peak field observed strain < 500 microstrain

Fatigue Testing Results

- > 2 million cycles with no failures
- First 1 million cycles at 1200 microstrain amplitude
- Second million cycles at 3000 microstrain amplitude
- Noticed downward drift in mean strain readings, but amplitude stayed constant
- No difference in lab test results between virgin and recycled materials

Conclusions

- No observed differences between pipes made with recycled materials vs. virgin resin to date
  - Both in lab and in field
- Pipes performing well in the field under commuter rail line with very shallow cover after nearly 2 years service
- Laboratory fatigue test indicates no concerns with fatigue related failures

Recommendations for Future Research

- Investigate the maximum strain capacity of pipes made with recycled materials with regards to fatigue loading
  - Helpful for understanding behavior under other loading conditions (e.g. freight cars or poor installation conditions)
- Evaluate additional blends of materials



THANK YOU!!