Full-Scale Test of Thermally-Induced Reflective Cracking: 5-Year Research at The FAA NAPTF

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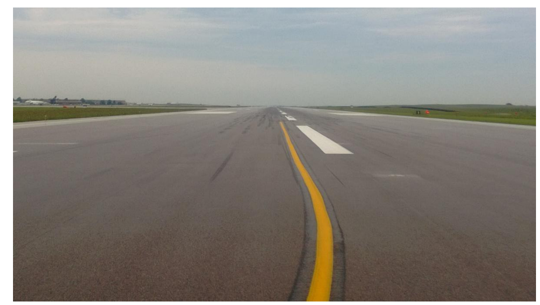


Date: Aug 6, 2014

Outline

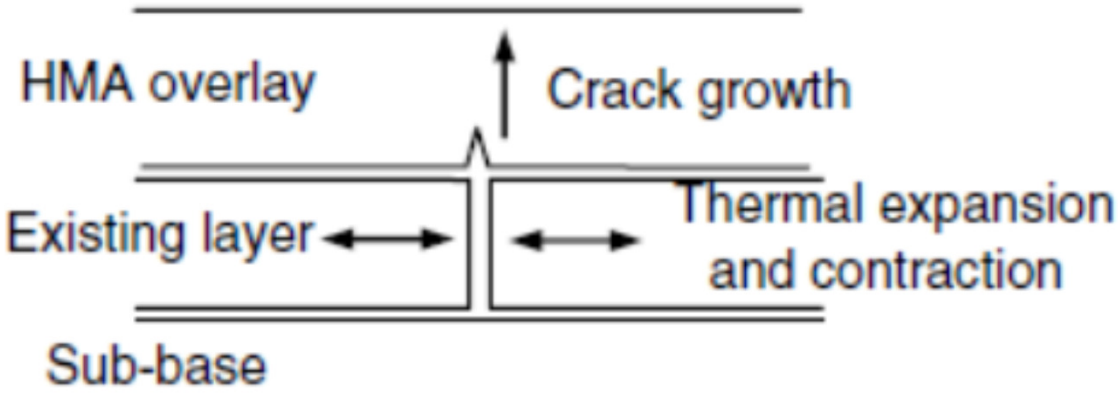
- Research needs
- Project overview (2009-2014)
  - Preliminary study
  - Temperature Effect Simulation System
  - Phase I, II, III tests
- Lessons learned
  - Advanced computational mechanics
  - Instrumentation
  - Material characterization
  - Construction

Research Needs

AC 150/5320-6D

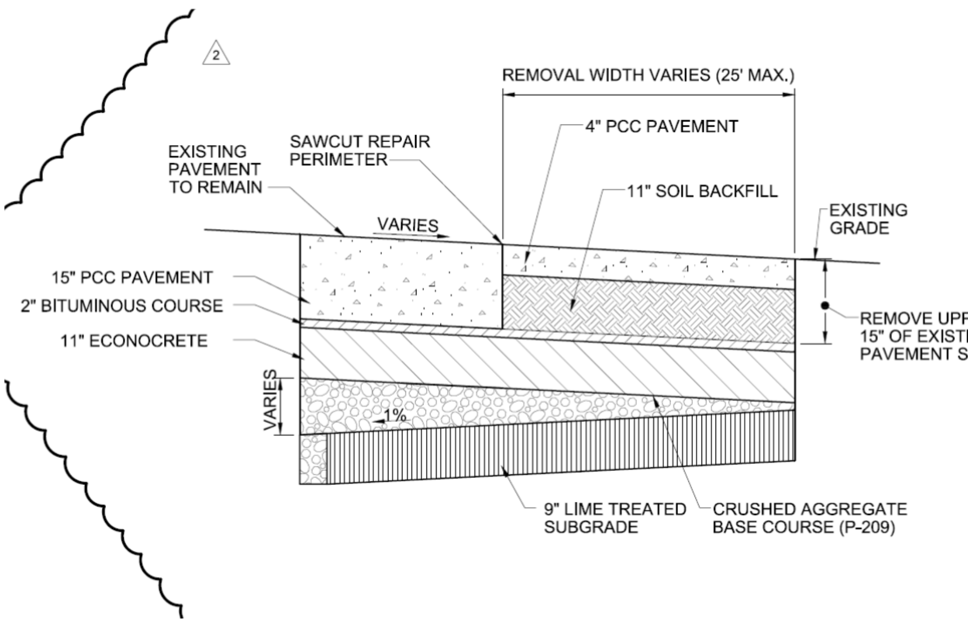
AC 150/5320-6E

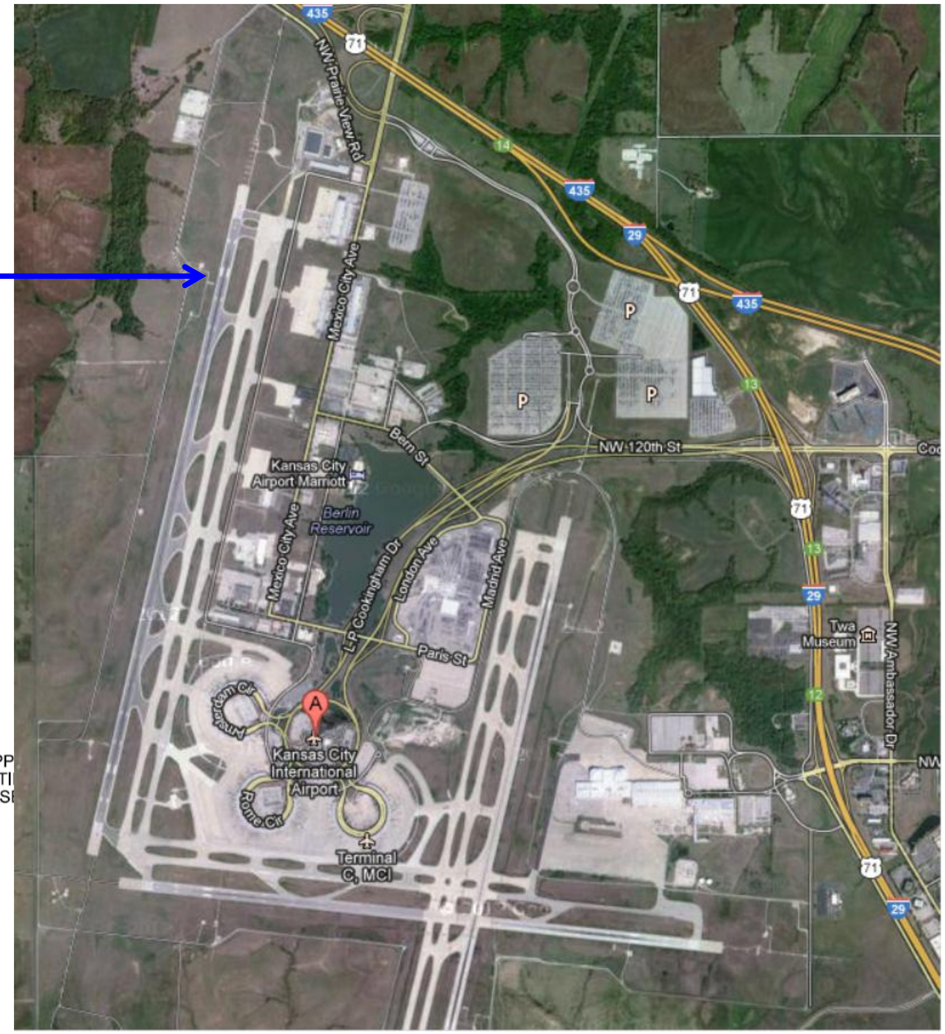
$$P = f(X_1, X_2, X_3, \ldots)$$



Kansas City Int’l Airport

Runway 1L-19R





2011 Rehabilitation

1. Removal (milling) 4” P-501 PCC
2. Crack seal with P-604
3. Placement of 4” P-401 HMA overlay
   - P-603 tack coat
   - Two 2-in lifts
4. Closure for HMA cure
5. Removal of FOD and debris
6. Open for traffic

2013 Distress Survey

Project Overview

Preliminary Study (2009-2010)

Examine the feasibility of substituting temperature load mechanically

↓

TESS (2010-2011)

Temperature Effect Simulation System

↓

Phase I Test (2011-2012)

Understand the mechanism of thermally-induced reflective cracking

↓

Phase II Test (2012-2013)

Determine if reflection cracks propagate roughly 1 inch per year

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Phase III Test (2013-2014)

Evaluate the effectiveness of Strain Relieving HMA Interlayer to mitigate thermally-induced reflection cracks

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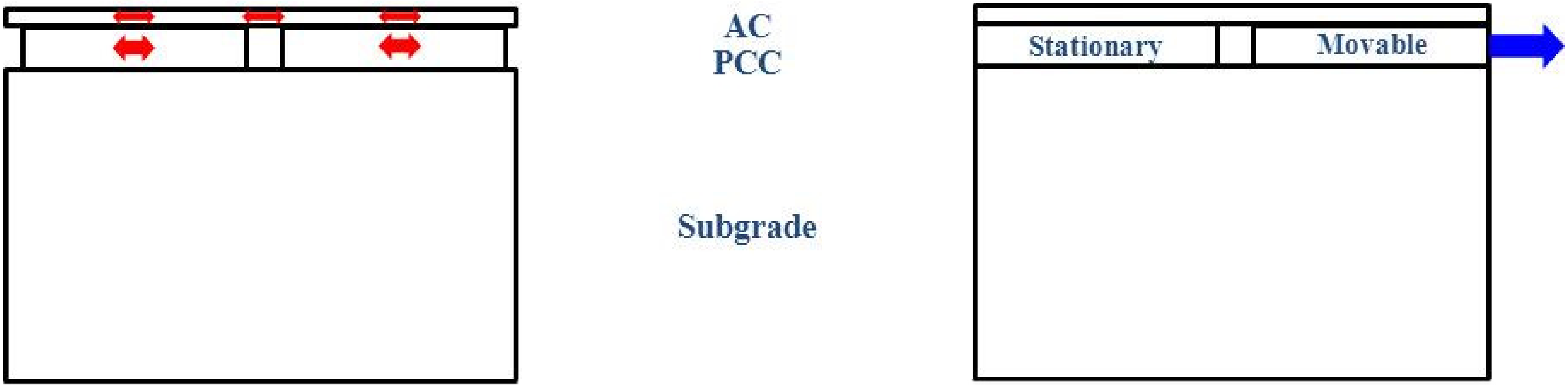
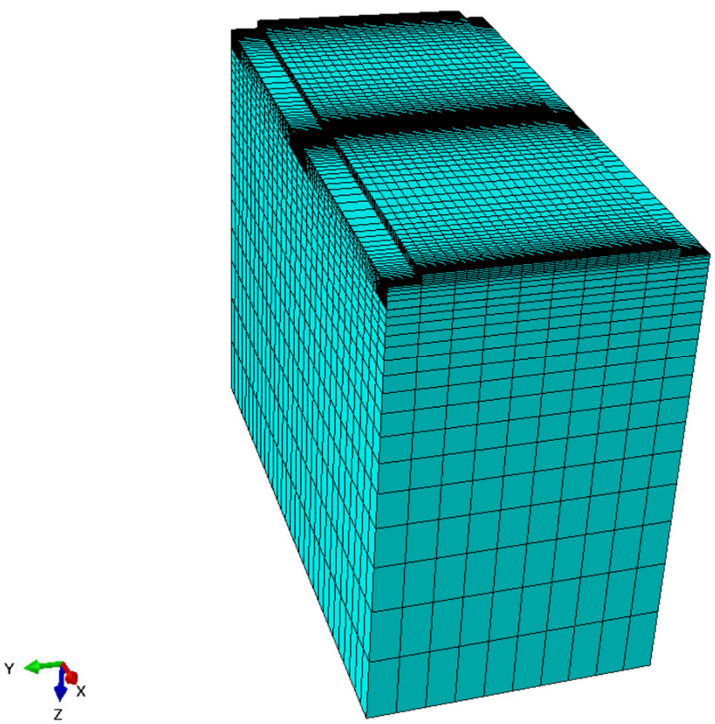
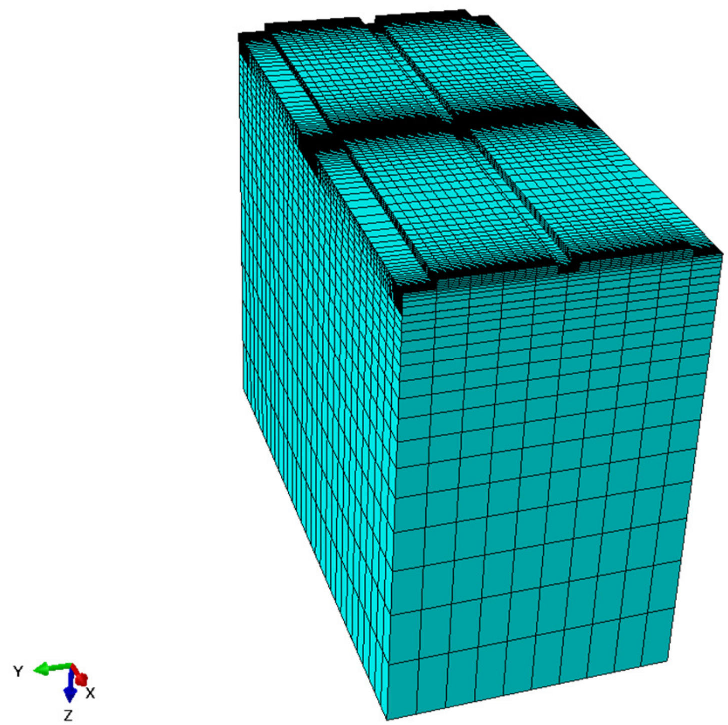
Phase IV Test (2014-2015)

Feasibility Study



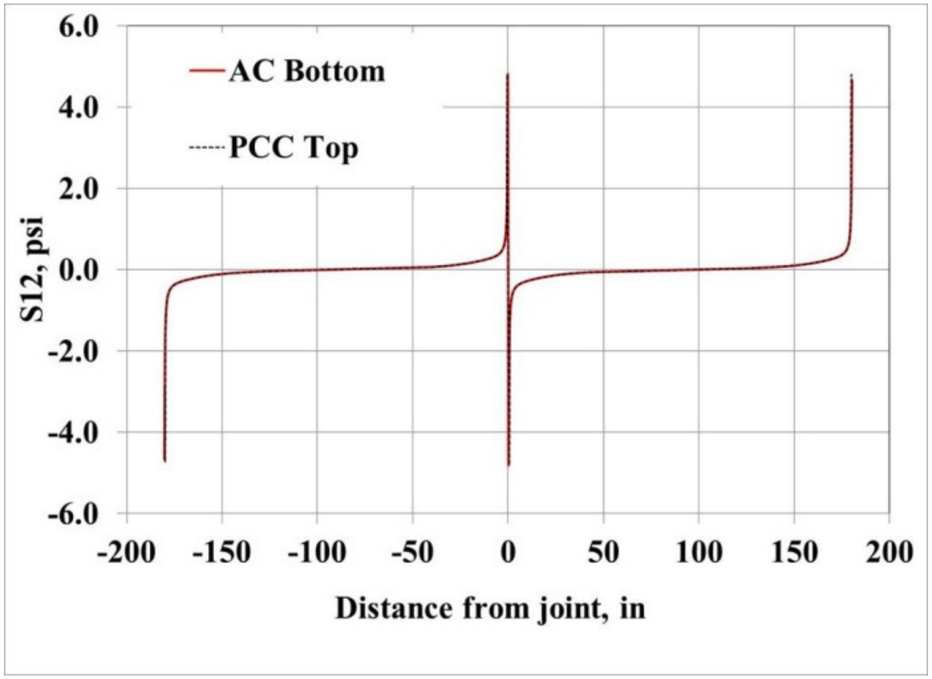


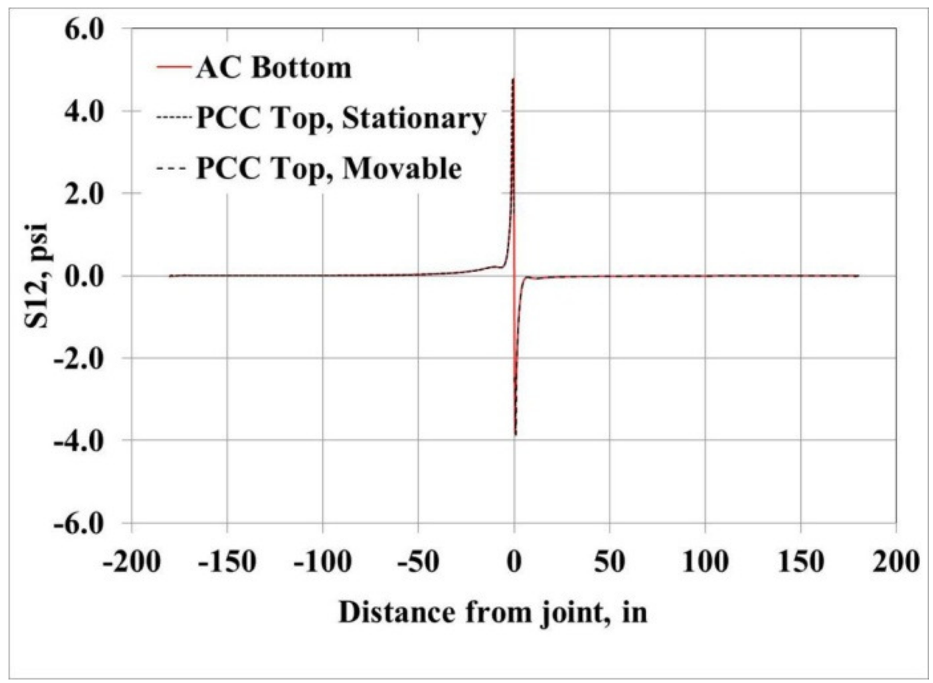


Evaluation of Tensile Stresses

Airport	Joint opening, in	Maximum tensile stress (s*11*) at bottom of AC, psi	
		temperature load	mechanical load
Fairbanks, AK	0.013	329	328
Scottsbluff, NE	0.013	321	320
Dulles, DC	0.012	292	291
Elkins, WV	0.017	424	425
Rapid City, SD	0.015	363	363
Concord, NH	0.015	361	360
Burns, OR	0.013	326	326
Augusta, GA	0.012	302	301
Roswell, NM	0.013	312	311
Bishop, CA	0.012	299	299

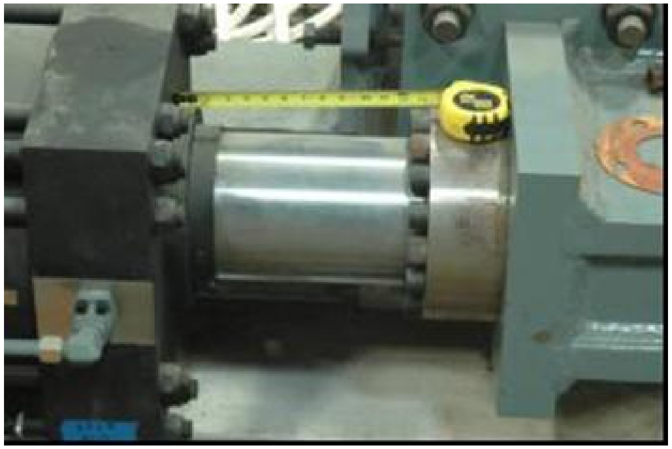
Evaluation of Shear Stresses





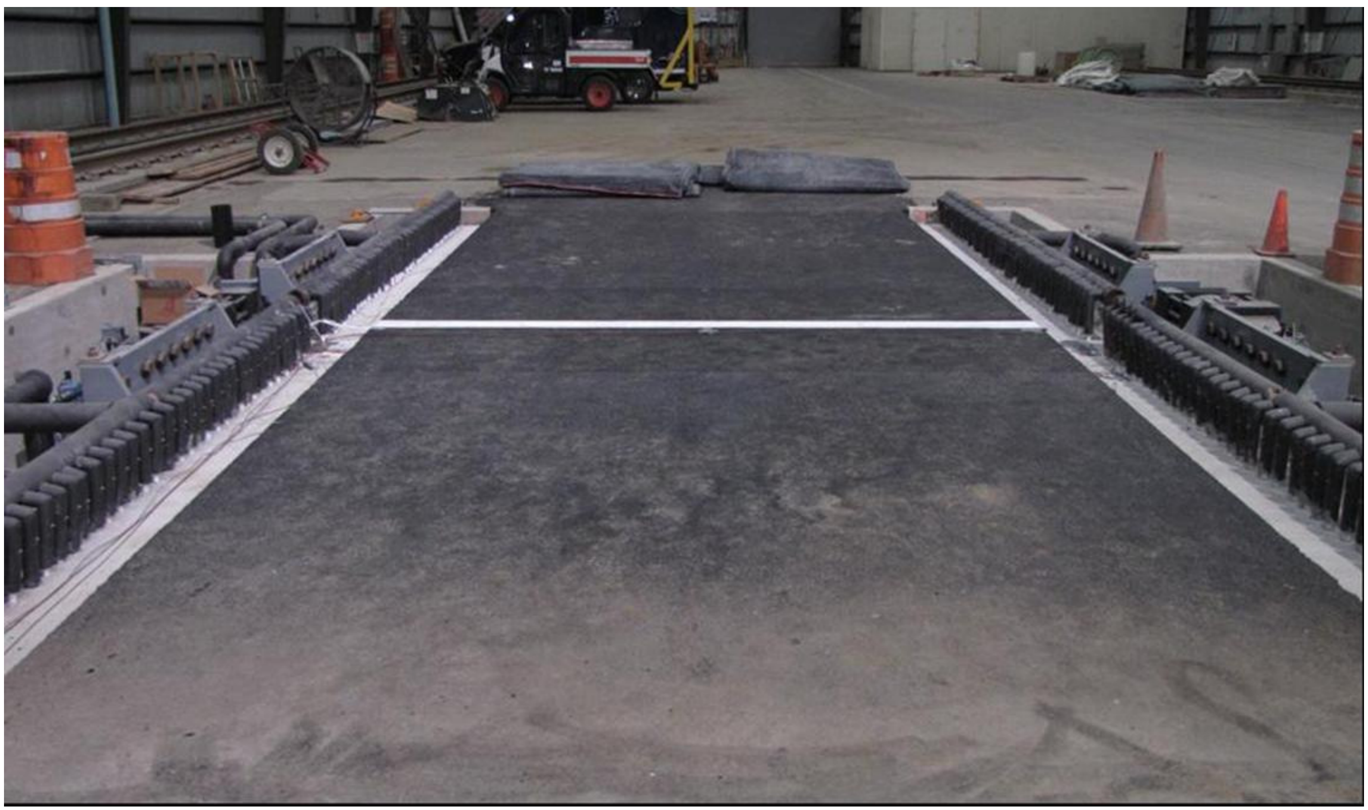
Temperature Effect Simulation System (TESS)




Phase I Test

In May 2012, the test began with a sinusoidal displacement waveform with a 0.015-in. joint opening. Two loading rates, one cycle per 600 and 300 sec, were used, respectively. Later on, a ramp loading with a displacement rate of 0.10 mil/sec was applied to propagate the crack through the top 0.5-in. overlay.



Phase I Test Findings

- Failure was fracture Mode I.
- Although the higher loading rate did not result in higher strain level, the loading rate had a substantial influence on the crack propagation, especially when the crack reached the upper portion of the overlay.
- Since the test protocol did not allow the overlay to relax, a significant joint closing force was generated and accumulated at the overlay bottom.

Phase II Test

Phase II test began on January 24, 2013. A maximum horizontal displacement (joint opening) of 0.012 in., a loading time of 150 sec, and a rest period of 600 sec were used. After 4869 cycles, the test concluded on March 8, 2013.

Phase II Test Findings

- "1 inch per year" was quite conservative for thermally-induced reflective cracking.
- Two overlay strips exhibited almost identical performance.
- Inclusion of a rest period at the end of each loading cycle allowed sufficient time for the overlay to relax.
- Once bottom-up reflection cracks reached a critical length, the crack evolution became very aggressive.

Phase III Test

Phase III test began on June 3, 2014. The test employed the same test protocol as Phase II test. After 6350 cycles, the test concluded on July 30, 2014.

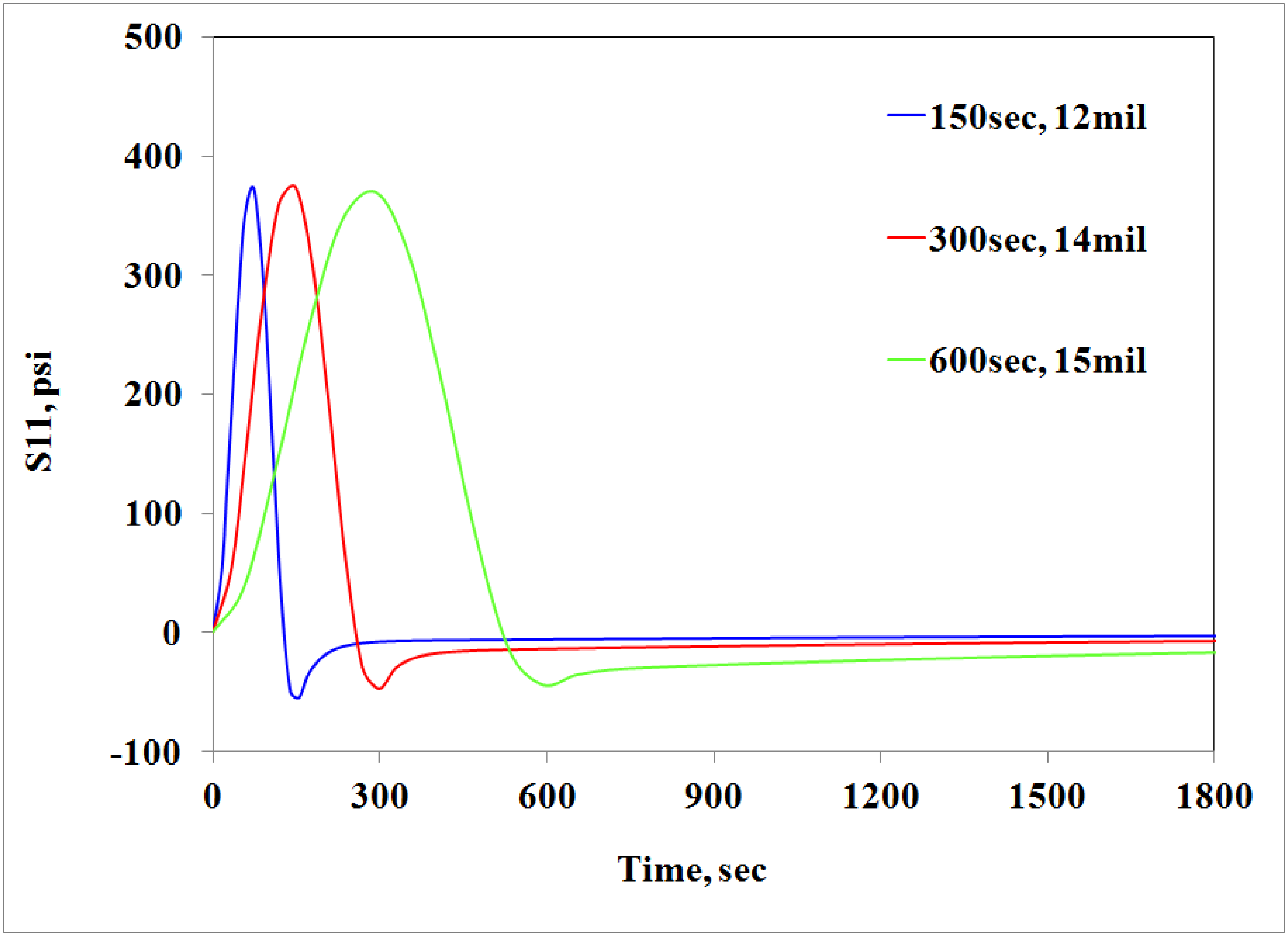
Phase III Test Findings

- The strain relieving interlayer enhanced the reflective cracking resistance of an HMA overlay. The effectiveness of strain relieving interlayer was more pronounced at an early stage of crack propagation and slowly diminished as the crack length increased.
- Inclusion of a 1-in.-thick interlayer between existing concrete slabs and the overlay extended overlay service life up to 15%. The intact interlayer had prevented spalling and moisture infiltration at the joint and therefore prolonged the structural integrity of the pavement.
- To realistically characterize the development of bottom-up reflection cracks, both mixed-mode fracture and crack channeling should be considered.

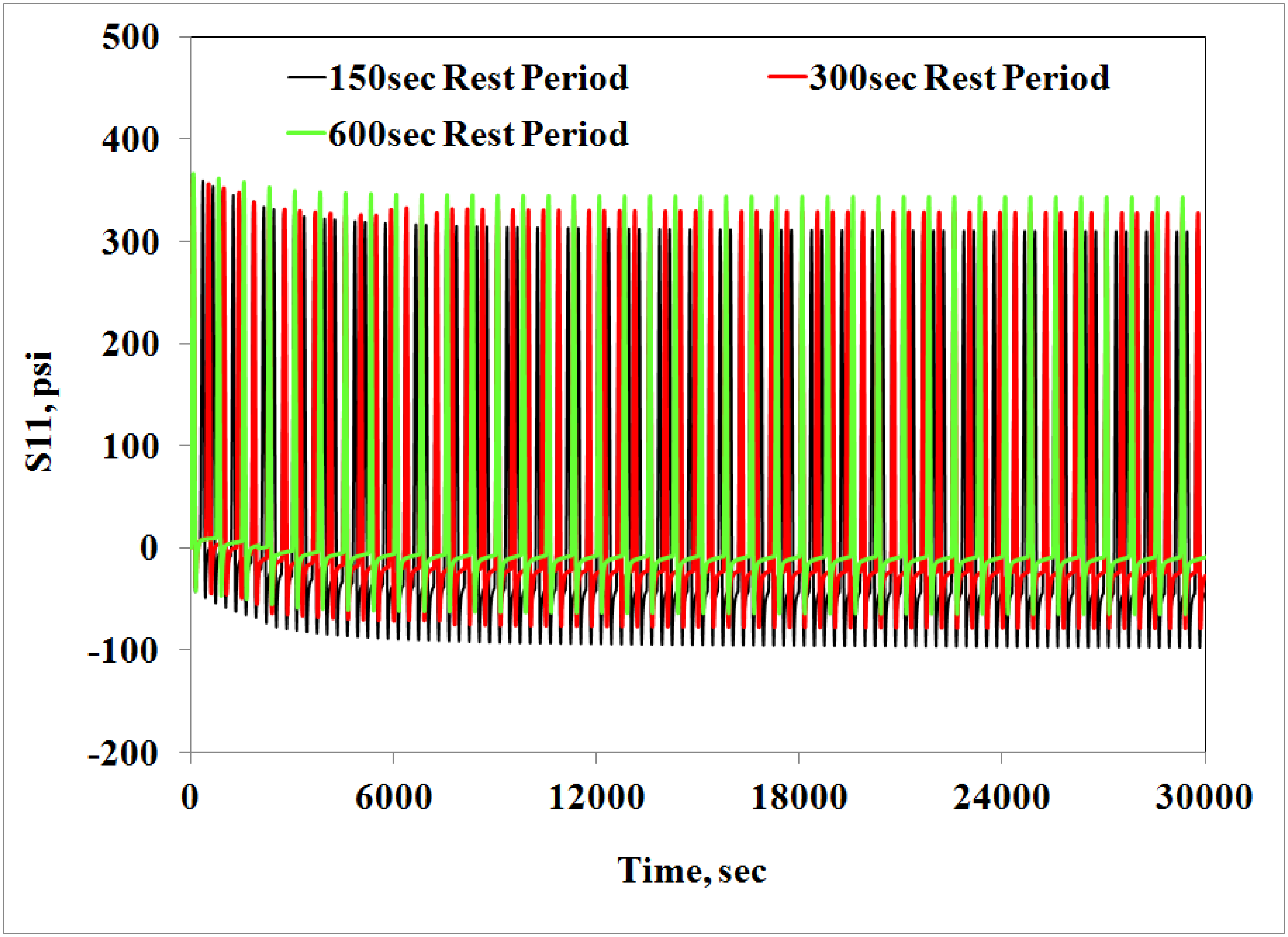
Lessons Learned

- Advanced computational mechanics
  - Optimization of test parameters
  - Facilitation of instrumentation
- Instrumentation
  - Crack initiation
  - Crack propagation
- Material characterization
  - Support of construction
  - Assistance to test protocol
- Construction challenges

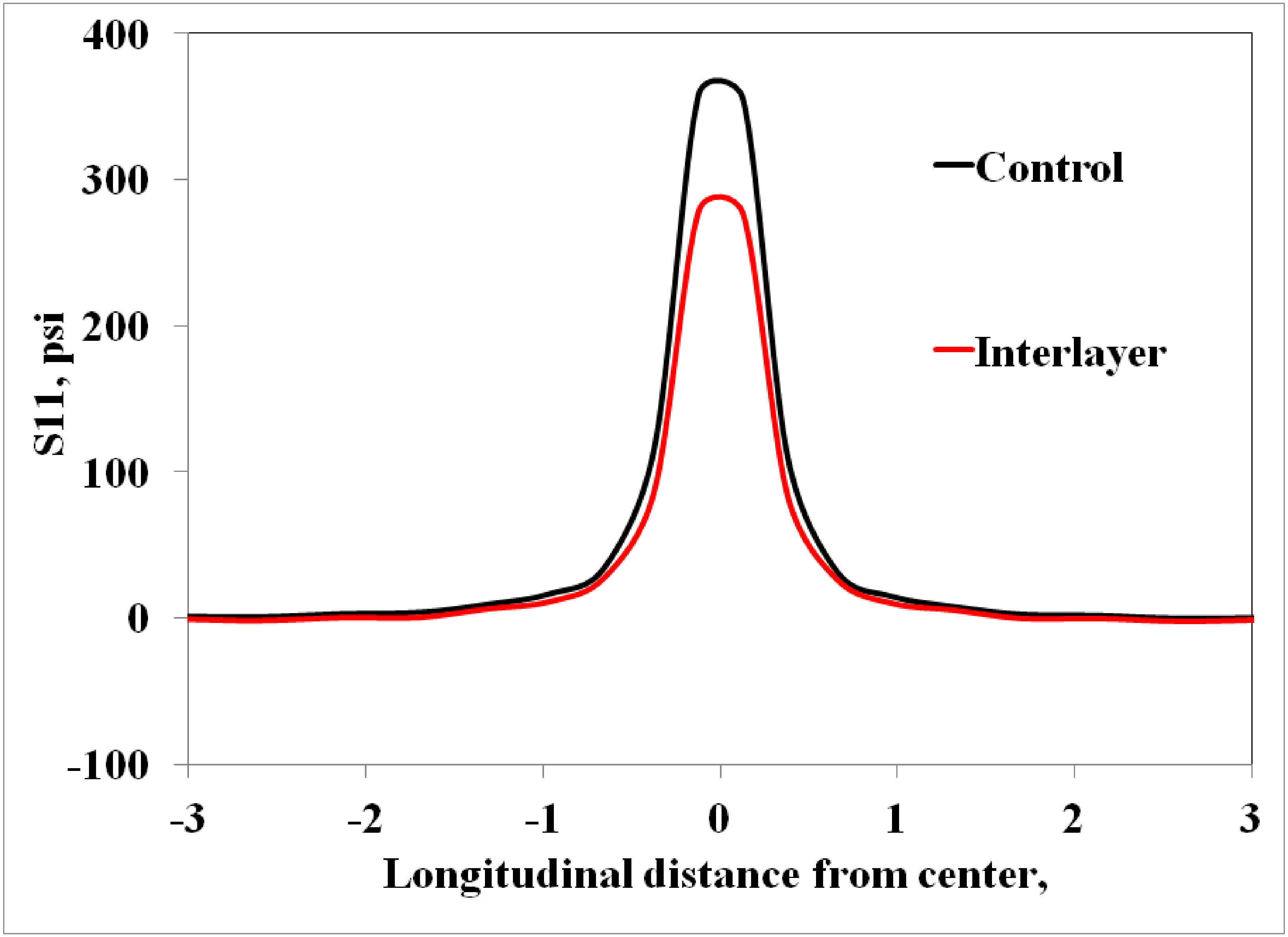
Optimization of Test Parameters



Optimization of Test Parameters



Facilitation of Instrumentation



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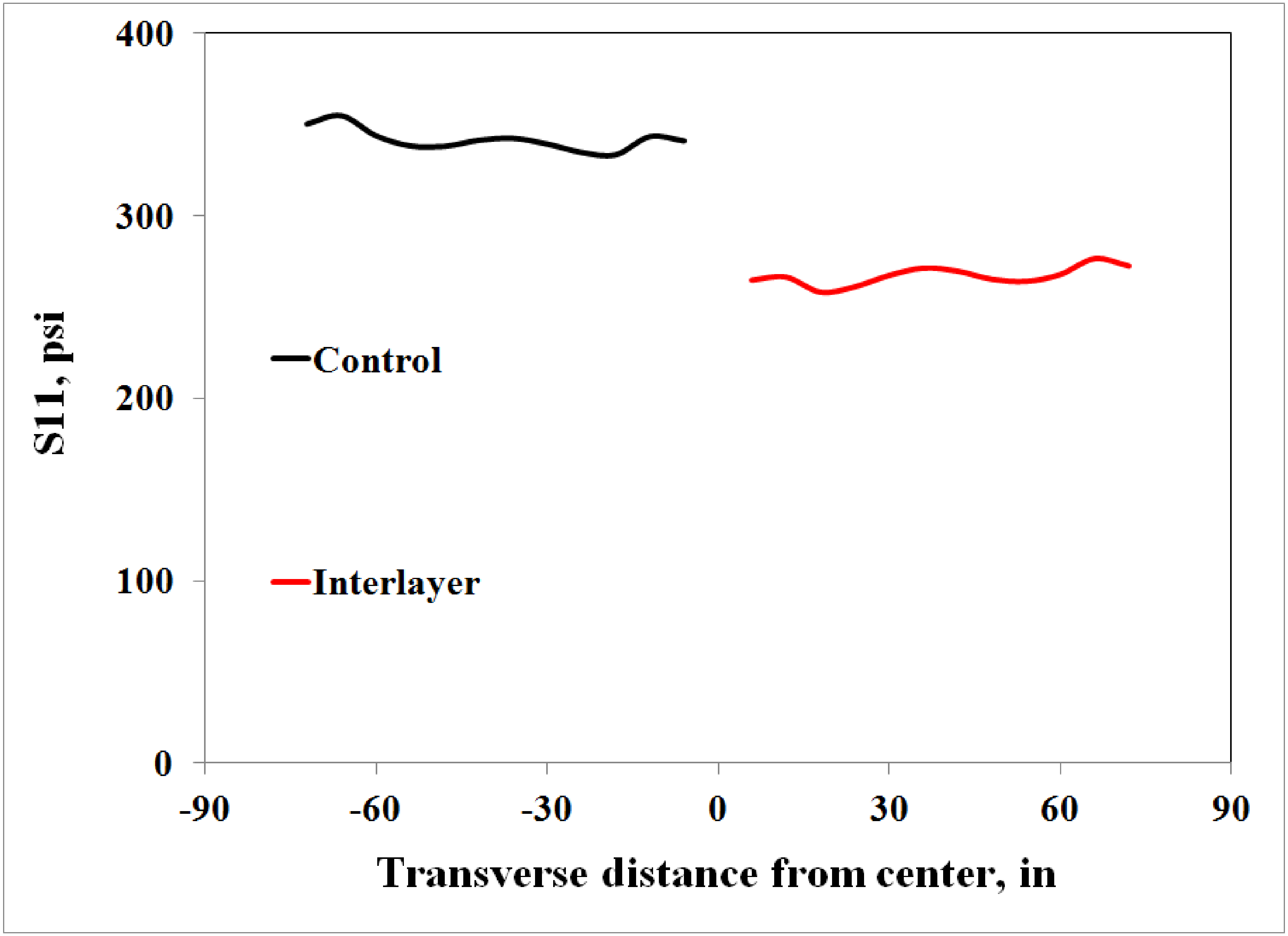
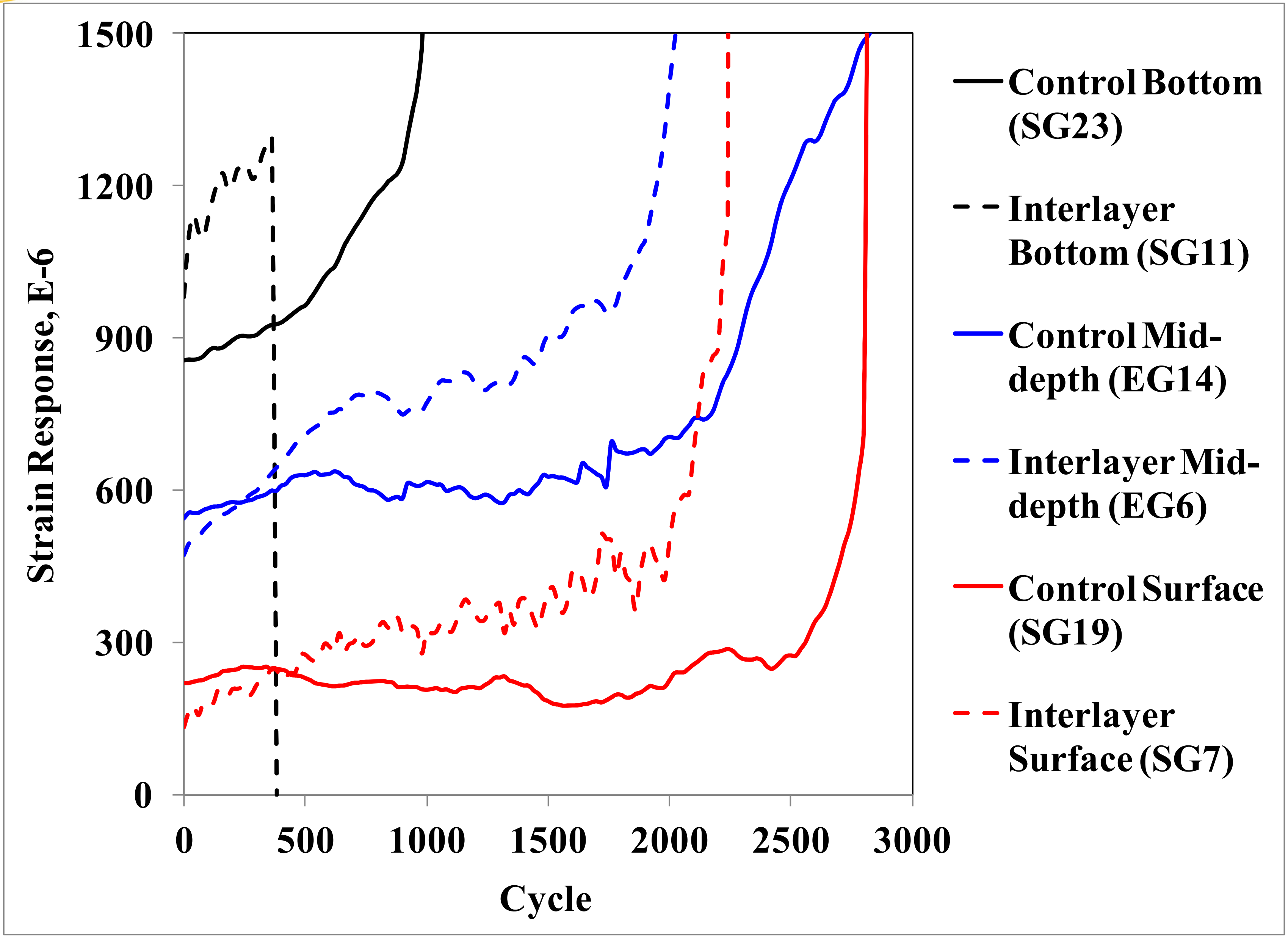
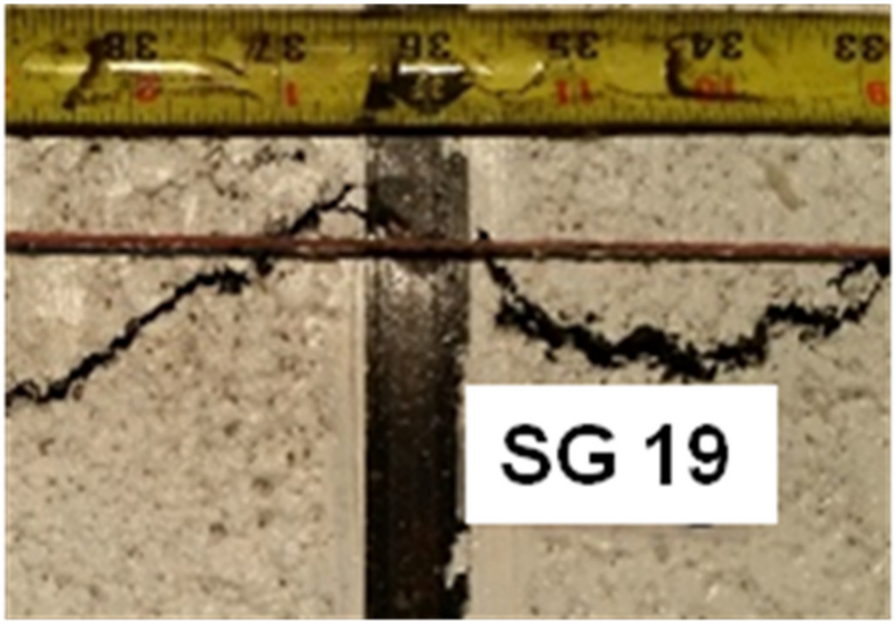


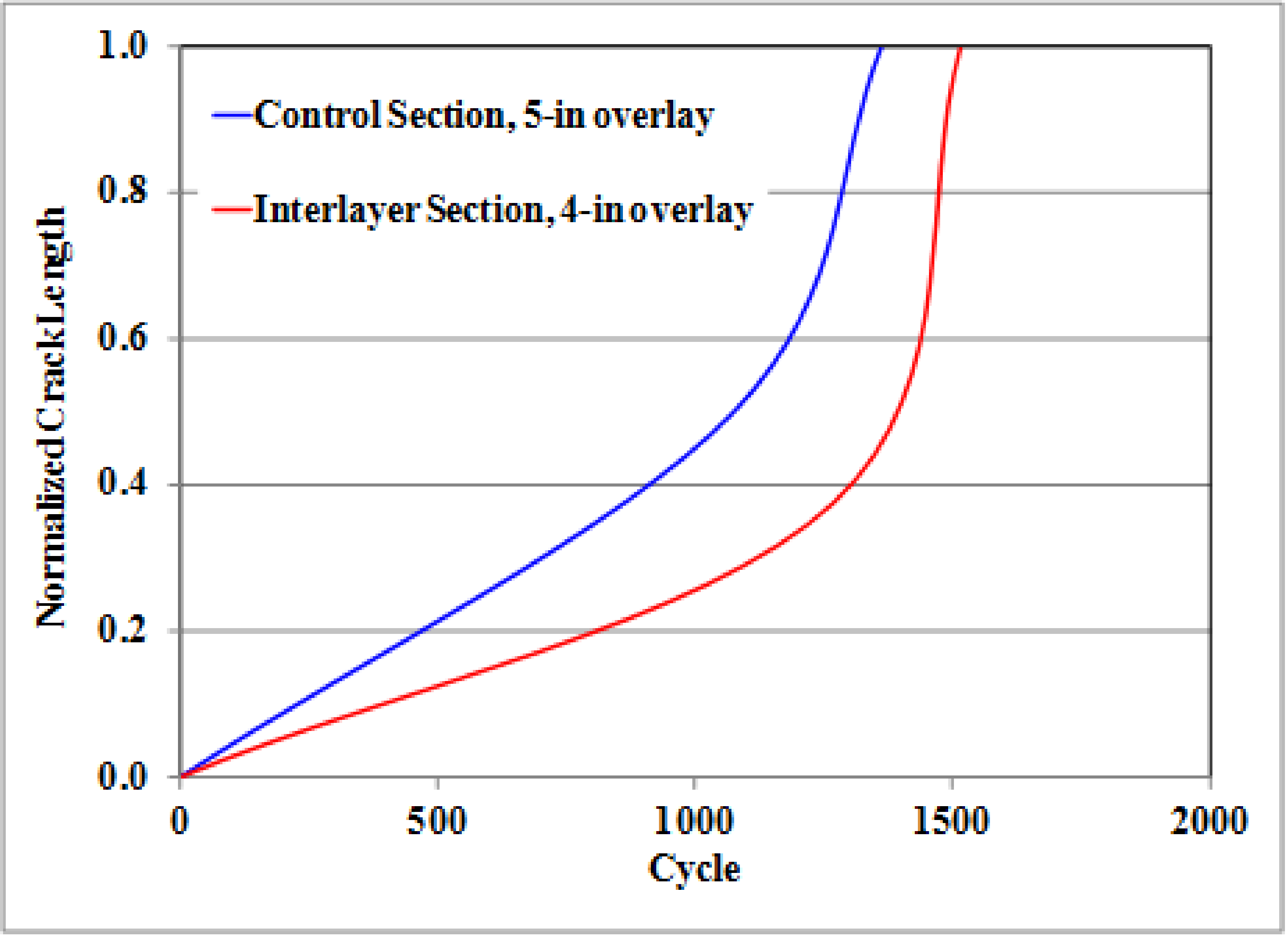
Crack Initiation



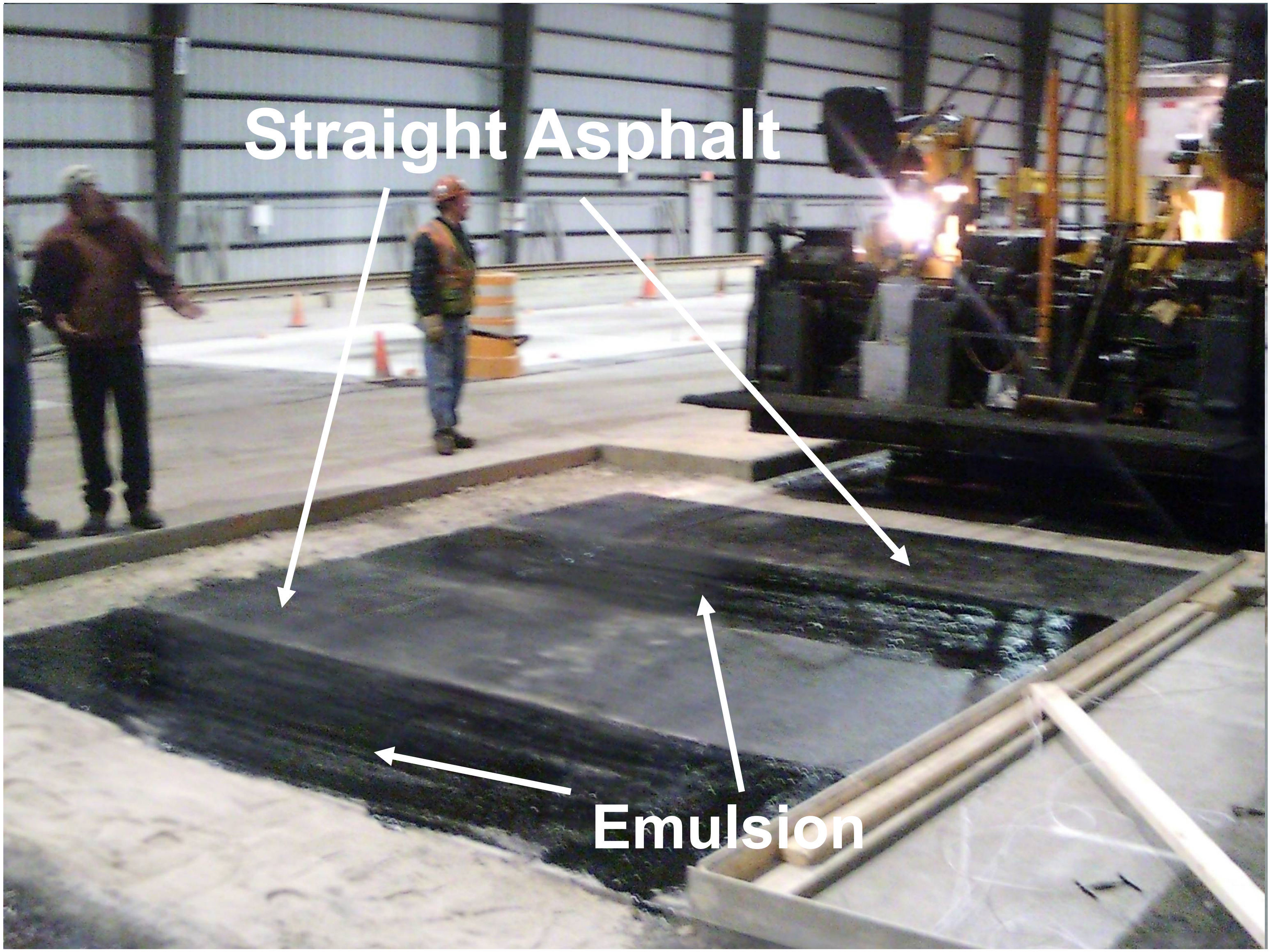
Crack Initiation



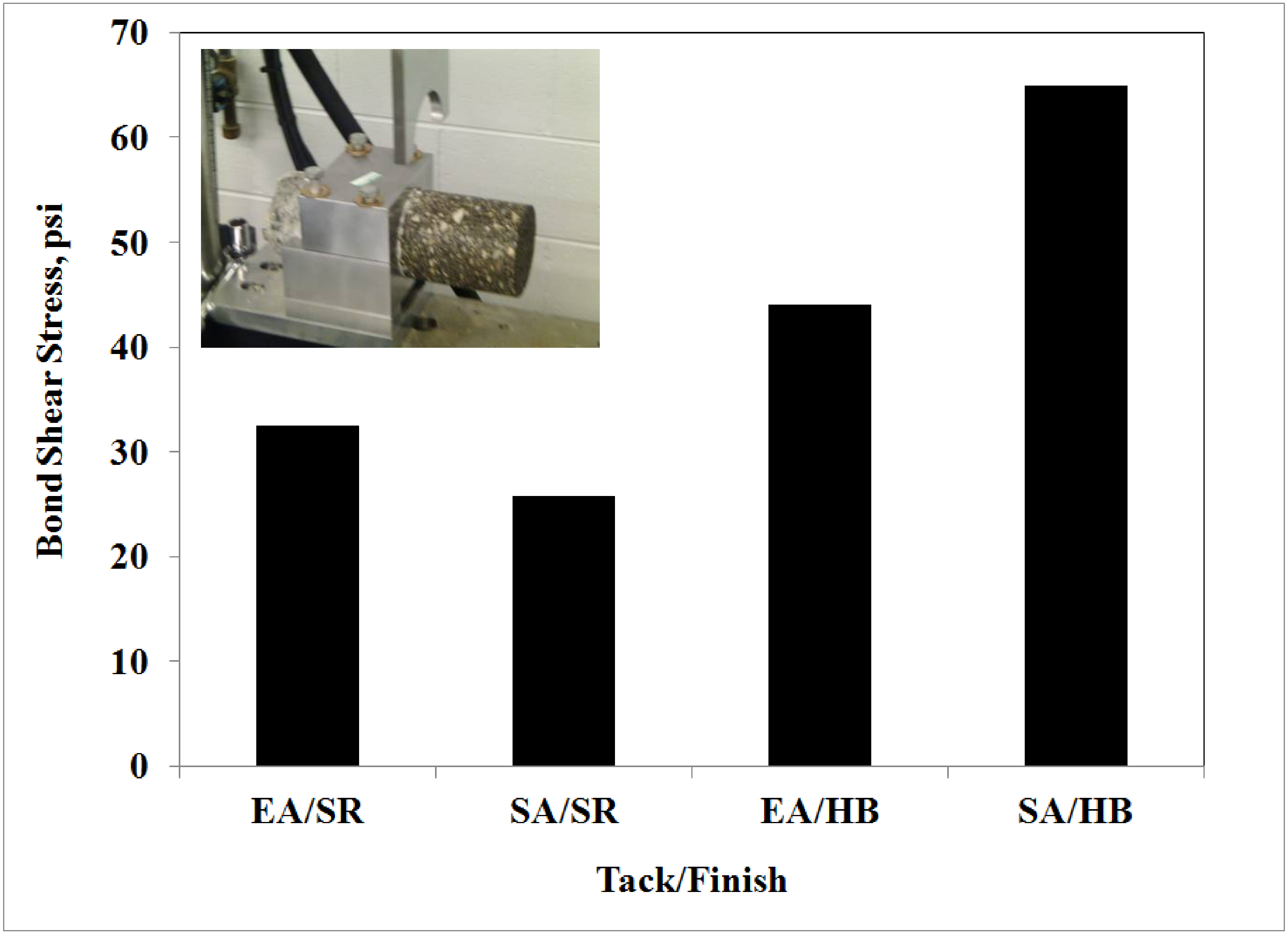
Crack Propagation



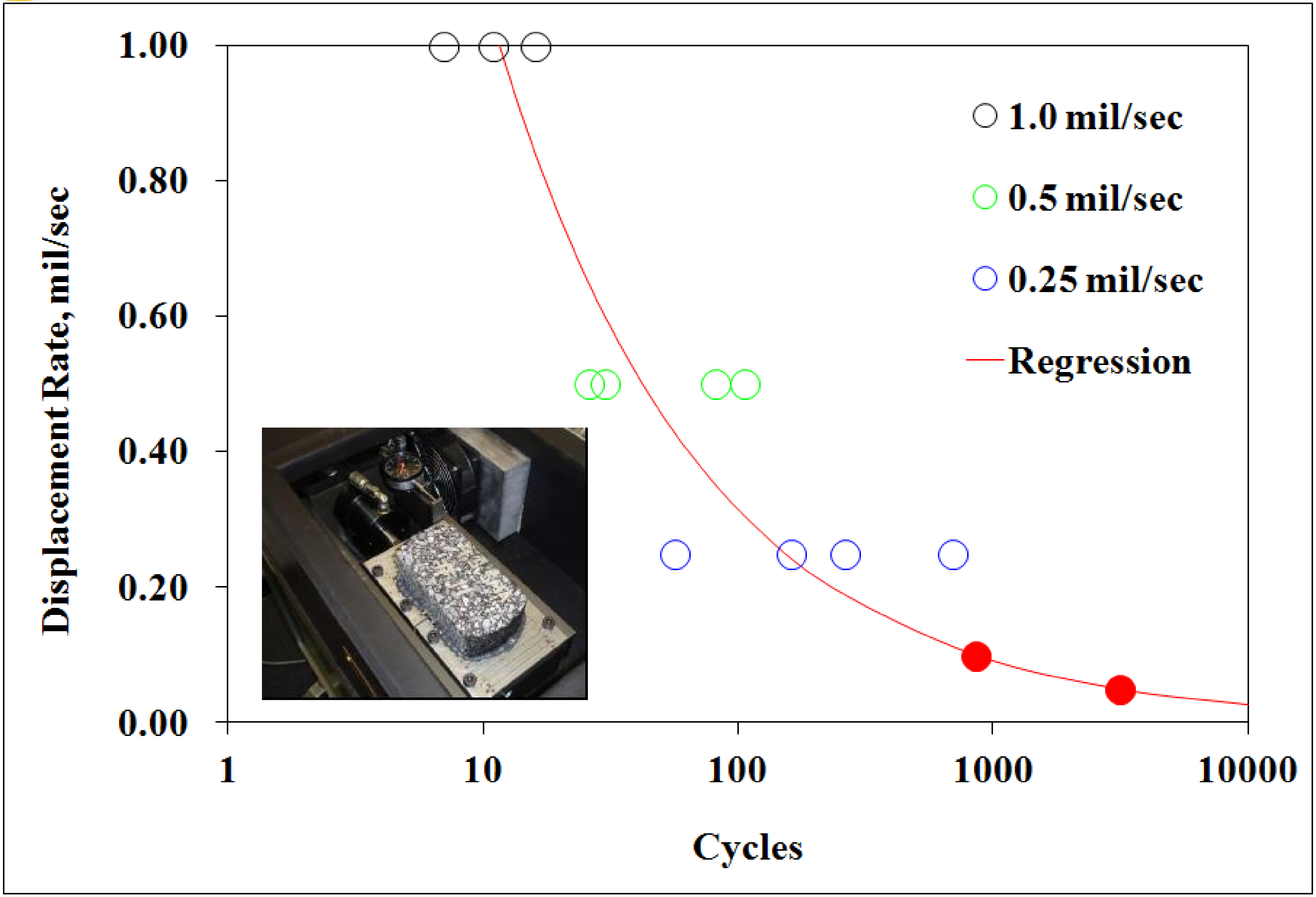
Support of Construction



Support of Construction



Assistance to Test Protocol



Construction Challenges

- Prior to the overlay construction, the existing pavement surface should be thoroughly cleaned to remove all dirt and dust.
- For thin HMA lift, segregation should be carefully detected and eliminated so that design volumetrics can be achieved.
- Between lifts, time was cautiously balanced to allow for the application of a tack coat, placement of instrumentation sensors, and an adequate mix temperature to achieve the desired density.
- Controlling and maintaining an adequate mix temperature are critical for interlayer HMA. There were unexplained spikes and dips in the temperature ranges that might have contributed to the tearing appearance in the surface of interlayer. However, after compaction, the interlayer was smooth and stable.
- A further lesson learned was to cover the embedded sensors with material close to the lift thickness (i.e., 1-in.) and then use the screed of the paver to strike off the excess HMA to the proper depth and grade. As a result, instrumentation damage could be reduced to a minimum.

Acknowledgements

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