# Truck Axle Configuration Effect on Roads

Connecting South Dakota and the Nation

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## Factors that Affect Road Life

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

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

Factors interact with each other

Federal Highway Administration
http://www.fhwa.dot.gov/pavement/management/rwd/or/

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## Tandem Axle with Lift Axle

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

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## Tandem Truck with Pup Trailer

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## 5-Axle Tractor-Semitrailer Gravel Hauler


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## Typical 6-Axle Configuration


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## Typical 7-Axle Configuration


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## 18-Wheel Tractor Trailer with Two-Axle Pup (Super Single Tires)

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## Tractor-Semitrailer and Pup Trailer with Single Axles, Dual Tires

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## Double Trailer Configuration


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## Double Trailer Configuration

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## Tire Mix: Standard Single, Super Single, Standard Single


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## Multi-Axle Configuration Seen in Codington County, SD

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## Typical Single-Axle Grain Cart

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## Modern Grain Cart – Large and Becoming More Common

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## Road "Wear" or "Damage" Depends Upon

- Axle Weight
- Axle Group Configuration
- Tire Width
- Number of Applications
- Vehicle Speed

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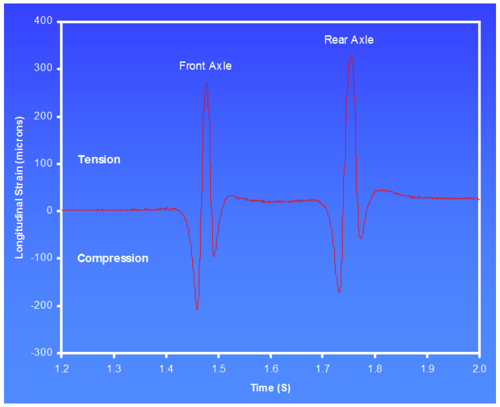
## Strain at the Bottom of HMA

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## AASHO Road Test 1956-1960

Near Ottawa, Illinois

Road test determined relationship between axle load and road damage

$$\frac{W_x}{W_{18}} = \left[\frac{L_{18}+L_{2s}}{L_x+L_{2x}}\right]^{4.79}\left[\frac{10^{G/\beta_x}}{10^{G/\beta_{18}}}\right]\left[L_{2x}\right]^{4.33}$$

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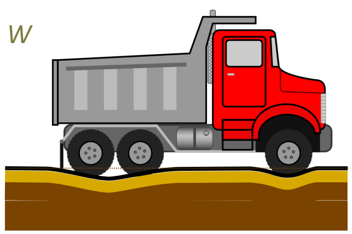
## Relationship of Load to Damage

- Deflection *d* is proportional to axle group weight *W*

  $d \propto W$

- Damage *D* is proportional to 4th power of deflection *d*

  $D \propto d{\uparrow}4$



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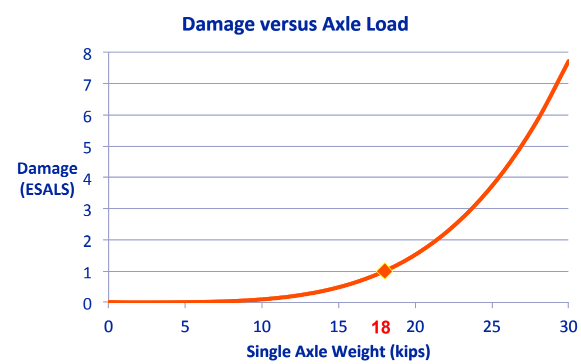
## 4th Power Damage Relationship

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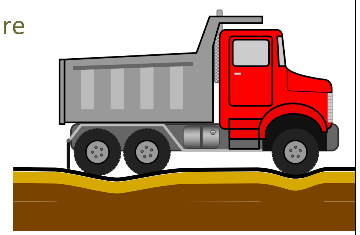
## Grouped Axles (Tandem, Tridem)

- 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

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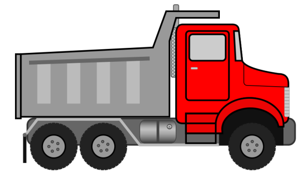
## Pavement Damage is Additive

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



| | Tandem Rear | Front | Vehicle |
|---|---|---|---|
| Weight | 34,000 | 13,200 | 47,200 |
| ESALS | 1.06 | 0.25 | 1.31 |

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## Effect of Overweight Loads

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

| Axle Group | | Legal | 5% Over | 10% Over | 20% Over |
|---|---|---|---|---|---|
| Single | Weight | 20,000 | 21,000 | 22,000 | 24,000 |
| | ESALS | 1.52 | 1.85 | 2.23 | 3.16 |
| Tandem | Weight | 34,000 | 35,700 | 37,400 | 40,800 |
| | ESALS | 1.06 | 1.29 | 1.55 | 2.20 |
| Tridem | Weight | 43,000 | 45,150 | 47,300 | 51,600 |
| | ESALS | 0.59 | 0.71 | 0.86 | 1.22 |

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## Restrictions to Limit Damage

| Restriction Type | Typical Application |
|---|---|
| Gross Weight | Limit large truck configurations (SD has no gross weight limit, but some counties have) |
| Axle Weight | Limit damage during spring breakup and to bridges |
| Speed | Limit damage during spring breakup (counterproductive) and to bridges (can be productive) |

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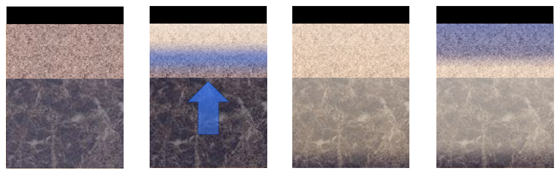
## Spring Load Restrictions

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



| moist unfrozen | moist freezing | fully frozen | thawing weak |
|---|---|---|---|
| Summer | Fall | Winter | Spring |

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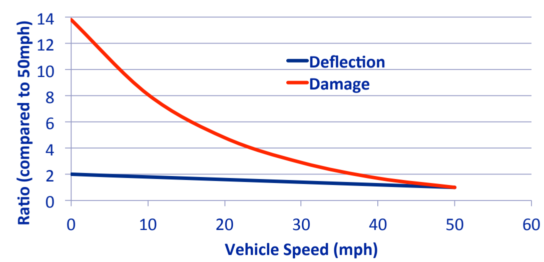
## Speed Restrictions

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

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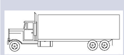
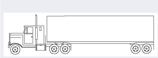
## Gross Weight Restrictions

| Configuration | Gross Weight | Estimated Payload | ESALS | ESALS per 1000 tons Payload |
|---|---|---|---|---|
|  | 47,200 | 30,000 (64%) | 1.31 | 87.4 |
|  | 81,200 | 50,000 (62%) | 2.37 | 94.9 |
|  | 99,700 | 66,000 (66%) | 1.47 | 44.5 |
|  | 112,200 | 75,000 (67%) | 3.39 | 90.4 |

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## Impacts of Long, Multi-Axle Loads on Local Roads

- Widened roadway and approaches at turn locations
- Scuffed pavements

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## Impact of Off-Road Vehicles




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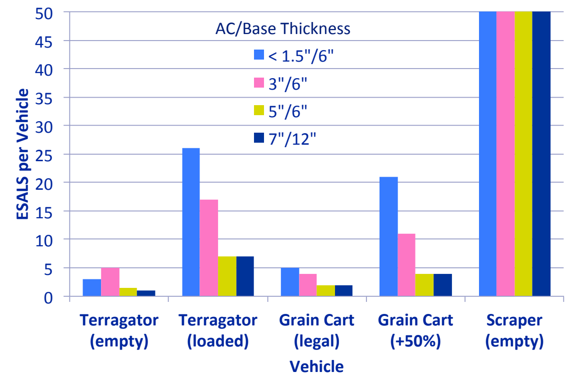


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## Effect of Wide-Base Super-Single Tires on Pavements

- 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

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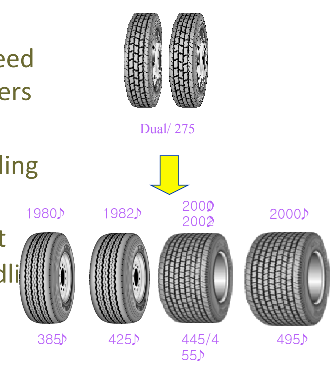
## Wide-Base Super-Single Tires

- 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 handli

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## Early & Recent Wide-Base Tires

**Early Generation**
- 385mm, 425mm
- High tire pressure
- Small contact area
- High contact stress
- High damage ratios
  - 1.5-2.0 for rutting
  - 2.0-4.0 for fatigue cracking

**New Generation**
- 445mm, 455mm
- Lower tire pressure
- 15-18% wider
- Lower damage ratios, vary by:
  - damage type
  - pavement structure
  - climate condition

Damage ratio is compared to dual tires of same axle weight

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## Damage Ratios on SD Pavements

| Type | AC | Base | Damage Ratio |
|---|---|---|---|
| Full Depth | >10” | no | 1.08 |
| Thick | 5-10” | yes | 0.88 |
| Thin on Strong | 2-5” | > 8” | 1.88 |
| Thin on Weak | 2-5” | < 8” | 1.88* |
| AC on PCCP | yes | PCC | 1.0** |
| Bituminous surface treatment | | | 1.88* |
| PCC Pavements | | | 1.0** |

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

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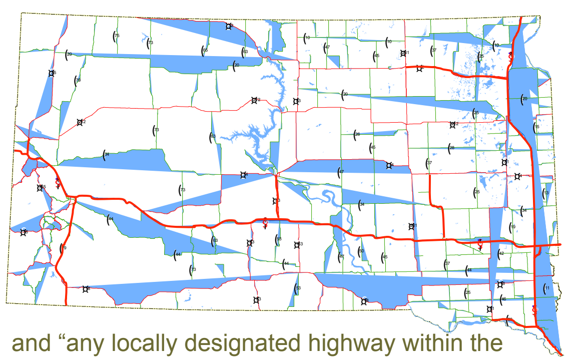
## SB154: Allows 445/455 mm Tires on Major SD Highways



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

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## Questions?

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Thank You!

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