Accelerated Pavement Testing Research Update

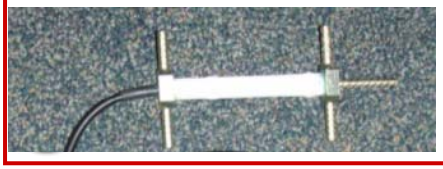
AD40(2) APT International Alliance Subcommittee
TRB 2010

Recent, Current & Planned Activities

- Recently Completed Research
  - ✓ Strain Gauge Repeatability
  - ✓ Impact of Wide-Base Tires on Pavement Damage
  - ✓ Validate Dominant Aggregate Size Range (DASR) porosity methodology for identification of rut susceptible mixes
- Current & Planned 2010 Research
  - ✓ Investigate ARMI contribution to rutting and reflective cracking
  - ✓ Calibrate MEPDG bottom-up fatigue equations
  - ✓ Continue top-down cracking research

Strain Gauge Repeatability

- Objective
  - ✓ Determine repeatability of strain gauges under APT loading
    - Embedded H-gauges
    - Surface foil strain gauges
  - ✓ Variable tire pressure, load, & pavement temperature



Strain Gauge Repeatability Test Matrix

Tire Load	Tire Pressure	Pavement Temperature
9 kips	80 psi	16° C
		20° C
12 kips	115 psi	30° C
		40° C
15 kips	125 psi	50° C

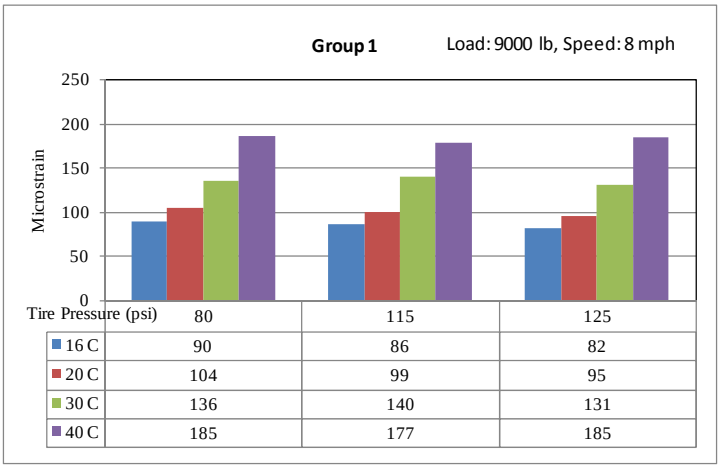
Strain Data Collection and Analysis

- Data collection
  - ✓ 4 duplicate gauges were used for each gauge type and orientation
  - ✓ 5 passes of the HVS was performed at each combination of load, pressure and temperature
- Data analysis
  - ✓ Strain was calculated using an automated procedure developed with MATLAB

Strain Gauge Repeatability Criteria

- Procedure similar to *ASTM C 802, Conducting an Interlaboratory Test Program to Determine the Precision of Test Methods for Construction Materials*
- Repeatability defined in terms of % COV
  - ✓ Repeatable: COV ≤ 10 %
  - ✓ Marginal: COV 10% to 20%
  - ✓ High variability: COV ≥ 20%

Sample Data



Tire Pressure (psi)	80	115	125
16 C	90	86	82
20 C	104	99	95
30 C	136	140	131
40 C	185	177	185

Strain Gauge Repeatability

- Outcomes
  - ✓ Strain measurements are repeatable when made at less than 50°C
  - ✓ Increased confidence in use of strain measurements to indicate pavement response and performance
  - ✓ Published paper at 2009 TRB conference

Wide-Base Tire Study

- Assess the impact of wide-base tires on pavement damage
  1. Goodyear Unisteel G149 RSA, 11R22.5 (Dual Tire)
  2. Goodyear G286 A SS, 425/65R22.5 (Super Single)
  3. Michelin X One XDA-HT Plus, 445/50R22.5 (445-mm)
  4. Michelin X One XDA-HT Plus, 455/55R22.5 (455-mm)

1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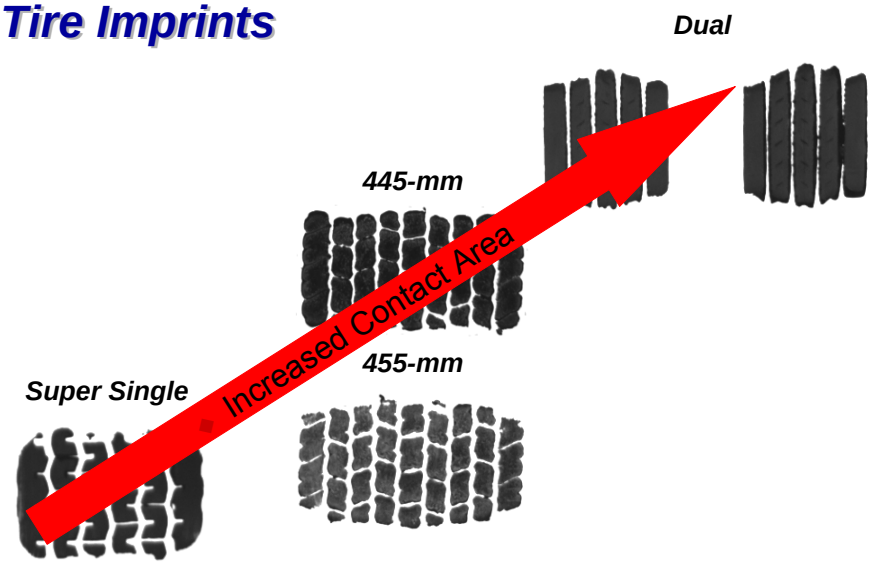
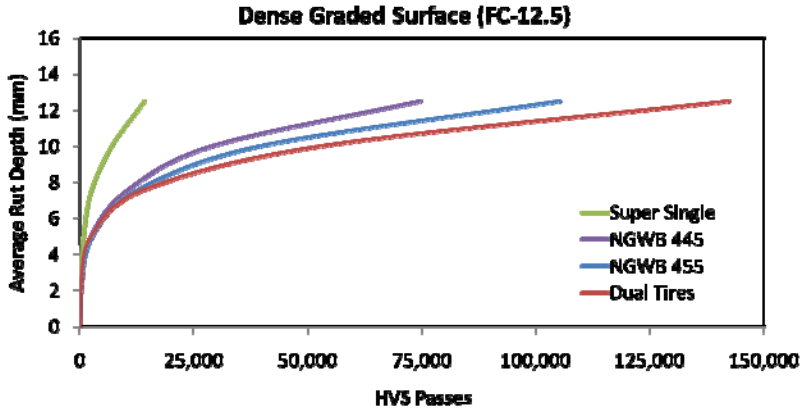
Experiment Design

- Rutting study with APT
  - ✓ Open graded FC-5
  - ✓ Dense graded FC-12.5
- Fatigue evaluation with finite element modeling
  - ✓ Dense graded FC-12.5

Tire Imprints

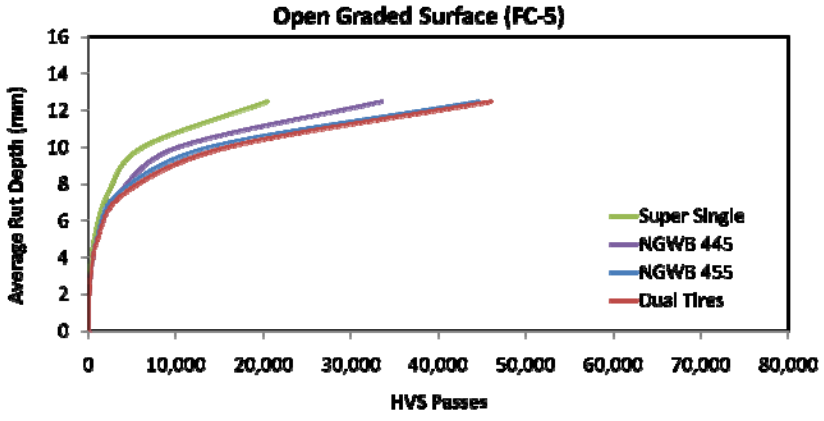


Rut Performance



Statistic	Passes Required for a 12.5-mm Rut Depth			
	Dual Tires	Super Single	NGWB 445mm	NGWB 455mm
Average	169,000	16,000	72,000	133,000
Rut Damage Ratio	1.0	10.6	2.3	1.3

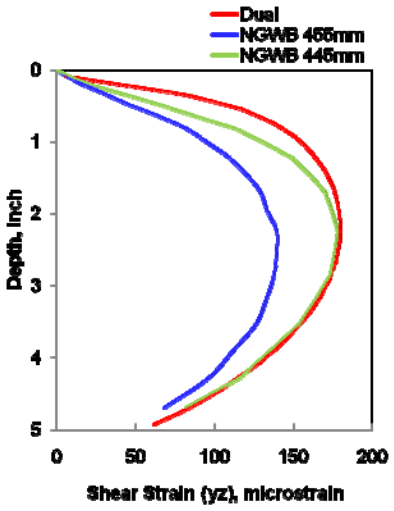
Rut Performance



Statistic	Passes Required for a 12.5-mm Rut Depth			
	Dual Tires	Super Single	NGWB 445mm	NGWB 455mm
Average	46,000	20,000	33,000	44,000
Rut Damage Ratio	1.0	2.3	1.4	1.0

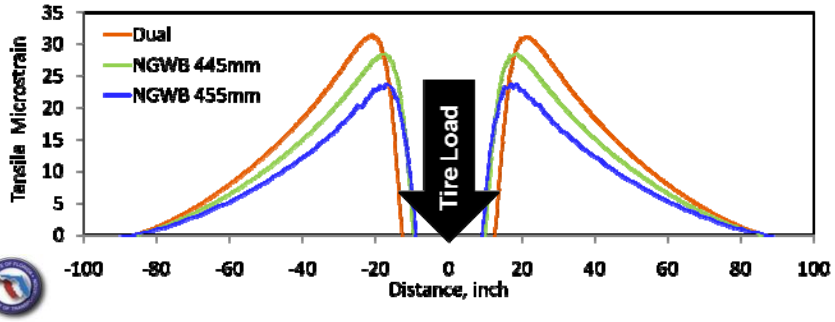
Shear Strain at the Tire Edge

- Similar max shear strains for dual and NGWB 445mm (but less at shallower depths)
- Estimated max shear strain for NGWB 455mm less than Dual
- Max shear strain located at a depth of approximately 2 inches



Surface Tensile Strain

- Maximum tensile strains from both new wide-base single tires are less than dual
- Maximum tensile strain is approximately 9 to 10 inches from tire edge



Tire Study Findings

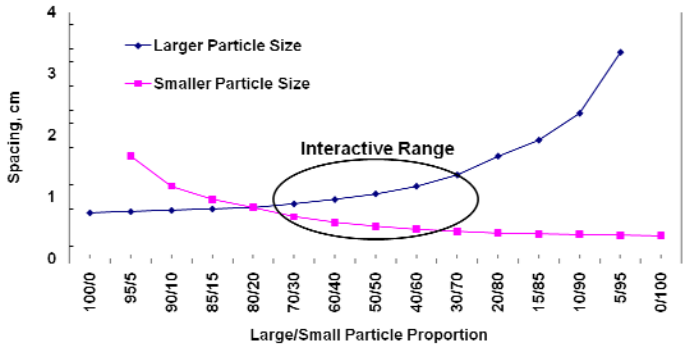
- Recommended use of 455-mm wide-base tire on Florida roadways
  - ✓ 455-mm wide-base tire performed as well or better than a standard dual tire
- 445-mm wide-base tire induced greater rutting damage and predicted to create more bottom-up cracking
- Super Single generated greatest damage in all categories

DASR Porosity

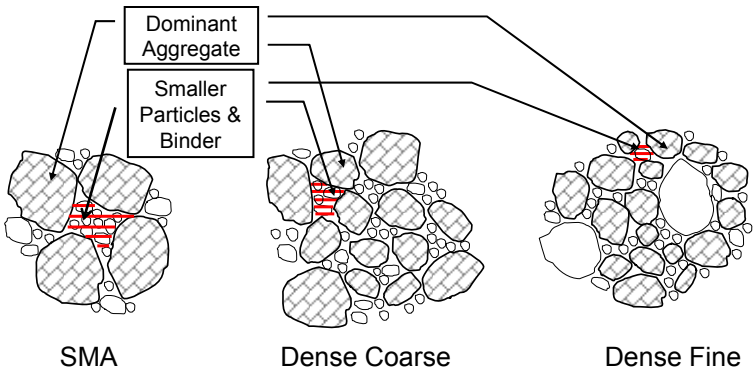
- Concept
  - ✓ In order to have good resistance to rutting the primary aggregate network should have adequate interlock
  - ✓ The primary interactive structural network is defined as the Dominant Aggregate Size Range (DASR)
  - ✓ Porosity can be used to determine aggregate contact

Dominant Aggregate Size Range

- Contiguous particle sizes must interact to be included in the DASR
- Interaction is determined by a spacing analysis of particles



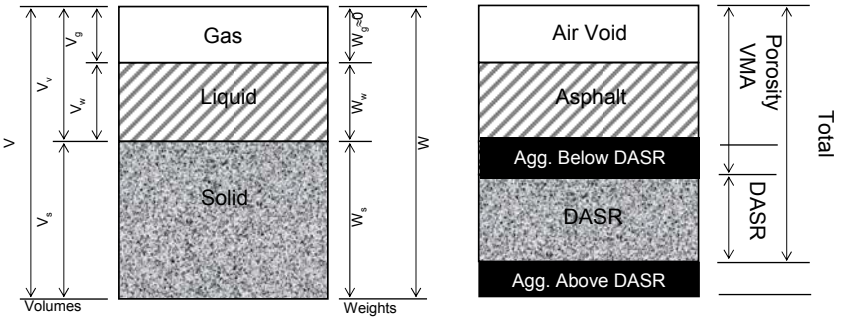
Dominant Aggregate Size Range



Porosity

- Interparticle contact is critical for good resistance to deformation
- Porosity can be used as a criterion for good aggregate contact among the DASR
  - ✓ For granular material, a porosity of 45% to 50% is required for good aggregate contact
  - ✓ Porosity can be defined as a function of VMA
    - For soil or any particulate system, $n = V_V / V$
    - For an asphalt mixture, n_{mix} = VMA

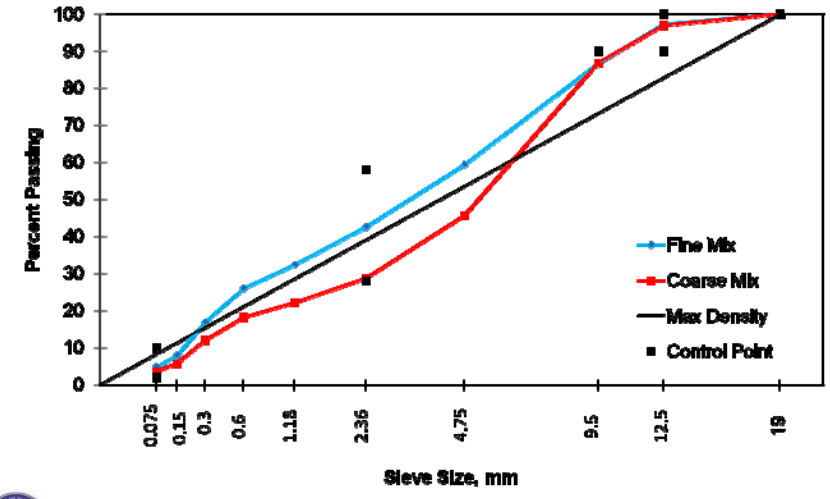
Porosity



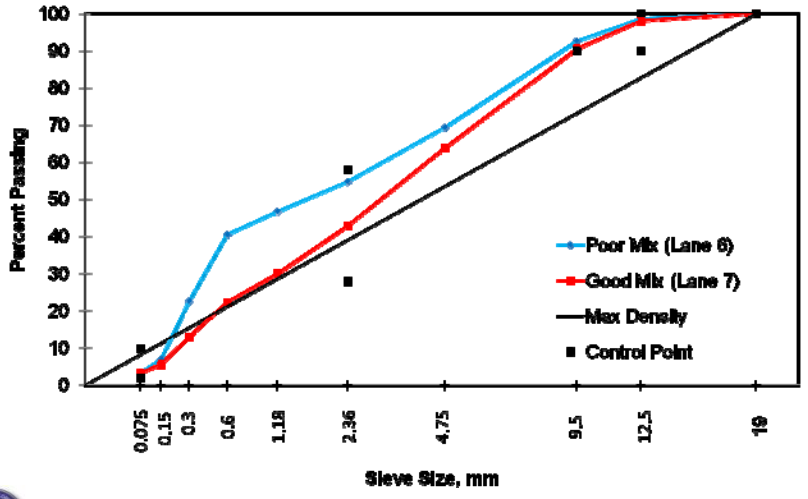
HVS Experiments

- Experiment 1
  - ✓ Coarse vs. fine graded mixtures
- Experiment 2
  - ✓ Two mixtures intentionally designed to evaluate DASR porosity

Experiment 1 Gradations



Experiment 2 Gradations



DASR Porosity Analysis

Parameter	Experiment 1		Experiment 2	
Mix	Fine	Coarse	Good	Poor
DASR, mm	4.75 to 1.18	4.75	4.75 to 1.18	4.75 to 1.18
Porosity	47	62	44	59

- DASR = Primary aggregate network
- For good aggregate interlock of the DASR, Porosity < 50%

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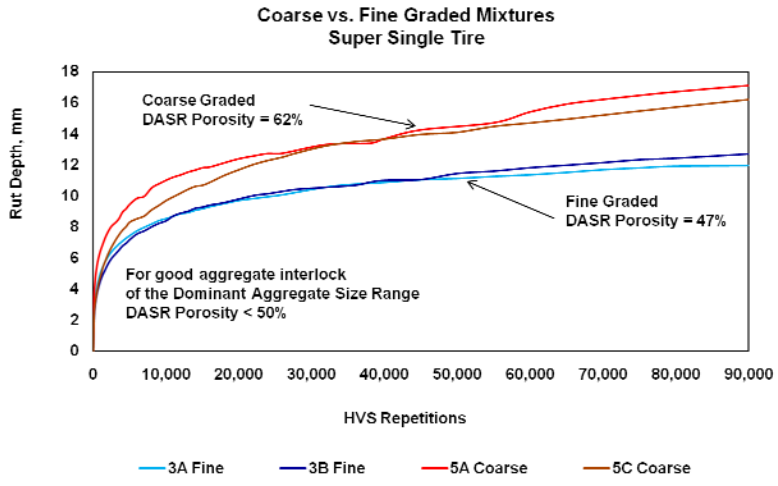
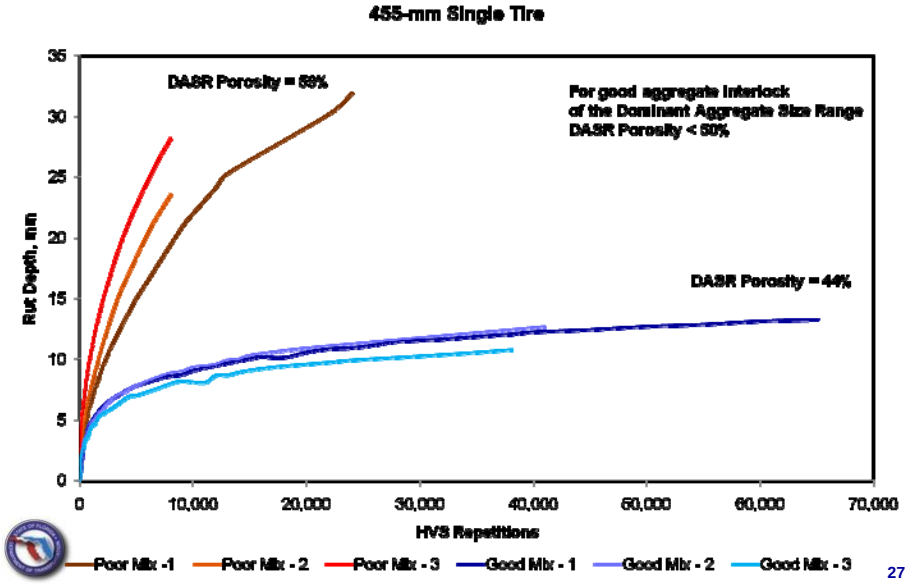
Experiment 1 Rut Profiles



Experiment 2 Rut Profiles



DASR Porosity Conclusions

- A mixture's DASR and the DASR porosity can be used to determine the interactive range of particle sizes and whether good contact exists between these particles
- Minor changes in a mixtures gradation may have a significant effect on rut performance
- Further research is currently underway to develop mix design guidelines that address DASR porosity

Current Round of APT Experiments

- Current & Planned Experiments
  - ✓ ARMI
    - Rut contribution and crack resistance
  - ✓ Bottom-up cracking
    - Calibrate MEPDG fatigue equations
  - ✓ Top-down cracking
    - Simulate cracking found in the field
    - Investigate mixture properties required to induce top-down cracking

ARMI Study

- Asphalt Rubber Membrane Interlayer (ARMI)
  - ✓ 20 percent asphalt rubber binder
    - Placed at 0.6 to 0.8 gal/yd^2
  - ✓ No. 6 stone
    - Placed at 0.26 to 0.33 ft^3/yd^2 with a rubber tire roller
  - ✓ Minimum 1.5 inch overlay required
- An ARMI is intended to mitigate reflective cracking
- Florida's first ARMI experiment over 30 years ago

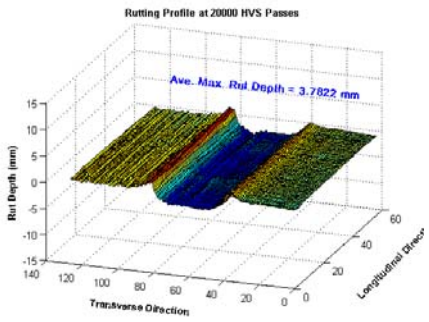
ARMI Study

ARMI Impact on Rutting

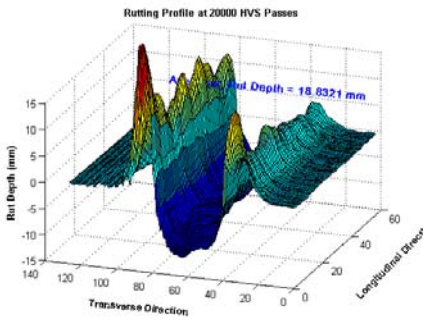
- Rutting investigation
  - ✓ Districts have reported that an ARMI may contribute to greater rutting
  - ✓ APT will investigate 2 inch and 4 inch overlays with and without ARMI
- 2 inch overlay experiment complete
  - ✓ APT showed that a 2 inch lift is not thick enough to adequately protect an ARMI
  - ✓ Thin lifts over an ARMI are not uncommon – either temporarily during construction prior to additional lifts or as a final design

Rut Profiles at 20,000 Passes

2-inch Overlay Without ARMI



2-inch Overlay With ARMI



ARMI Impact on Cracking

- Cracking investigation
  - ✓ Study crack performance of overlaid concrete with and without ARMI
  - ✓ There has been some controversy over the effectiveness of an ARMI for reflective crack control, particularly when considering the cost

MEPDG Bottom-Up Fatigue Calibration

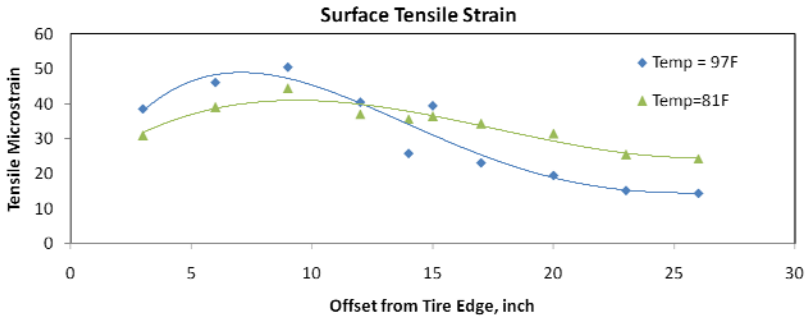
- Objective
  - ✓ Determine calibration coefficients for MEDG fatigue equations
- Two lanes and test pit dedicated to study
  - ✓ 1 inch thick, 2 inch thick, and 3 inch thick test sections
  - ✓ 3 inch section on test pit with water table control

Top-Down Cracking

- Recently completed test on Lane 1A
  - ✓ Aged and unaged test section
- Observations
  - ✓ Aging is critical to top-down cracking
  - ✓ Cracks formed near the tire edge
  - ✓ Shifting the load was found to help propagate the cracks

Top-Down Cracking Observations

- Literature indicates that top-down cracks may form in the wheel path, but propagate due to thermal stress, stiffness gradients, and loading location
  - ✓ This was observed on Lane 1A: Top-down cracks did not propagate after ~100,000 passes after formation
  - ✓ Surface strain measurements indicate that maximum strain occurs 9 to 10 inches from wheel edge



Top-Down Cracking Observations