Factors that Affect Road Life

**Characteristics of the Road**
- Design
- Materials
- Construction Quality
- Maintenance

Factors interact with each other

**Things Imposed on the Road**
- Environment
- **Traffic Loads**

Truck Axle Configuration Effect on Roads

Aaron Breyfogle, PE, Transportation Research Engineer
David Huft, Research Program Manager
October 22, 2014

Tandem Axle with Lift Axle

- Heavy vehicle traffic is increasing rapidly on local roads
  - Size
  - Weight
  - Length
  - Number of vehicles
  - Number of units
  - Number of axles

Tandem Truck with Pup Trailer
5-Axle Tractor-Semitrailor Gravel Hauler

Typical 6-Axle Configuration

Typical 7-Axle Configuration

18-Wheel Tractor Trailer with Two-Axle Pup (Super Single Tires)
Tractor-Semitrailer and Pup Trailer with Single Axles, Dual Tires

Double Trailer Configuration

Multi-Axle Configuration Seen in Codington County, SD

Typical Single-Axle Grain Cart

Modern Grain Cart – Large and Becoming More Common

Road “Wear” or “Damage” Depends Upon

- Axle Weight
- Axle Group Configuration
- Tire Width
- Number of Applications
- Vehicle Speed
Strain at the Bottom of HMA

Relationship of Load to Damage

- Deflection $d$ is proportional to axle group weight $W$
  $$d \propto W$$
- Damage $D$ is proportional to 4th power of deflection $d$
  $$D \propto d^4$$

4th Power Damage Relationship

AASHO Road Test 1956-1960

Road test determined relationship between axle load and road damage

$$\frac{W}{W_1} = \left[ \frac{L_1 + L_2}{L_1 + L_2} \right]^{10} \cdot \left[ L_2 \right]^{15}$$

Near Ottawa, Illinois
Grouped Axles (Tandem, Tridem)

- Grouped axles share load equally
- Deflection drops proportionately
- Grouped axles cause a single deflection

Result: Damage is reduced greatly

18,000 lb single = 1 ESAL
34,000 lb tandem = 1 ESAL
43,000 lb tridem ≈ 0.6 ESAL

Pavement Damage is Additive

- Vehicle Damage = Σ Axle Group Damages
- Cumulative Damage = Σ Vehicle Damages

<table>
<thead>
<tr>
<th></th>
<th>Tandem Rear</th>
<th>Front</th>
<th>Vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>34,000</td>
<td>13,200</td>
<td>47,200</td>
</tr>
<tr>
<td>ESALS</td>
<td>1.06</td>
<td>0.25</td>
<td>1.31</td>
</tr>
</tbody>
</table>

Effect of Overweight Loads

- Seemingly small overloads increase road damage significantly (4th power relationship)
- 10% overload = 46% damage increase
- 20% overload = 107% damage increase

<table>
<thead>
<tr>
<th>Axle Group</th>
<th>Legal</th>
<th>5% Over</th>
<th>10% Over</th>
<th>20% Over</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single</td>
<td>Weight</td>
<td>20,000</td>
<td>21,000</td>
<td>22,000</td>
</tr>
<tr>
<td></td>
<td>ESALS</td>
<td>1.52</td>
<td>1.85</td>
<td>2.23</td>
</tr>
<tr>
<td>Tandem</td>
<td>Weight</td>
<td>34,000</td>
<td>35,700</td>
<td>37,400</td>
</tr>
<tr>
<td></td>
<td>ESALS</td>
<td>1.06</td>
<td>1.29</td>
<td>1.55</td>
</tr>
<tr>
<td>Tridem</td>
<td>Weight</td>
<td>43,000</td>
<td>45,150</td>
<td>47,300</td>
</tr>
<tr>
<td></td>
<td>ESALS</td>
<td>0.59</td>
<td>0.71</td>
<td>0.86</td>
</tr>
</tbody>
</table>

Restrictions to Limit Damage

<table>
<thead>
<tr>
<th>Restriction Type</th>
<th>Typical Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross Weight</td>
<td>Limit large truck configurations (SD has no gross weight limit, but some counties have)</td>
</tr>
<tr>
<td>Axle Weight</td>
<td>Limit damage during spring breakup and to bridges</td>
</tr>
<tr>
<td>Speed</td>
<td>Limit damage during spring breakup (counterproductive) and to bridges (can be productive)</td>
</tr>
</tbody>
</table>
Spring Load Restrictions

Moisture in base and subgrade freezes and thaws top-down, causing moisture to be drawn upward and trapped during spring thaw.

Speed Restrictions

Slower speed allows viscoelastic pavement to deflect more, increasing pavement damage.

Gross Weight Restrictions

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Gross Weight</th>
<th>Estimated Payload</th>
<th>ESALS</th>
<th>ESALS per 1000 tons Payload</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>47,200</td>
<td>30,000 (64%)</td>
<td>1.31</td>
<td>87.4</td>
</tr>
<tr>
<td></td>
<td>81,200</td>
<td>50,000 (62%)</td>
<td>2.37</td>
<td>94.9</td>
</tr>
<tr>
<td></td>
<td>99,700</td>
<td>66,000 (66%)</td>
<td>1.47</td>
<td>44.5</td>
</tr>
<tr>
<td></td>
<td>112,200</td>
<td>75,000 (67%)</td>
<td>3.39</td>
<td>90.4</td>
</tr>
</tbody>
</table>

Impacts of Long, Multi-Axle Loads on Local Roads

- Widened roadway and approaches at turn locations
- Scuffed pavements
Impact of Off-Road Vehicles

- Terragator (empty)
- Terragator (loaded)
- Grain Cart (legal)
- Grain Cart (+50%)
- Scraper (empty)

ESALs per Vehicle

AC/Base Thickness

- <1.5"/6"
- 3"/6"
- 5"/6"
- 7"/12"

**Effect of Wide-Base Super-Single Tires on Pavements**

- In SD, wide-base tires could substitute for standard duals, but at lower legal weight on single axles
  - 17,500 lb for 445mm tires
  - 18,000 lb for 455 mm tires
  - 20,000 lb for dual-tire configurations
- Research evaluated if same load could be allowed

**Wide-Base Super-Single Tires**

- Introduced to North America in 1980s
- Design for high-speed long-distance carriers
- Fuel economy
- Reduced tire recycling
- Increased payload
- Better ride comfort
- Better vehicle handling
Early & Recent Wide-Base Tires

<table>
<thead>
<tr>
<th>Early Generation</th>
<th>New Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>■ 385mm, 425mm</td>
<td>■ 445mm, 455mm</td>
</tr>
<tr>
<td>■ High tire pressure</td>
<td>■ Lower tire pressure</td>
</tr>
<tr>
<td>■ Small contact area</td>
<td>■ 15-18% wider</td>
</tr>
<tr>
<td>■ High contact stress</td>
<td>■ Lower damage ratios, vary by:</td>
</tr>
<tr>
<td>■ High damage ratios</td>
<td></td>
</tr>
<tr>
<td>– 1.5-2.0 for rutting</td>
<td></td>
</tr>
<tr>
<td>– 2.0-4.0 for fatigue cracking</td>
<td></td>
</tr>
</tbody>
</table>

Damage ratio is compared to dual tires of same axle weight

Damage Ratios on SD Pavements

<table>
<thead>
<tr>
<th>Type</th>
<th>AC</th>
<th>Base</th>
<th>Damage Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Depth</td>
<td>&gt;10”</td>
<td>no</td>
<td>1.08</td>
</tr>
<tr>
<td>Thick</td>
<td>5-10”</td>
<td>yes</td>
<td>0.88</td>
</tr>
<tr>
<td>Thin on Strong</td>
<td>2-5”</td>
<td>&gt; 8”</td>
<td>1.88</td>
</tr>
<tr>
<td>Thin on Weak</td>
<td>2-5”</td>
<td>&lt; 8”</td>
<td>1.88*</td>
</tr>
<tr>
<td>AC on PCCP</td>
<td>yes</td>
<td>PCC</td>
<td>1.0**</td>
</tr>
<tr>
<td>Bituminous surface treatment</td>
<td></td>
<td></td>
<td>1.88*</td>
</tr>
<tr>
<td>PCC Pavements</td>
<td></td>
<td></td>
<td>1.0**</td>
</tr>
</tbody>
</table>

Damage ratio is approximately 1 on thick asphalt, but higher on thin pavements. Effect on unpaved roads is not known.

SB154: Allows 445/455 mm Tires on Major SD Highways

and “any locally designated highway within the corporate limits of any municipality adjacent to the Interstate highway system”

Questions?

1. Please contact:  
   David L. Huft  
   SDDOT Office of Research  
   700 East Broadway  
   Pierre, SD 57501-2586  
   Phone: 605.773.3358  
   Fax: 605.773.4713  
   dave.huft@state.sd.us

2.

3.

4. Thank You!

5.