Impact of Wide-Base Single Tires on Pavement Damage
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)
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°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
# Pavement Sections for APT Study

Open-Grade Surface  
Lanes 2, 3, and 4

<table>
<thead>
<tr>
<th>0.75 inch (19-mm) FC-5, ARB-12</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 inch (50-mm) SP-12.5, PG 67-22, 93% Gmm</td>
</tr>
<tr>
<td>3.5 inch (89-mm) Existing SP-12.5</td>
</tr>
<tr>
<td>10.5 inch (265-mm) Limerock Base Course</td>
</tr>
<tr>
<td>12 inch (305-mm) Granular Subbase</td>
</tr>
</tbody>
</table>

Dense-Grade Surface  
Lanes 5, 6, and 7

<table>
<thead>
<tr>
<th>2 inch (50-mm) FC-12.5, ARB-5 93% Gmm</th>
</tr>
</thead>
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<tr>
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Note: ARB-12 represents 12% asphalt rubber binder.
Loading Conditions

- Each tire inflated to recommended pressure
- 9 kip load
- 5-inch wander
- Constant temperature maintained at 50°C
### Rut Performance

#### Dense Graded Surface (FC-12.5)

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Passes Required for a 12.5-mm Rut Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dual Tires</td>
</tr>
<tr>
<td>Average</td>
<td>169,000</td>
</tr>
<tr>
<td>Rut Damage Ratio</td>
<td>1.0</td>
</tr>
</tbody>
</table>
**Rut Performance**

**Open Graded Surface (FC-5)**

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Dual Tires</th>
<th>Super Single</th>
<th>NGWB 445mm</th>
<th>NGWB 455mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>46,000</td>
<td>20,000</td>
<td>33,000</td>
<td>44,000</td>
</tr>
<tr>
<td>Rut Damage Ratio</td>
<td>1.0</td>
<td>2.3</td>
<td>1.4</td>
<td>1.0</td>
</tr>
</tbody>
</table>
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/m³)

- 10.5 in (267mm) limerock base
  - $E = 80$ ksi (552 MPa)
  - $v = 0.40$
  - Density = 115 pcf (1,842 kg/m³)

- 36 in (915mm) subgrade
  - $E = 19$ ksi (131 MPa)
  - $v = 0.45$
  - Density = 113 pcf (1,810 kg/m³)
Tire Imprints

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

445mm

9 kip

12 kip

15 kip

455mm
Tire Imprints

Dual

Super Single

9 kip

12 kip

15 kip
Tire Contact Areas

Contact Area at Recommended Inflation Pressure

9 kip load used in study

Tire Contact Area, in²

Applied Load, kips

- Dual
- Super Single
- NGWB 445mm
- NGWB 455mm
As the load increases, the tread length increases.
Tire Model

Dual Tires

NGWB 455mm

NGWB 445mm

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

[Graph showing tensile strain in microstrains for Dual, NGWB 455mm, and NGWB 445mm tires.]

Dual Longitudinal Stress
455-mm Longitudinal Stress
445-mm Longitudinal Stress
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