Impact of Wide-Base Single Tires on Pavement Damage

Background

- Dual tires have traditionally provided the largest footprint to adequately distribute axle loads and limit pavement damage

- The trucking industry is encouraging the use of a new generation of wide-base single tires
  - ✓ Economical benefits
  - ✓ Safety benefits
  - ✓ Environmental benefits
  - ✓ Positive driver feedback
  - ✓ Contact area approaches that of dual tires

Background

- Reported potential disadvantages from the American Trucking Association
  - ✓ Mixed results on tread wear
    - Potentially significantly faster tread wear for local and urban operations
  - ✓ Reports of increased retread failures
    - Retread failure leads to higher rates of vehicle damage

Objective

- 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)

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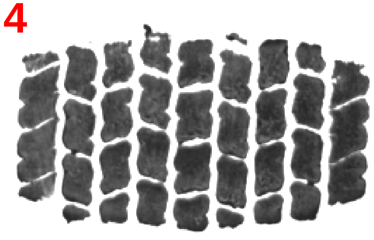


Pavement Damage Potential

- Two primary pavement failure mechanisms in Florida
  - ✓ Rutting
  - ✓ Fatigue cracking (bottom-up and top-down)
- Recent findings from literature regarding new wide-base single tires when compared to dual tires
  - ✓ Generate similar rut depths
  - ✓ Induce greater tensile strain at the HMA bottom
  - ✓ Produce similar or less shear strains near the HMA surface

Experiment Design

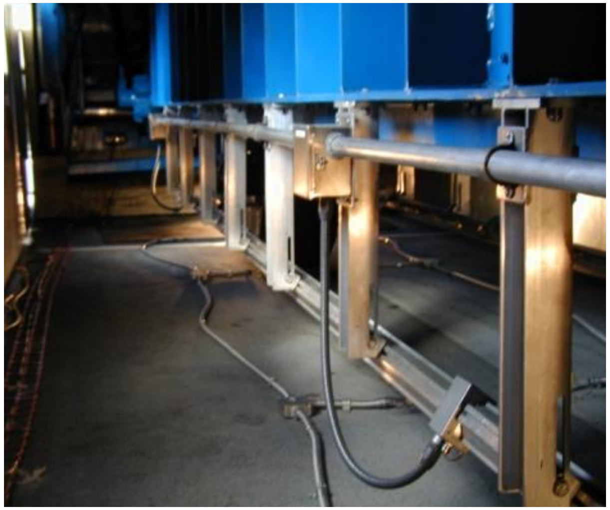
- Rutting study with APT
  - ✓ Open graded FC-5
  - ✓ Dense graded FC-12.5
- Fatigue evaluation with finite element modeling
  - ✓ Dense graded FC-12.5

Heavy Vehicle Simulator

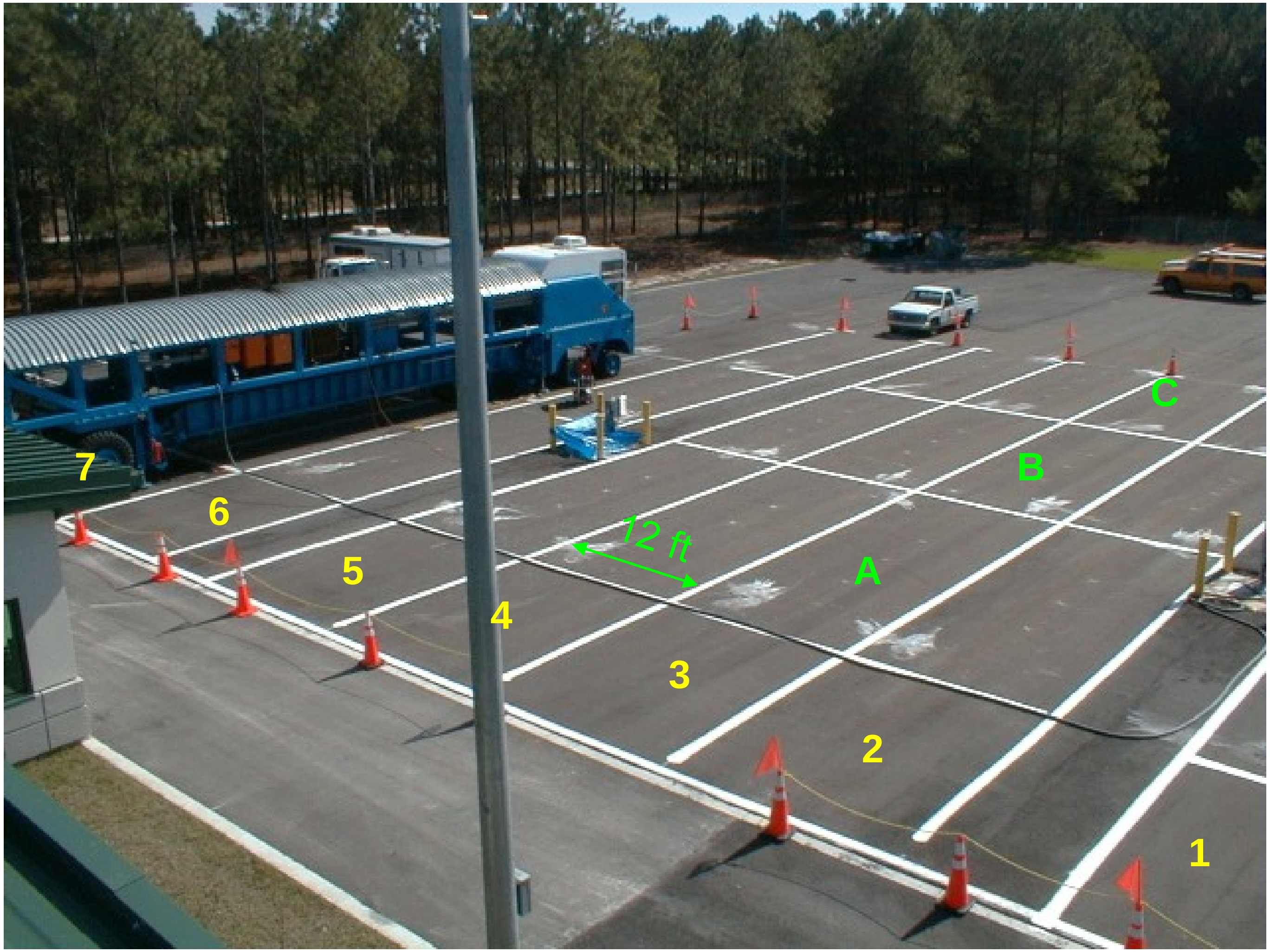
- Dynatest HVS, Mark IV
- Wheel speed up to 8 mph
- Loading: 7 to 24 kips
- Wander from 0 to 30 inches

Heating System

- Radiant heaters attached to both sides of HVS test beam
- Insulated panels enclose test area
- Rutting tests conducted at 50^{o}C



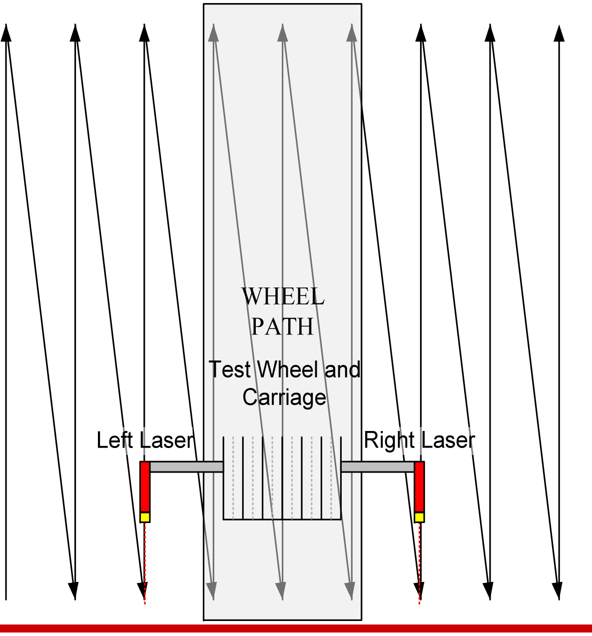
APT Facility



Rut Measurement with Laser Profiler

- Two 16 kHz Lasers, mounted 762mm (30 in) apart
- Wheel is unloaded
- Wheel carriage travels at 4 kph (2.5 mph)
- Profile time is approximately 15 minutes
- Profiles collected several times throughout test

Laser profiler



Pavement Sections for APT Study

Open-Grade Surface Lanes 2, 3, and 4	Dense-Grade Surface Lanes 5, 6, and 7
0.75 inch (19-mm) FC-5, ARB-12	
2 inch (50-mm) SP-12.5, PG 67-22, 93% Gmm	2 inch (50-mm) FC-12.5, ARB-5 93% Gmm
3.5 inch (89-mm) Existing SP-12.5	3.5 inch (89-mm) Existing SP-12.5
10.5 inch (265-mm) Limerock Base Course	10.5 inch (265-mm) Limerock Base Course
12 inch (305-mm) Granular Subbase	12 inch (305-mm) Granular Subbase

Note: ARB-12 represents 12% asphalt rubber binder.

Test Sections

North

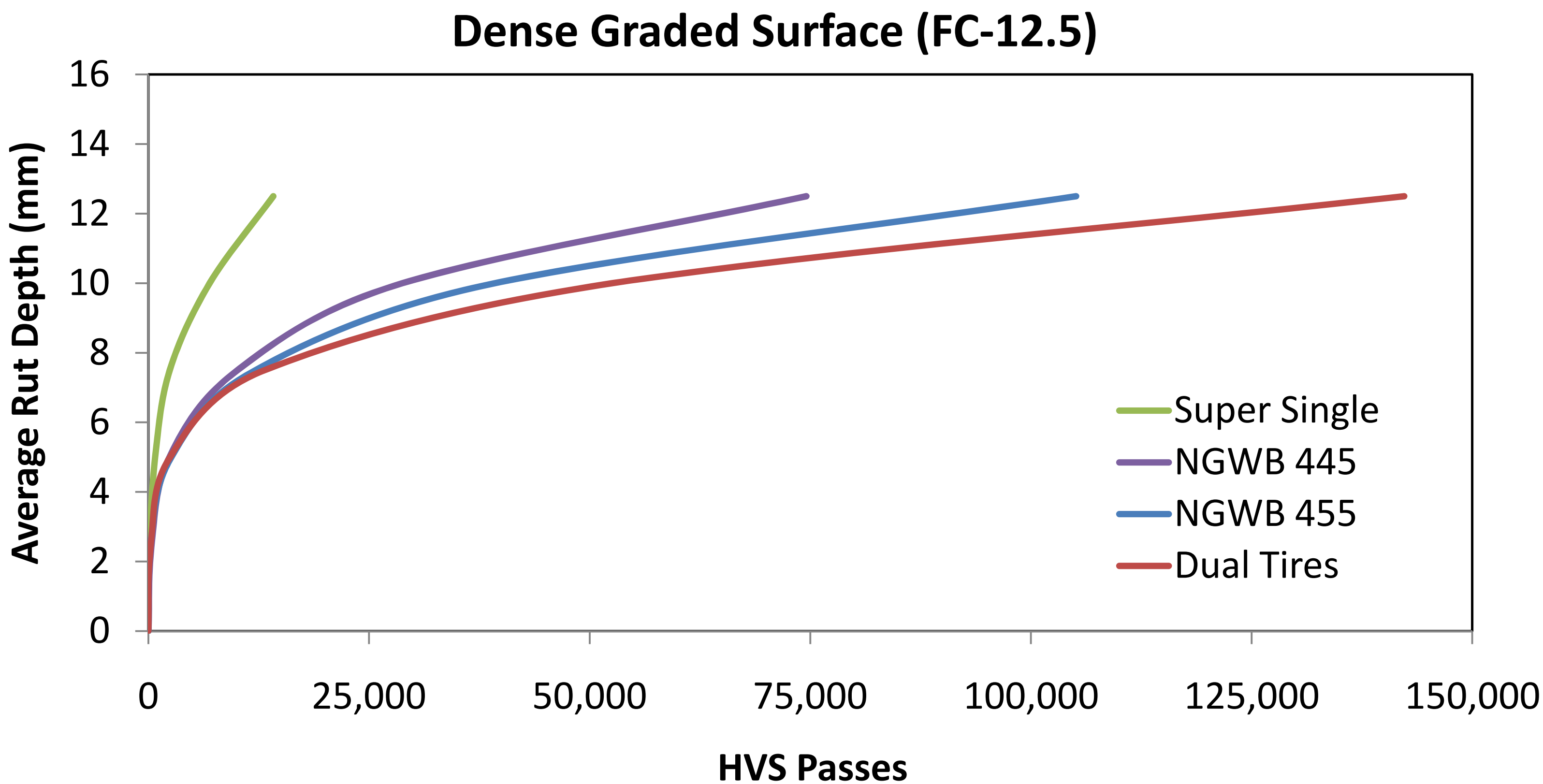
	Open Grade						Dense Grade						
	Lane 2		Lane 3		Lane 4		Lane 5		Lane 6		Lane 7		
Section A	No Test		NGWB 455	Super Single	Dual Tires	NGWB 445	Dual Tires		NGWB 445		Dual Tires	NGWB 455	44 ft
Section B	Dual Tires	Super Single	NGWB 445	NGWB 455	Super Single	Dual Tires	NGWB 455	NGWB 445	NGWB 455	Dual Tires	NGWB 445	Super Single	44 ft
Section C	NGWB 445	NGWB 455	Dual Tires	NGWB 445	NGWB 455	Super Single	Super Single	NGWB 445	NGWB 455	Dual Tires	Super Single	NGWB 445	44 ft
											12 ft		

Note: Not to scale.

Loading Conditions

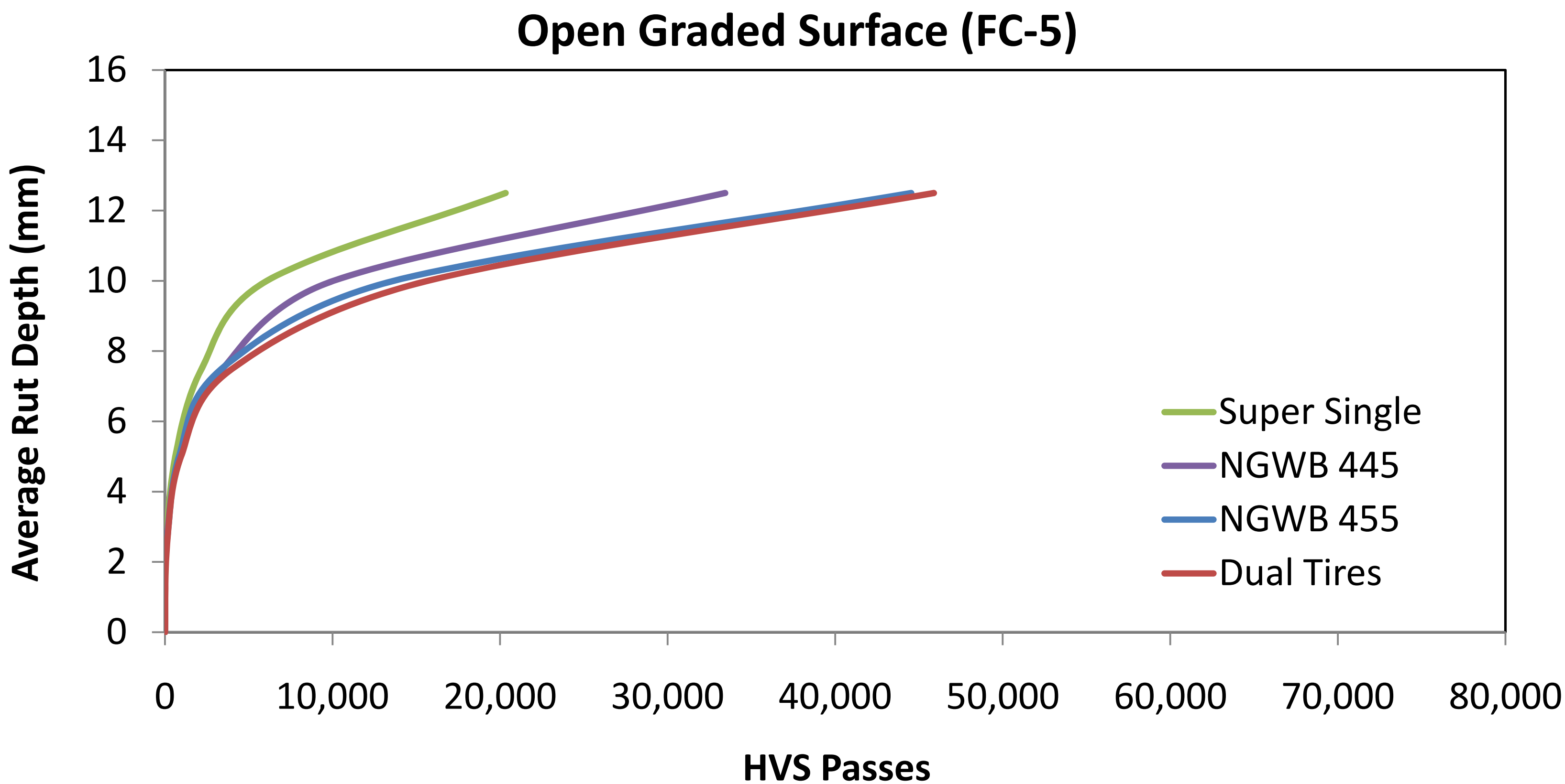
- Each tire inflated to recommended pressure
- 9 kip load
- 5-inch wander
- Constant temperature maintained at 50ºC

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

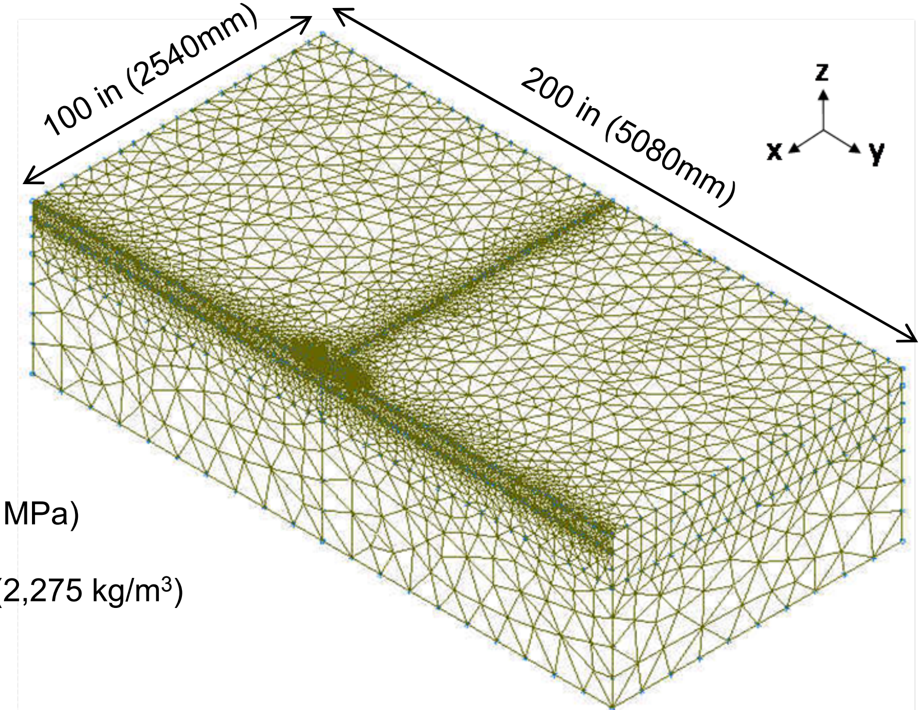


Statistic	Passes Required for a 12.5-mm Rut Depth			
	Dual Tires	Super Single	NGWB 445mm	NGWB 455mm
Average	46,000	20,000	33,000	44,000
Rut Damage Ratio	1.0	2.3	1.4	1.0

Finite Element Analysis

- Objective: Predict strains critical to fatigue cracking
  - ✓ Bottom-up cracking
    - Longitudinal tensile strain at the bottom of the HMA
  - ✓ Top-down cracking
    - Shear strain below the tire edge
    - Transverse tensile surface strain away from tire edge

Pavement Structure Model

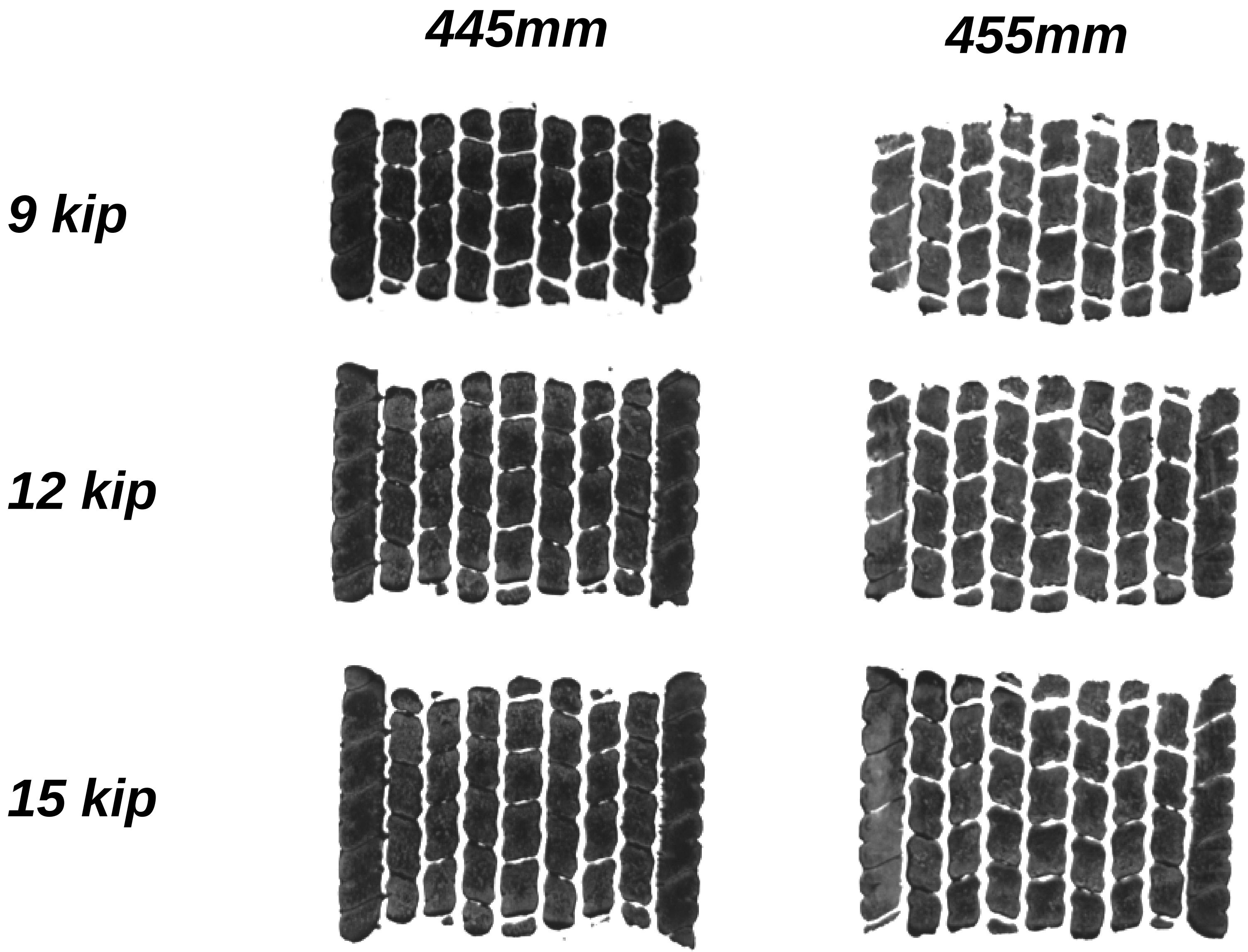


5.1 in (130mm) HMA	E = 700 ksi (4,825 MPa) v = 0.3 Density = 142 pcf (2,275 kg/m^3)
10.5 in (267mm) limerock base	E = 80 ksi (552 MPa) v = 0.40 Density = 115 pcf (1,842 kg/m^3)
36 in (915mm) subgrade	E = 19 ksi (131 MPa) v = 0.45 Density = 113 pcf (1,810 kg/m^3)

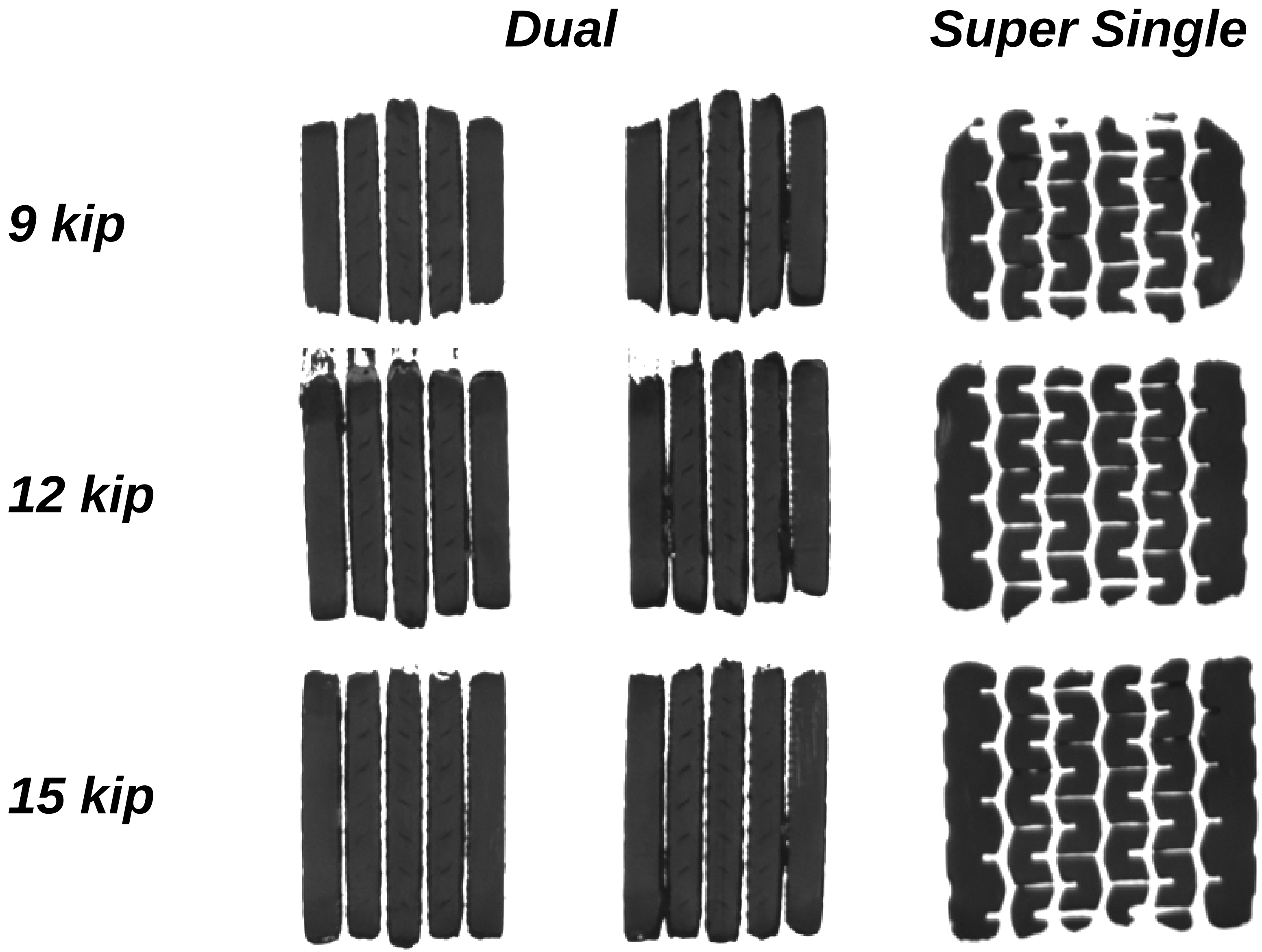
Tire Imprints

- Dimensions measured from tire imprints
- Contact stress taken from literature

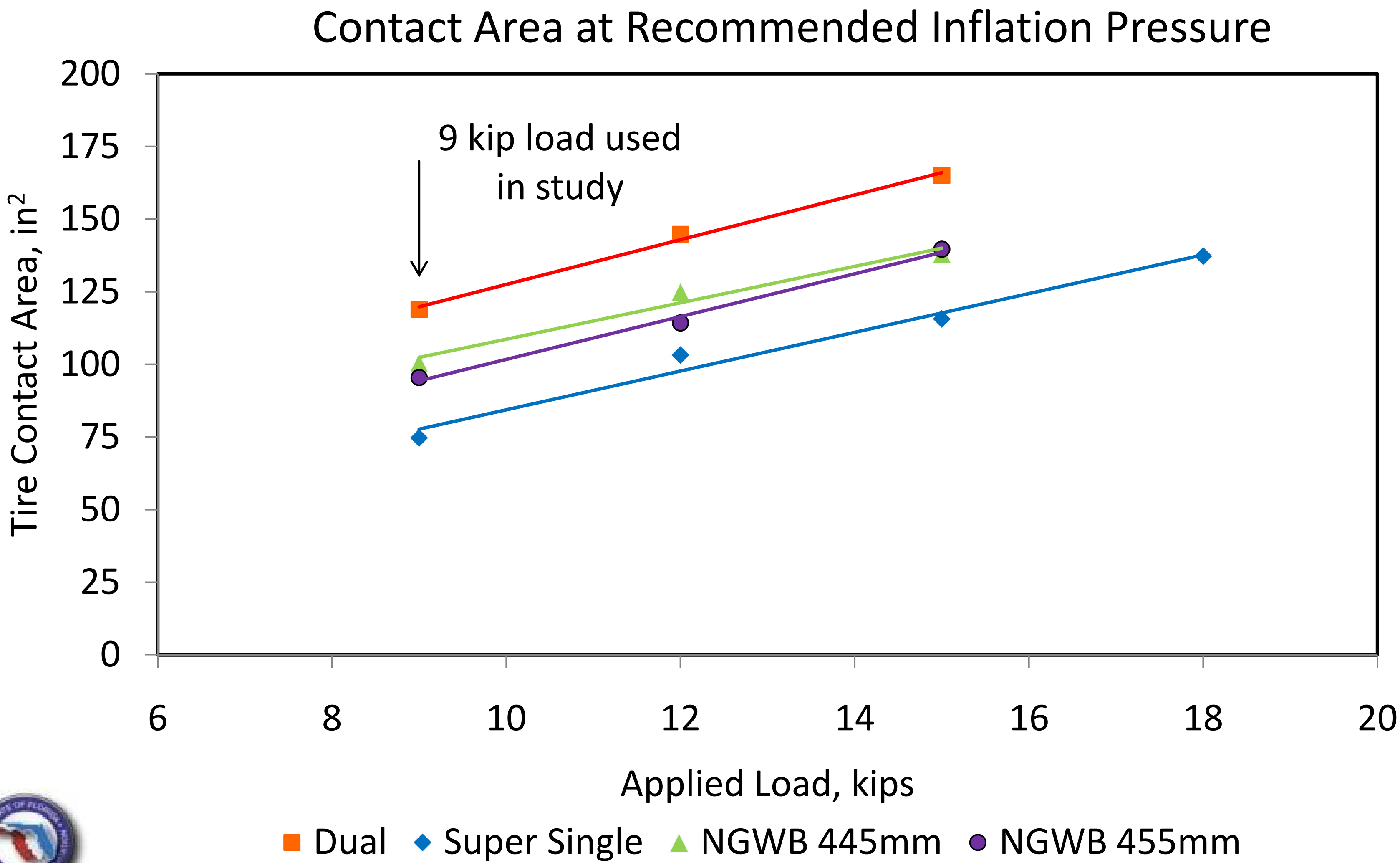
Tire Imprints



Tire Imprints

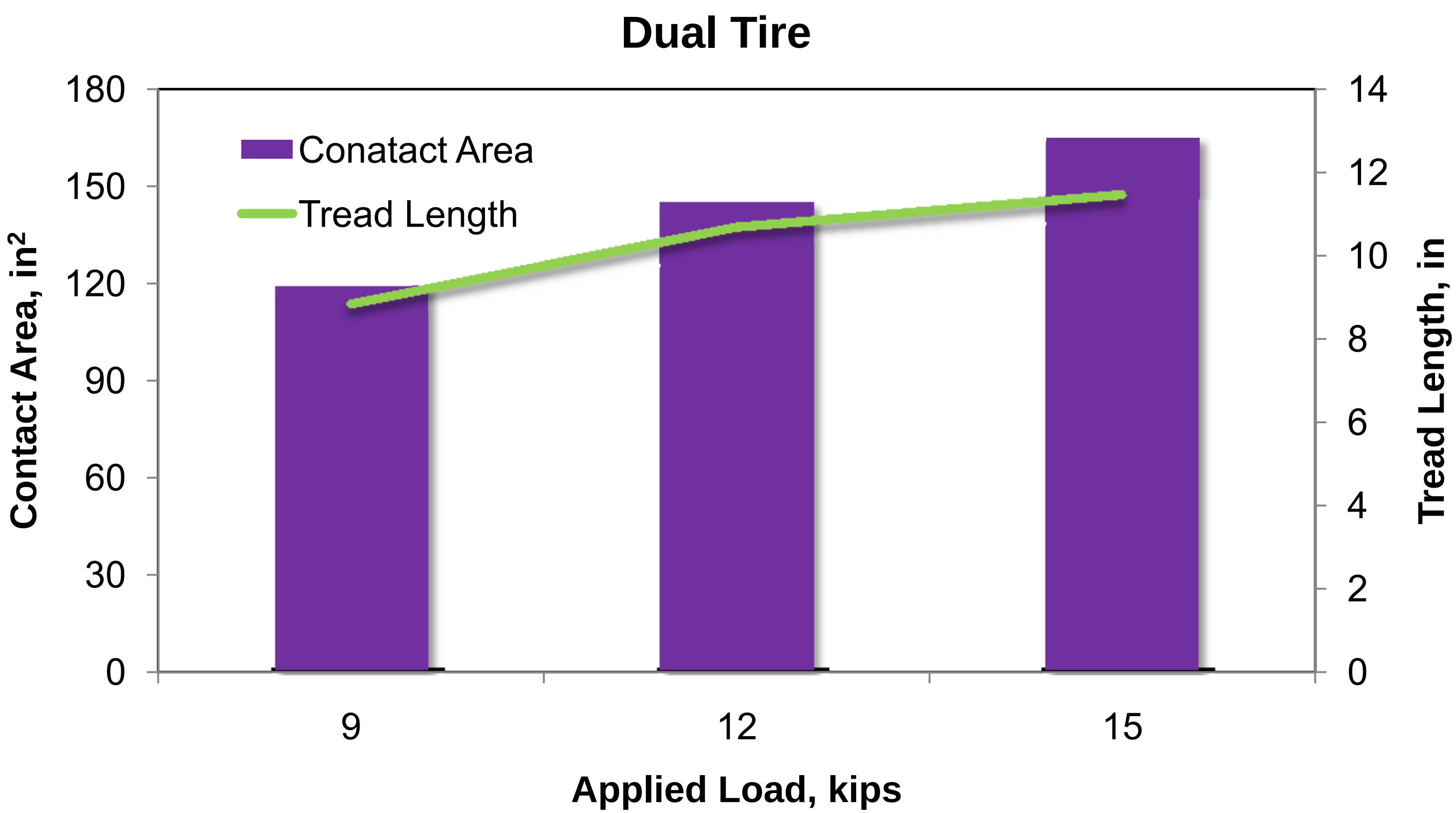


Tire Contact Areas

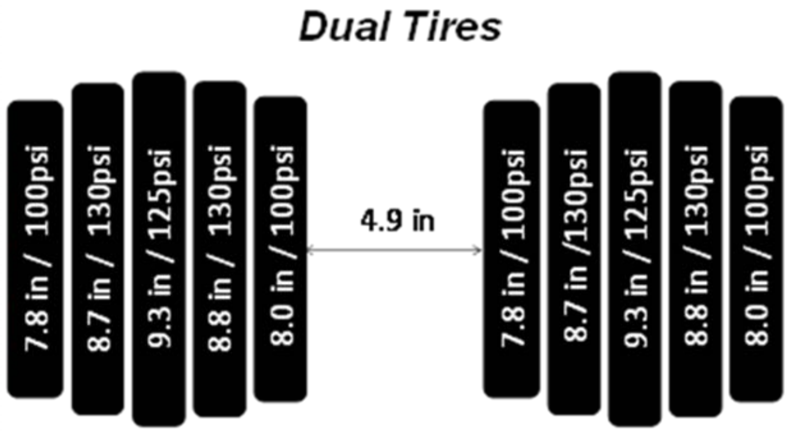


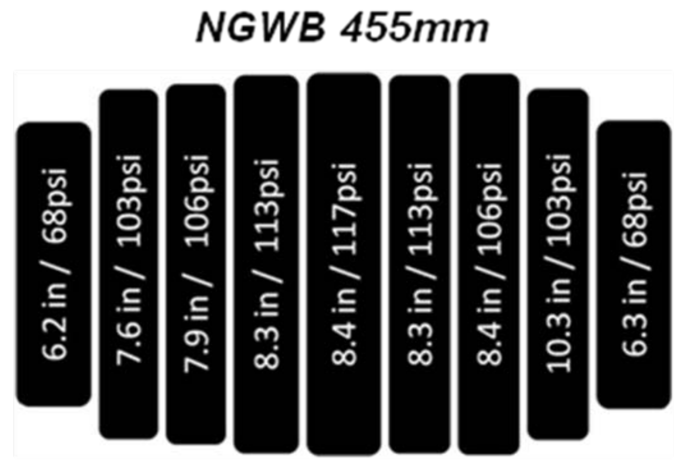
Tread Length

- As the load increases, the tread length increases

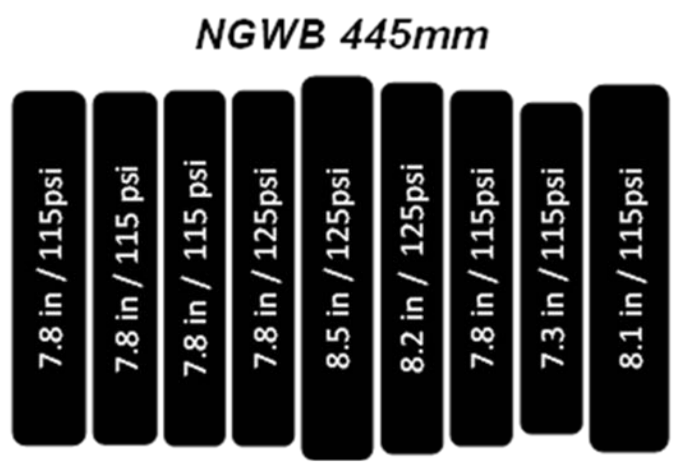


Tire Model



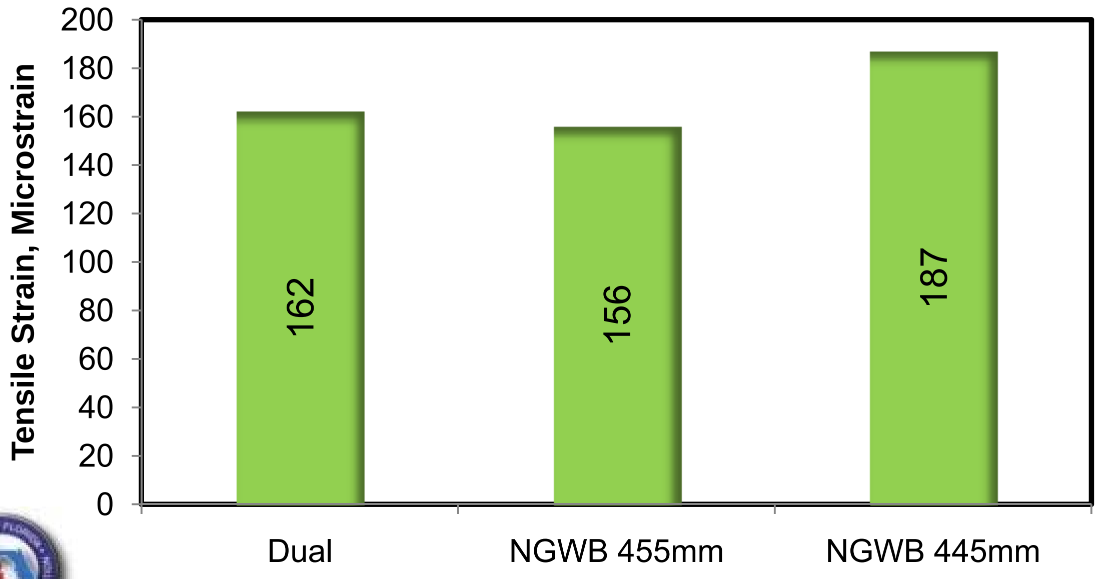


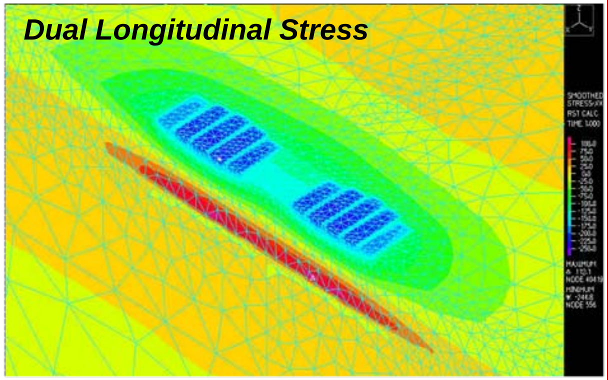
Note:
1 inch = 25.4 mm
1 psi = 6.89 kPa

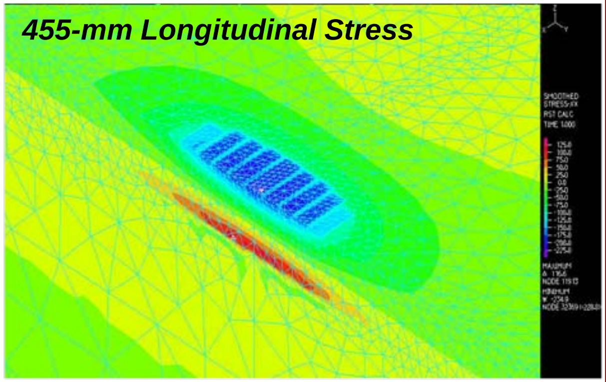


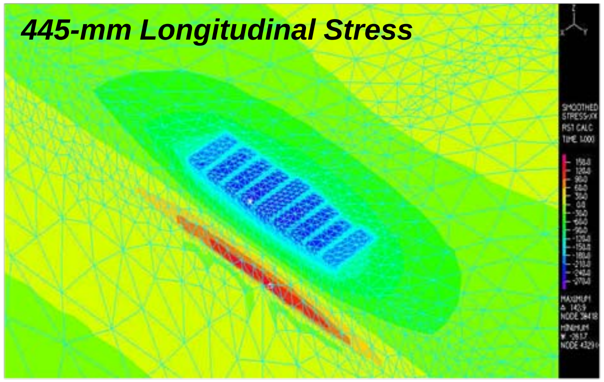
Bottom-Up Fatigue Cracking

- Similar strains predicted for Dual and NGWB 455mm single tire
- Predicted greater strain for NGWB 445mm tire







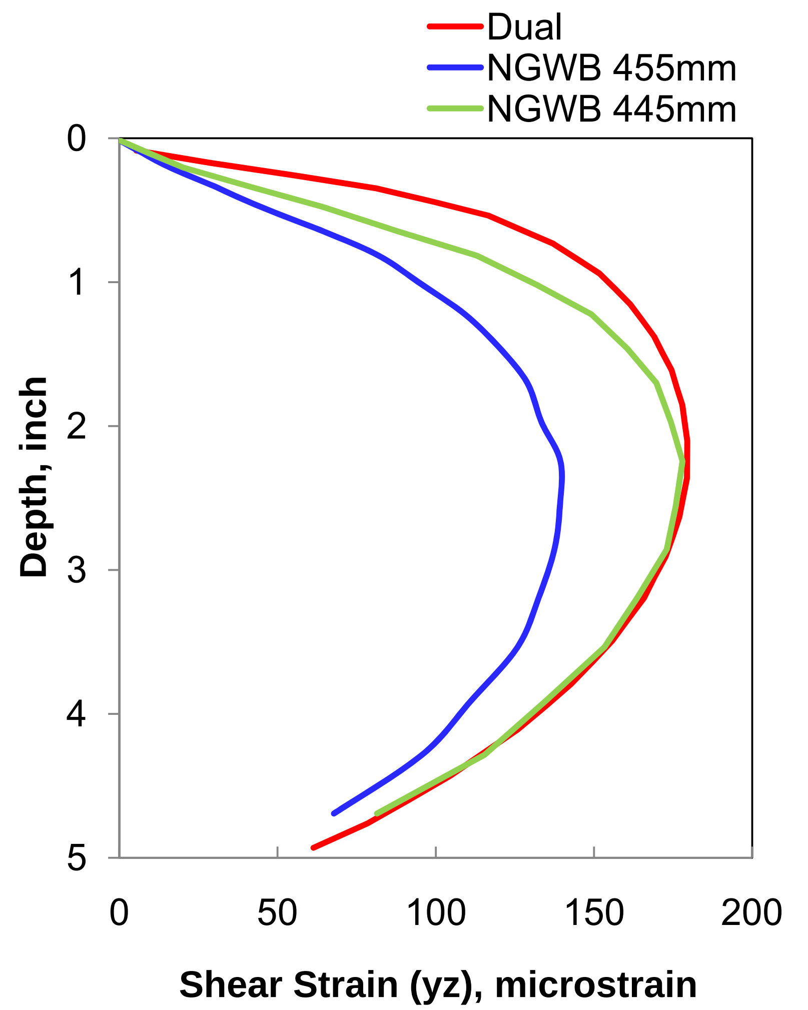


Top-Down Cracking

- Critical strains for top-down cracking
  - ✓ Top-down cracking is primarily observed as longitudinal cracks within or near the wheel path
  - ✓ Shear strain below the tire edge is thought to be critical in initial formation
  - ✓ Tensile strain away from tire edge may be critical for formation and propagation of cracks, particularly for older pavements subjected to aging

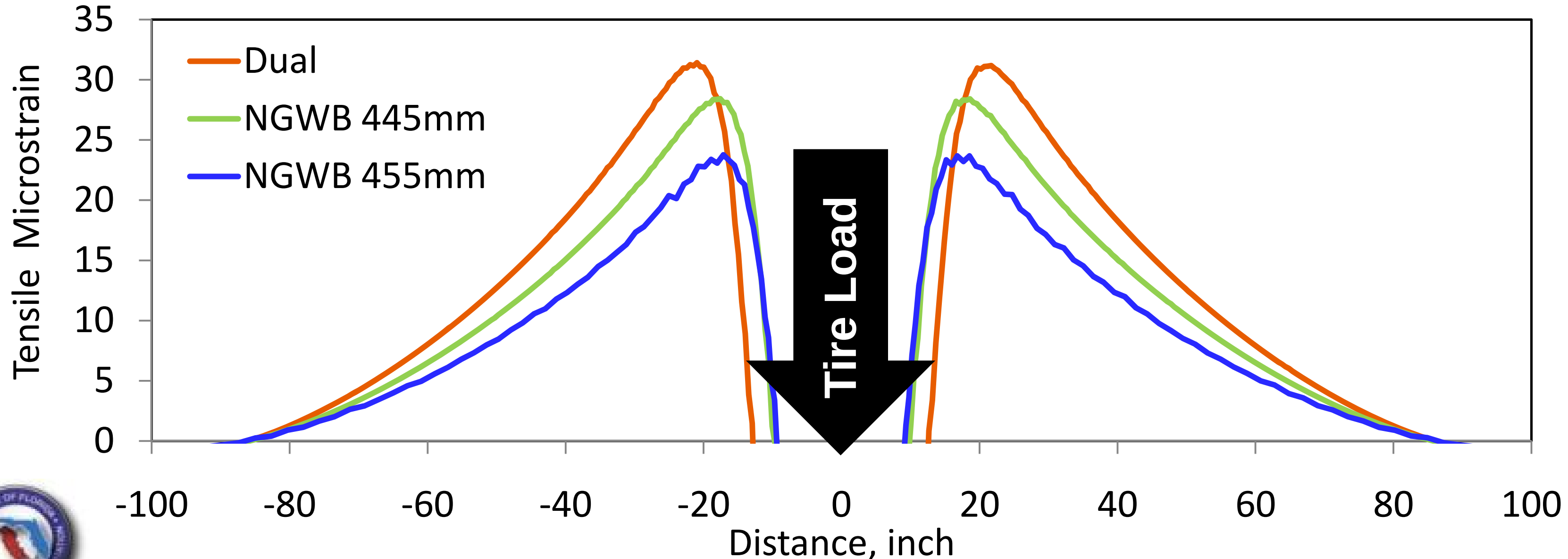
Shear Strain at the Tire Edge

- 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

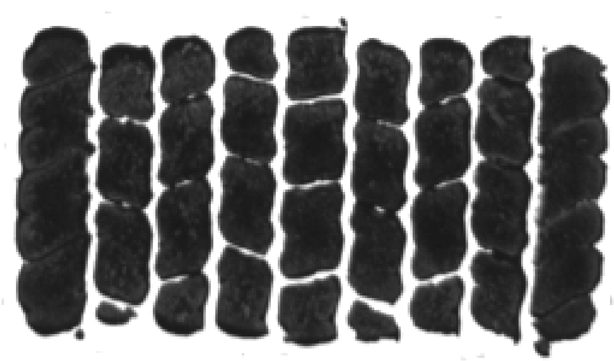
- Maximum tensile strains from both new wide-base single tires are less than dual
- Maximum tensile strain is approximately 9 to 10 inches from tire edge



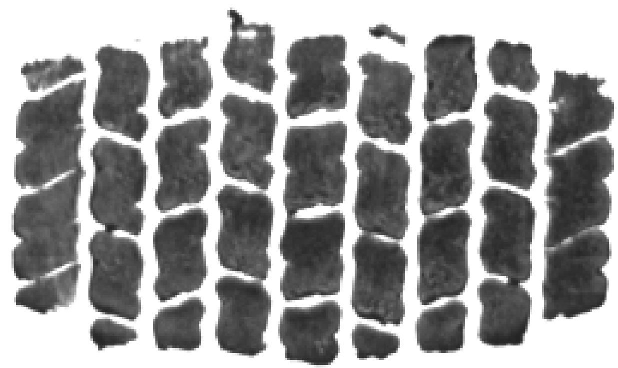
General Findings

- Increased tire contact area reduces pavement damage
- Tire/tread geometry plays a role in pavement damage

NGWB 445 mm at 100 psi



NGWB 455 mm at 100 psi



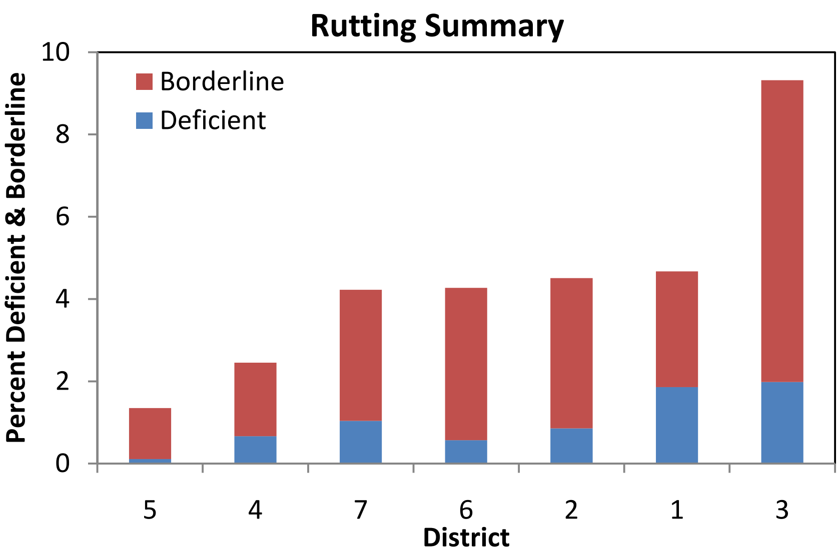
- In general, findings agree with literature

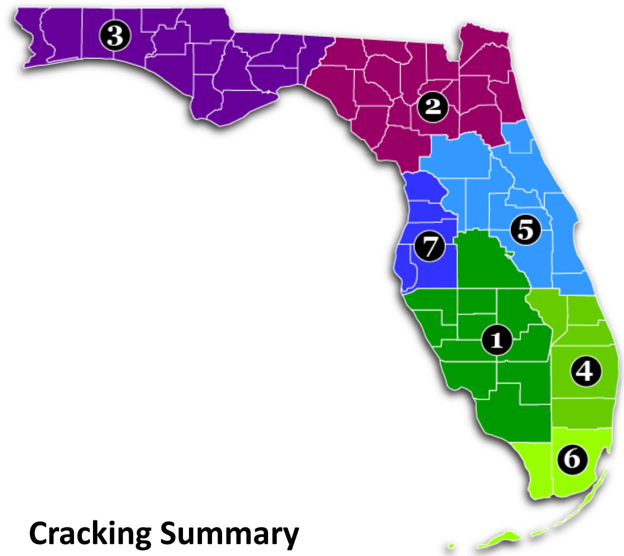
Pavement Damage Summary

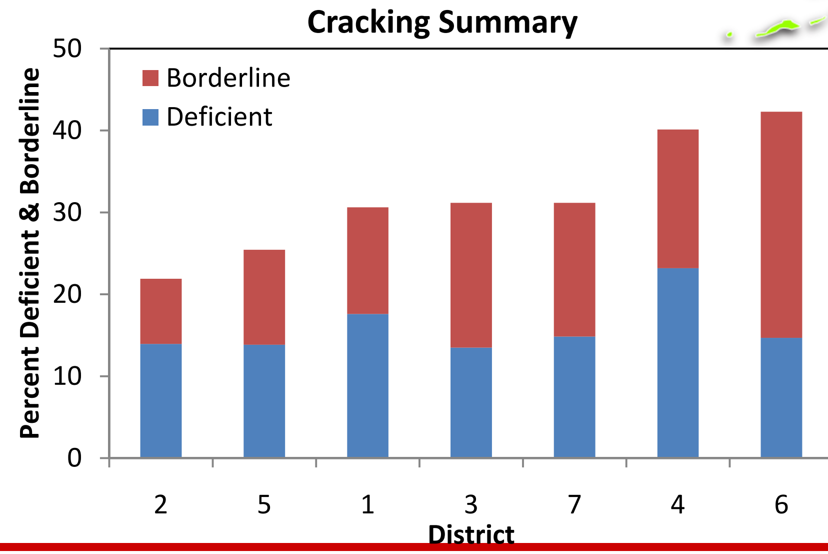
- Comparisons to a standard dual tire:
  - ✓ Rutting (APT)
    - 455mm: Similar rutting performance
    - 445mm: Rutted twice as fast on dense-graded mixture
    - Super Single: Rutted significantly greater on both mixtures
  - ✓ Bottom-up cracking (FEA)
    - 455mm: Predicted to induce similar tensile strain
    - 445mm: Predicted to induce greater tensile strain
  - ✓ Top-down cracking (FEA)
    - 455mm: Predicted to induce less shear strain and tensile strain
    - 445mm: Predicted to induce similar shear strain and less tensile strain

Impact on Florida Roadways

- 2008 pavement condition survey shows many roadway miles are borderline deficient in cracking and rutting







Impact on Florida Roadways

- Cracking patterns will likely continue similar trend (perhaps slight increase in bottom-up cracking if 445mm wide-base tire is added)
- Rutting will likely accelerate if the 445mm wide-base single tire is added