Rural Road Safety Attitude – Get One!

Hosted by Ray Brushart, Safety Circuit Rider
Ohio LTAP Center
It Starts with One...
The Time is...

- NOW
- LATER
• 2008 – FHWA began promoting certain infrastructure-oriented safety treatments and strategies to reduce serious injuries and fatalities on US highways. This became known as the Proven Safety Countermeasures Initiative. This list was updated in 2012 and again in 2017.

• This list of Proven Safety Countermeasures has now reached a total of 20 treatments and strategies that practitioners can implement to successfully address roadway departure, intersection, and pedestrian and bicycle crashes.

• Transportation agencies are strongly encouraged to consider these research proven safety countermeasures.
Guidance Memorandums on Promoting the Implementation of Proven Safety Countermeasures:

2008  2012  2017

Select any of the following icons to learn more about the specific countermeasure

- Roadside Design Improvement at Curves
- Reduced Left-Turn Conflict Intersections
- Systemic Application of Multiple Low Cost Countermeasures at Stop Controlled Intersections
- Leading Pedestrian Interval
- Local Road Safety Plan
- USLIMITS2
- Enhanced Delineation and Friction for Horizontal Curves
- Longitudinal Rumble Strips and Stripes on Two-Lane Roads
- Median Barrier
- Safety Edges
- Backplates with Retroreflective Borders
- Corridor Access Management
- Dedicated Left- and Right-Turn Lanes at Intersections
- Roundabouts
- Yellow Change Intervals
- Medians and Pedestrian Crossing Islands in Urban and Rural Areas
- Pedestrian Hybrid Beacon
- Road Diet
- Walkways
- Road Safety Audit
FHWA - Roadway Departure Safety
Which of these 20 Proven Countermeasures are applicable to 2-Lane Rural Roads?

- Enhanced Delineation and Friction at Horizontal Curves
- Systemic Application of Multiple Low-Cost Countermeasures at Stop-Controlled Intersections
- Longitudinal Rumble Strips and Stripes on 2-Lane Roads
- The Safety Edge
- Roadside Design Improvement at Curves
- Local Road Safety Plan
- Road Safety Audits
Roadway Departure Crash - A non-intersection crash in which a vehicle crosses an edge line, a centerline, or otherwise leaves the traveled way.

National Fatal Crashes
(Average 2009-2011)
30,305 Fatal Crashes/Year
15,783 Fatal RwD Crashes/Year

Source: NHSTA FARS
Systemic Approach to Safety

1. Install “systematically” at numerous sections
   - Not limited to the highest crash locations

2. Over-representation
   - 5% of mileage = 20% of the statewide problem

- Reverse of the traditional approach
- Start with countermeasures
  - Effective, low-cost
  - Find sections with targeted crash types
- Low Cost Countermeasures
- Find Over-representation
- Statewide reduction of RD fatalities
Exercise

• Look at Fatal Crashes plotted in rural Humboldt County California over four years (2005 through 2008)
• Can you see a place that needs to be treated?
Humboldt County Fatal Crashes

Source: http://www.safetrec-demo.berkeley.edu/index.php
## Fatal Crash Types

### 2005

<table>
<thead>
<tr>
<th>Factor</th>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: Head-On</td>
<td>424</td>
<td>11%</td>
</tr>
<tr>
<td>B: Sidewipe</td>
<td>173</td>
<td>5%</td>
</tr>
<tr>
<td>C: Rear End</td>
<td>305</td>
<td>8%</td>
</tr>
<tr>
<td>D: Broadside</td>
<td>720</td>
<td>19%</td>
</tr>
<tr>
<td>E: Hit Object</td>
<td>1017</td>
<td>27%</td>
</tr>
<tr>
<td>F: Overturned</td>
<td>441</td>
<td>12%</td>
</tr>
<tr>
<td>G: Vehicle/Pedestrian</td>
<td>658</td>
<td>17%</td>
</tr>
<tr>
<td>H: Other</td>
<td>75</td>
<td>2%</td>
</tr>
<tr>
<td>NS: Not Stated</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>UN: Unknown</td>
<td>11</td>
<td>0%</td>
</tr>
<tr>
<td>OTHERS</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>3822</td>
<td>100%</td>
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### 2006

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<th>Percent</th>
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</thead>
<tbody>
<tr>
<td>A: Head-On</td>
<td>447</td>
<td>12%</td>
</tr>
<tr>
<td>B: Sidewipe</td>
<td>173</td>
<td>5%</td>
</tr>
<tr>
<td>C: Rear End</td>
<td>325</td>
<td>9%</td>
</tr>
<tr>
<td>D: Broadside</td>
<td>595</td>
<td>18%</td>
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<tr>
<td>E: Hit Object</td>
<td>1007</td>
<td>27%</td>
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<tr>
<td>F: Overturned</td>
<td>408</td>
<td>11%</td>
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<tr>
<td>G: Vehicle/Pedestrian</td>
<td>851</td>
<td>17%</td>
</tr>
<tr>
<td>H: Other</td>
<td>79</td>
<td>2%</td>
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<tr>
<td>NS: Not Stated</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>UN: Unknown</td>
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<tr>
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### 2007

<table>
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<tr>
<td>A: Head-On</td>
<td>390</td>
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<td>B: Sidewipe</td>
<td>133</td>
<td>4%</td>
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<td>C: Rear End</td>
<td>315</td>
<td>9%</td>
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<tr>
<td>D: Broadside</td>
<td>608</td>
<td>17%</td>
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<tr>
<td>E: Hit Object</td>
<td>1024</td>
<td>28%</td>
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<td>F: Overturned</td>
<td>414</td>
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<td>G: Vehicle/Pedestrian</td>
<td>585</td>
<td>16%</td>
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<tr>
<td>H: Other</td>
<td>79</td>
<td>2%</td>
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<tr>
<td>NS: Not Stated</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>UN: Unknown</td>
<td>9</td>
<td>0%</td>
</tr>
<tr>
<td>OTHERS</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>3557</td>
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### 2008

<table>
<thead>
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<th>Number</th>
<th>Percent</th>
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<tbody>
<tr>
<td>A: Head-On</td>
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</tr>
<tr>
<td>B: Sidewipe</td>
<td>148</td>
<td>5%</td>
</tr>
<tr>
<td>C: Rear End</td>
<td>267</td>
<td>8%</td>
</tr>
<tr>
<td>D: Broadside</td>
<td>507</td>
<td>16%</td>
</tr>
<tr>
<td>E: Hit Object</td>
<td>883</td>
<td>28%</td>
</tr>
<tr>
<td>F: Overturned</td>
<td>305</td>
<td>10%</td>
</tr>
<tr>
<td>G: Vehicle/Pedestrian</td>
<td>589</td>
<td>19%</td>
</tr>
<tr>
<td>H: Other</td>
<td>104</td>
<td>3%</td>
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<tr>
<td>NS: Not Stated</td>
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<td>0%</td>
</tr>
<tr>
<td>UN: Unknown</td>
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<td>0%</td>
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<tr>
<td>OTHERS</td>
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<td>0%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>3113</td>
<td>100%</td>
</tr>
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</table>

Source: http://www.safetrec-demo.berkeley.edu/index.php
fatal crash locations

are random
fatal crash types are predictable
Township Road Crashes by Severity
Belmont County - Mead Township
Enhanced Delineation and Friction for Horizontal Curves

**Enhanced Delineation Treatments**

- can alert drivers in advance of the curve and vary by the severity of the curvature and operating speed. Price ranges for these strategies are low to moderate. Treatments include the following:
Keep Vehicles on the Roadway

- Markings & Delineation
- Signs
- Rumbles
- Revising Widths
- Friction
  - Skid Resistant
  - High Friction
Delineation to Keep Vehicles on the Roadway

- Crash Types Addressed by Delineation:
  - Curve Crashes
  - Head-on Collisions
  - Night Time Crashes
  - Other Run-off-Road Crashes
Section 3B.07 Warrants for Use of Edge Lines

Standard:
Edge line markings shall be placed on paved streets or highways with the following characteristics:
A. Freeways,
B. Expressways, and
C. Rural arterials with a traveled way of 20 feet or more in width and an ADT of 6,000 vehicles per day or greater.

Guidance:
Edge line markings should be placed on paved streets or highways with the following characteristics:
A. Rural arterials and collectors with a traveled way of 20 feet or more in width and an ADT of 3,000 vehicles per day or greater.
B. At other paved streets and highways where an engineering study indicates a need for edge line markings.
Are Wider Edge Lines Better?

### 4-inch Width

![Image of a road with 4-inch edge lines]

### 6-inch Width

![Image of a road with 6-inch edge lines]

<table>
<thead>
<tr>
<th>Countermeasure: Install wider markings WITHOUT resurfacing</th>
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</thead>
<tbody>
<tr>
<td>CMF</td>
</tr>
<tr>
<td>-----</td>
</tr>
<tr>
<td>0.78</td>
</tr>
</tbody>
</table>
Section 3B.01 Yellow Center Line Pavement Markings and Warrants

Standard:
Center line markings shall be placed on all paved urban arterials and collectors that have a traveled way of 20 feet or more in width and an ADT of 6,000 vehicles per day or greater. Center line markings shall also be placed on all paved two-way streets or highways that have three or more lanes for moving motor vehicle traffic.
Section 3B.01 Yellow Center Line Pavement Markings and Warrants

Guidance:
Center line markings should be placed on paved urban arterials and collectors that have a traveled way of 20 feet or more in width and an ADT of 4,000 vehicles per day or greater. Center line markings should also be placed on all rural arterials and collectors that have a traveled way of 18 feet or more in width and an ADT of 3,000 vehicles per day or greater. Center line markings should also be placed on other traveled ways where an engineering study indicates such a need. Engineering judgment should be used in determining whether to place center line markings on traveled ways that are less than 16 feet wide because of the potential for traffic encroaching on the pavement edges, traffic being affected by parked vehicles, and traffic encroaching into the opposing traffic lane.
In-Lane Pavement Markings

Keep markings well maintained
Curve Advance Marking

PennDOT preliminary study: 33% crash reduction
Markings gives drivers the illusion they’re traveling faster than they are
Reflective Barrier Delineation
Signs to Keep Vehicles on the Roadway

• Crash Types Addressed by Signing:
  – Curve Crashes
    • Includes crashes in the head-on and run-off-road (ROR) categories
  – Nighttime Crashes
    • Mostly ROR crashes
### Warning Signing for Curves

**Advance Warning Signs for Curves:**

<table>
<thead>
<tr>
<th>CMF</th>
<th>CRF (%)</th>
<th>Quality</th>
<th>Crash Type</th>
<th>Crash Severity</th>
<th>Roadway Type</th>
<th>Area Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.7</td>
<td>30</td>
<td>★★★★★★</td>
<td>All</td>
<td>Serious injury, Minor injury</td>
<td>Not specified</td>
<td>Not specified</td>
</tr>
<tr>
<td>0.92</td>
<td>8</td>
<td>★★★★★★</td>
<td>All</td>
<td>Property Damage Only (PDO)</td>
<td>Not specified</td>
<td>Not specified</td>
</tr>
</tbody>
</table>

**Countermeasure:** Advance static curve warning signs
Table 2C-5. Horizontal Alignment Sign Selection

<table>
<thead>
<tr>
<th>Type of Horizontal Alignment Sign</th>
<th>Difference Between Speed Limit and Advisory Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5 mph</td>
</tr>
<tr>
<td>Turn (W1-1), Curve (W1-2), Reverse Turn (W1-3), Reverse Curve (W1-4), Winding Road (W1-5), and Combination Horizontal Alignment/Intersection (W10-1) (see Section 2C.07 to determine which sign to use)</td>
<td>Recommended</td>
</tr>
<tr>
<td>Advisory Speed Plaque (W13-1P)</td>
<td>Recommended</td>
</tr>
<tr>
<td>Chevron (W1-8) and/or One Direction Large Arrow (W1-6)</td>
<td>Optional</td>
</tr>
<tr>
<td>Exit Speed (W13-2) and Ramp Speed (W13-3) on exit ramp</td>
<td>Optional</td>
</tr>
</tbody>
</table>
Advisory Speed Plaque!!
### Table 2C-5. Horizontal Alignment Sign Selection

<table>
<thead>
<tr>
<th>Type of Horizontal Alignment Sign</th>
<th>Difference Between Speed Limit and Advisory Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5 mph</td>
</tr>
<tr>
<td>Turn (W1-1), Curve (W1-2), Reverse Turn (W1-3), Reverse Curve (W1-4), Winding Road (W1-5), and Combination Horizontal Alignment/Intersection (W10-1) (see Section 2C.07 to determine which sign to use)</td>
<td>Recommended</td>
</tr>
<tr>
<td>Advisory Speed Plaque (W13-1P)</td>
<td>Recommended</td>
</tr>
<tr>
<td>Chevrons (W1-8) and/or One Direction Large Arrow (W1-6)</td>
<td>Optional</td>
</tr>
<tr>
<td>Exit Speed (W13-2) and Ramp Speed (W13-3) on exit ramp</td>
<td>Optional</td>
</tr>
</tbody>
</table>
### Warning Signing for Curves

**Chevrons:**

![Chevron Sign](image)

**Countermeasure:** Install chevron signs on horizontal curves

<table>
<thead>
<tr>
<th>CMF</th>
<th>CRF(%)</th>
<th>Quality</th>
<th>Crash Type</th>
<th>Crash Severity</th>
<th>Roadway Type</th>
<th>Area Type</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.96</td>
<td>4</td>
<td>3</td>
<td>Non-intersection</td>
<td>All</td>
<td>All</td>
<td>Rural</td>
<td>Srinivasan et al., 2009</td>
</tr>
<tr>
<td>0.94</td>
<td>0</td>
<td>3</td>
<td>Head on, Non-intersection, Run off road, Sideswipe</td>
<td>All</td>
<td>All</td>
<td>Rural</td>
<td>Srinivasan et al., 2009</td>
</tr>
<tr>
<td>0.84</td>
<td>16</td>
<td>3</td>
<td>Non-intersection</td>
<td>Fatal, Serious injury, Minor injury</td>
<td>All</td>
<td>Rural</td>
<td>Srinivasan et al., 2009</td>
</tr>
<tr>
<td>0.75</td>
<td>25</td>
<td>3</td>
<td>Nighttime, Non-intersection</td>
<td>All</td>
<td>All</td>
<td>Rural</td>
<td>Srinivasan et al., 2009</td>
</tr>
<tr>
<td>0.78</td>
<td>22</td>
<td>3</td>
<td>Head on, Nighttime, Non-intersection, Run off road, Sideswipe</td>
<td>All</td>
<td>All</td>
<td>Rural</td>
<td>Srinivasan et al., 2009</td>
</tr>
</tbody>
</table>
Post Delineation
Table 2C-6. Typical Spacing of Chevron Alignment Signs on Horizontal Curves

<table>
<thead>
<tr>
<th>Advisory Speed</th>
<th>Curve Radius</th>
<th>Sign Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 or less</td>
<td>Less than 200</td>
<td>40</td>
</tr>
<tr>
<td>20 to 30</td>
<td>200 to 400</td>
<td>80</td>
</tr>
<tr>
<td>35 to 45</td>
<td>401 to 700</td>
<td>120</td>
</tr>
<tr>
<td>50 to 60</td>
<td>701 to 1,250</td>
<td>160</td>
</tr>
<tr>
<td>More than 60</td>
<td>More than 1,250</td>
<td>200</td>
</tr>
</tbody>
</table>

Note: The relationship between the curve radius and the advisory speed shown in this table should not be used to determine the advisory speed.
Orient Chevron to Traffic Approach
Multiple Curves

- A Winding Road (W1-5) sign may be used instead of multiple Turn (W1-1) or Curve (W1-2) signs where there are three or more changes in roadway alignment each separated by a tangent distance of less than 600 feet.
- A NEXT XX MILES (W7-3aP) Supplemental distance plaque (see Section 2C.55) may be installed below the Winding Road sign where continuous roadway curves exist for a specific distance.
Bad Signs are Out There

Some agencies need better sign maintenance guidance
Sign Maintenance

Daytime:

Nighttime:
Sign Visibility – Vegetation Management
Enhanced Delineation and Friction for Horizontal Curves

**Increased Pavement Friction**

- High friction surface treatment (HFST) is another highly cost-effective countermeasure.
- HFST compensates for the high friction demand at curves where the available pavement friction is not adequate to support operating speeds due to one or more of the following situations:
  - Sharp curves.
  - Inadequate cross-slope design.
Enhanced Delineation and Friction for Horizontal Curves

SAFETY BENEFITS:

CHEVRON SIGNS

25% Reduction in nighttime crashes

16% Reduction in non-intersection fatal and injury crashes

Source: CMF Clearinghouse, CMF IDs 2438 and 2439

HIGH FRICTION SURFACE TREATMENTS

52% Reduction in wet road crashes

24% Reduction in curve crashes

Source: CMF Clearinghouse, CMF IDs 7900 and 7901
Enhanced Friction for Horizontal Curves

**Increased Pavement Friction**

- Wet conditions. $f$
- Polished roadway surfaces.
- Driving speeds in excess of the curve advisory speed.
Provide Skid-Resistant Pavement Surfaces

15.2 A - Reduce the likelihood of a vehicle leaving its lane and either crossing the roadway centerline or leaving the roadway at a horizontal curve.
Provide Skid Resistant Pavement Surfaces


➢ Every State shall have a program to improve highway safety such that "there are standards for pavement design and construction with specific provisions for high skid resistance qualities.

➢ Each State shall have a "program for resurfacing or other surface treatment with emphasis on correction of locations or sections of streets and highways with low skid resistance and high or potentially high accident rates susceptible to reduction by providing improved surfaces."
Improving Friction to Keep Vehicles on the Roadway

• Crash Types addressed by improving pavement friction:
  – wet weather
  – other skidding (e.g. too fast for conditions)
  – curves
Strategies for Reducing Crashes (Where Can Friction Benefit Safety?)

1. Horizontal curves
2. Approach to intersections
3. Grades

When the pavement has:
- Marginal friction effected from weather
- Low friction
- Friction values not compatible with approach speeds and geometrics (friction demand)
Skid related crashes are determined by many factors:

- Road Geometry
- Vehicle Speeds
- Driver Actions
- Weather Conditions
- Traffic Characteristics
Provide Skid Resistant Pavement Surfaces

The margin of safety against skidding on curves is defined as the difference between the available tire-pavement friction and the friction demand of the vehicle as it tracks the curve.
Conceptual Relationship Between Friction Demand, Speed and Friction Availability
AASHTO Horizontal Curve Design Model

\[ e + f = \frac{V^2}{15} R \]

e = superelevation

f = side friction factor

V = design speed (mph)

R = radius of curve (ft)
When crash types were examined for these drivers excessively speeding, researchers found that speeding was the leading cause of single-driver right or left roadside departure with traction loss and the third leading cause of head-on crashes.

…primarily on curves, at night, on local or collector roadways, and during clear weather.
Truck Operations on Curves

- Trucks with high centers of gravity may overturn before losing control due to skidding
- Skidding trucks may lead to overturn
- Trucks on downgrade curves generate greater lateral friction demand (Superelevation Is Not As Effective)
- Margin of safety for ‘f’ is lower for trucks

Reference NCHRP 439
What is a High Friction Surface Treatment?

High Friction Surface Treatments (HFST) are pavement surfacing overlay systems with:
- exceptional skid-resistant properties that are not typically acquired by conventional materials
- and retains the higher friction property for a much longer time.

• Commercially available resin-based products and processes
• Generally applied in short sections to improve spot locations where friction demand is critical.
HFST Aggregates

- Recommended aggregate is calcined bauxite which provide the highest resistance to polishing, but flint, granite, slags and other materials have been evaluated.

- Generally 3-4 mm maximum size
HFST Binder Materials

• Binder system (proprietary blends)
  – Bitumen-extended epoxy resins
  – Epoxy-resin
  – Polyester-resin
  – Polyurethane-resin
  – Acrylic-resin
HFST Installation

- Manually - Manual mixing of epoxy material and application with squeegee
- Automated (machine-aided) - Machine mixing and application of epoxy (limited hand/squeegee work)
Hamilton County OH
PennDOT Test Site

State Route 0611, Northampton County, PA
in Segment 40 along the Delaware River

An area commonly known as the “Canal Locks”

About 5 miles south of Easton, PA
## Crash Data for Rte 611 Curve

### Northampton Rte 611 Seg 40 (off 1000-1900) Years 1997 to 2005

<table>
<thead>
<tr>
<th>CRASH YEAR</th>
<th>DIST</th>
<th>COG</th>
<th>COLL TYPE</th>
<th>INT TYPE</th>
<th>URBAN TYPE</th>
<th>RURAL</th>
<th>ILLUMINATION</th>
<th>WEATHER</th>
<th>TRAVEL DIRECTION</th>
<th>ROAD SURFACE</th>
<th>ROAD COND</th>
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<tr>
<td>1997</td>
<td>05</td>
<td>48</td>
<td>HFO</td>
<td>MIDB</td>
<td>RUR</td>
<td>DARK</td>
<td>RAIN</td>
<td>WET</td>
<td>SOUTH</td>
<td>WET</td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td>05</td>
<td>48</td>
<td>HFO</td>
<td>MIDB</td>
<td>RUR</td>
<td>DARK</td>
<td>SNOW</td>
<td>NORTH</td>
<td>WET</td>
<td>SNOW</td>
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<td>1998</td>
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<td>MIDB</td>
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<td>MIDB</td>
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<td>DAYLIGHT</td>
<td>RAIN</td>
<td>SOUTH</td>
<td>WET</td>
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</table>
Begins at 8:30 AM   6/13/07
Mixed 2 part epoxy resin is hand spread with a serrated squeegee.
2:30 PM: Swept, Dry and Ready for Traffic
# Friction Testing & Crash Results

## Friction Results

<table>
<thead>
<tr>
<th></th>
<th>Test Lane</th>
<th>Control Lane</th>
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</thead>
<tbody>
<tr>
<td>Before Installation</td>
<td>= avg 24 *</td>
<td>avg 34 *</td>
</tr>
<tr>
<td>After Installation</td>
<td>(June 13th, 2007)</td>
<td>* 11/30/06</td>
</tr>
<tr>
<td>Aug ’07</td>
<td>= avg 75</td>
<td>avg 34</td>
</tr>
<tr>
<td>Apr ’08</td>
<td>= avg 75</td>
<td>avg 40</td>
</tr>
<tr>
<td>Nov ‘08</td>
<td>= avg 72</td>
<td>avg 44</td>
</tr>
<tr>
<td>Mar ‘09</td>
<td>= avg 74</td>
<td>avg 58 * Repaved</td>
</tr>
<tr>
<td>Nov ‘09</td>
<td>= avg 72</td>
<td>avg 44</td>
</tr>
<tr>
<td>Jun ‘10</td>
<td>= avg 71</td>
<td>avg 44</td>
</tr>
</tbody>
</table>

|                      | Bauxite Aggregate          |

## Reportable Crash Results

Before Installation = 21 (south lane)

After Installation = 0 * as of 4/12/2012
Systemic Application of Multiple Low-Cost Countermeasures at Stop-Controlled Intersections

Average Benefit-Cost Ratio

12:1

Example of countermeasures on the stop approach.

Example of countermeasures on the through approach.
Systemic Application of Multiple Low-Cost Countermeasures at Stop-Controlled Intersections

• This systemic approach to intersection safety involves deploying a group of multiple low-cost countermeasures, such as enhanced signing and pavement markings, at a large number of stop-controlled intersections within a jurisdiction. It is designed to increase driver awareness and recognition of the intersections and potential conflicts.
Systemic Application of Multiple Low-Cost Countermeasures at Stop-Controlled Intersections

On the Through Approach:

• Doubled up (left and right), oversized *advance intersection warning signs*, with street name sign plaques.

• Enhanced pavement markings that delineate through-lane edge lines.

Example of countermeasures on the through approach.
Systemic Application of Multiple Low-Cost Countermeasures at Stop-Controlled Intersections

On the STOP Approach:

• Doubled up (left and right), oversized advance “STOP Ahead” intersection warning signs.
• Doubled up, oversized Stop signs.
• Retroreflective sheeting on sign posts.
• Properly placed STOP bar.
Systemic Application of Multiple Low-Cost Countermeasures at Stop-Controlled Intersections

- Basic sign and marking improvements; including an optimally-placed stop bar on the pavement
- 6 ft or greater raised divider on stop approach
- Flashing solar LED beacons on advance intersection warning signs and STOP signs
- Flashing overhead intersection beacons
Systemic Application of Multiple Low-Cost Countermeasures at **Stop-Controlled Intersections**

- Reflective panels on sign posts
- Dynamic warning signs: advise through traffic of a stopped vehicle in intersection; advice traffic on high-speed stop approach that a stopped condition is ahead
- Transverse rumble strips across STOP approach lanes in rural areas (where noise is not an issue)
- Extension of through edge line using short skip pattern
Systemic Application of Multiple Low-Cost Countermeasures at Stop-Controlled Intersections

- New/upgraded lighting
- Skid resistant surface
- Lane narrowing using pavement marking and shoulder rumble strips
- Peripheral transverse pavement markings
- Dynamic speed warning sign on through approach to reduce speed
Systemic Application of Multiple Low-Cost Countermeasures at Stop-Controlled Intersections

• "Slow" pavement markings
• High-friction surface treatment
• Roundabouts
• Left-turn lanes
• Other geometric improvements (e.g., elimination of skew, vertical curve)
Longitudinal Rumble Strips and Stripes

- *Longitudinal rumble strips* are milled or raised elements on the pavement intended to alert drivers through vibration and sound that their vehicles have left the travel lane. They can be installed on the shoulder, edge line of the travel lane, or at or near center line of an undivided roadway.
Longitudinal Rumble Strips and Stripes

• *Rumble stripes* are edge line or center line rumble strips where the pavement marking is placed over the rumble strip, which can result in an increased visibility of the pavement marking during wet, nighttime conditions.
Longitudinal Rumble Strips and Stripes

SAFETY BENEFITS:

Center Line Rumble Strips  
44-64%  
Head-on, opposite-direction, and sideswipe fatal and injury crashes

Shoulder Rumble Strips  
13-51%  
Single vehicle, run-off-road fatal and injury crashes

Rumble Strip Guidance
Installing Rumbles to Keep Vehicles on the Roadway

- Rumble Strips address similar crash types as pavement markings, especially when roadway departure is a result of a **Distracted or Drowsy Driver**
- On roads with snow cover on the markings, rumble strips can help driver with **proper lane placement**
Shoulder Rumble Strips
Crash Reduction Factors (CRF’s)

• Rural freeways
  Shoulder rumble strips (combined)
    • 11% reduction in SVROR crashes (SE = 6)
    • 16% reduction in SVROR FI crashes (SE = 8)

• Rural two-lane roads
  Shoulder rumble strips
    • 15% reduction in SVROR crashes (SE = 7)
    • 29% reduction in SVROR FI crashes (SE =9)

Source: NCHRP Report 641
(Includes data for rolled in and milled in shoulder rumbles)
Rumble Placement

- Shoulder
- Edge Line / Rumble Stripe
- Centerline
Primary Rumble Strip Dimensions

- FHWA Technical Advisory 5040.39
Factors Affecting Noise of Rumble Strips

The noise model predicts the noise produced inside the vehicle by rumbles based on the following:

- Depth
- Width
- Length
- Spacing
- Speed

Modifications of these characteristics can reduce the effectiveness but In-Service Evaluations of different designs still show significant crash reductions.

Source: NCHRP Report 641
Rumble StripEs

Rumble Stripes
Michigan initiative with edge line painted over shoulder rumble strip.

Comparison of painted edgeline in Rain
Michigan initiative with edge line painted over shoulder rumble strip.

Michigan I-75 - After 1st Winter
Rumble Stripes on MS 589

Mississippi
Install centerline rumble strips
Placement of Centerline Rumble Strips (cont)

Centerline rumble strips
Milled across markings / joint

Centerline rumble strips on either side of pavement markings (least common)

Centerline rumble strips
Variable spacing
Combining Shoulder and Centerline Rumbles

Bicycle Friendly Shoulder Rumble Strip and Centerline Rumble Stripe
Washington
Bicycle Issues

• Gaps can allow bicyclist to move between lane and shoulder without traversing the rumble
• Shallower rumbles (3/8” versus 5/8”) may be an acceptable compromise
Rumbles and Bicyclists

• Do rumbles provide a benefit to bicyclists?
Centerline Rumble Strips & Motorcyclists

Minnesota DOT Study Findings

- Zero of 9845 motorcycle crash reports mentioned rumble strips as a factor
- 44 hours of observation showed:
  - Small number of rumble strip crossings
  - No instances of directional changes or unusual riding behavior during crossing.
  - Rumble strips did not seem to inhibit any passing opportunities.
- Closed-course examination showed no steering, braking or throttle adjustments during strip crossing.
  - Post-ride interviews confirmed these observations
  - No rider expressed difficulty or concern with crossing rumble strips.

Conclusion - no indication that centerline rumble strips pose a hazard to cyclists

http://www.lrrb.org/pdf/200807TS.pdf
Chip Seals and Rumbles

Rumble Over Chip Seal
Michigan

Chip Seal Over Rumble
Washington
Safety Edge

SafetyEdge℠

Example of SafetyEdge℠ after backfill material settles or erodes.

Source: FHWA

SAFETY BENEFIT:

11%

Reduction in fatal and injury crashes

Source: Safety Effects of the SafetyEdge℠ FHWA-SA-17-044
Pavement Edge Drop-Offs Can Contribute to Crashes

• Roadway departures account for 53 percent of fatal crashes.
• When a driver drifts off the roadway and tries to steer back onto the pavement, a vertical pavement edge can create a "tire scrubbing" condition that may result in over-steering.
• If drivers over-steer to return to the roadway without reducing speed, they are prone to lose control of the vehicle.
• The resulting crashes tend to be more severe than other crash types.
Pavement Edge Drop-Offs Can Contribute to Crashes

This is a typical diagram for a crash caused by tire scrubbing. The vehicle at left scrubbed the edge of the pavement, and when it returned, the driver overcorrected, lost control, crossed into the adjacent lane, and struck an oncoming vehicle. (Graphic source: AAA Foundation for Highway Safety)
Safety Edge

- SafetyEdge℠ is a simple and effective solution to mitigate pavement edge-related crashes.
- When installed properly, simply consolidating the edge of the pavement to 30-degree shape during the paving process can eliminate the problem of vertical edge drop-off.
- Research has shown this shape "provides a transition from on-roadway surface to shoulder and back so smooth it defies assignment of any degree of severity..."
Safety Edge

SafetyEdge\textsuperscript{SM} adds nominal cost to repaving a road.

Calculated benefit-cost ratios typically range between \$500-1400. 

Rural road crashes involving edge drop-offs are 2 to 4 times more likely to include a fatality than other crashes on similar roads.

Source: Safety Effects of the SafetyEdge\textsuperscript{SM}, FHWA-SA-11-044.

Safety Edge – Key Benefits

- **Its ability to saves lives** by allowing vehicles to safely return to the travel lane and mitigate pavement edge drop-off.

- **An improvement can be seen in pavement durability** by reducing edge raveling.

- **Its cost is low**, which is attributed to the addition of typically less than 1 percent of the project's total asphalt quantity.
Safety Edge
Safety edge has been integrated into the 2019 C&MS. Design guidance for when to use safety edge is in the Pavement Design Manual section 105 and construction details are in BP-3.2 and BP-8.2. No plan notes, details, or as per plan items are required when using safety edge with 2019 specifications.

For projects using 2016 specifications and prior, contact the Office of Pavement Engineering.
Roadside Design Improvements at Curves

Increasing the Clear Zone prevents crashes

- 3.3 ft
- 16.7 ft
- 30 ft

+22% CRASH REDUCTION
+44% CRASH REDUCTION

27% of all fatal crashes occur at curves

80% of all fatal crashes at curves are roadway departure crashes
Roadside Design Improvements at Curves

- Roadside design improvement at curves is a strategy encompassing several treatments that target the high-risk roadside environment along the outside of horizontal curves.
- These treatments prevent roadway departure fatalities by giving vehicles the opportunity to recover safely and by reducing crash severity.
- Roadside design improvements can be implemented alone or in combination and are particularly recommended at horizontal curves—where data indicates a higher-risk for roadway departure fatalities—and where cost effectiveness can be maximized.
Improvements to Provide for a Safe Recovery

- In cases where a vehicle leaves the roadway, strategic roadside design elements, including clear zone addition or widening, slope flattening, and shoulder addition or widening, can provide drivers with an opportunity to regain control and re-enter the roadway.
Clear Zone

• an unobstructed, traversable area beyond the edge of the through traveled way for the recovery of errant vehicles.

• free of rigid fixed objects such as trees and utility cabinets or poles.
Slope Flattening

- Reduces the steepness of the side slope to increase drivers' ability to keep the vehicle stable, regain control of the vehicle, and avoid obstacles.
Shield Obstacles

• New Barrier for
  – Slopes
  – Fixed objects
  – Median barrier

• Upgrading existing Hardware
Improvements to Reduce Crash Severity

• Since not all roadside hazards can be removed at curves, installing roadside barriers to shield unmovable objects or embankments may be an appropriate treatment.
Reducing Crash Severity at Curves

- **Cable barrier** is a flexible barrier made from wire rope supported between frangible posts.
Cable Barriers in Curves

• may be the most versatile and forgiving barrier systems available for reducing the severity of run-off-road crashes.
Cable Barriers in Curves – ODOT’S Roadside Safety Field Guide

- can be expected to have increased deflection
- Reducing the post spacing may be an effective countermeasure, but objective criteria have not yet been established.
- High tensioned cable systems should be considered for severe curvilinear alignments.
Guardrail

- a semi-rigid barrier, usually either a steel box beam or W-beam.

- These deflect less than flexible barriers, so they can be located closer to objects where space is limited.
Guardrail - ODOT

- Also called Semi-Rigid Systems
- Midwest Guardrail System (MGS)
  - Test Level: NCHRP 350/MASH TL-3
- Strong-Steel or Wood Post W-Beam with wood or plastic block-outs
  - Test Level: NCHRP 350/MASH TL-3
Crashworthy Terminals

- Tangent versus Flared
- Energy Absorbing versus Non-Energy Absorbing
1. **Remove** the obstacle
2. **Redesign** the obstacle for safe traversal
3. **Relocate** the obstacle further from road
4. **Reduce** obstacle severity (make breakaway)
5. **Shield** the obstacle
6. **Delineate** the obstacle

*Refer to RDG Page 1-4*
Option 2: Make Traversable
Option 2: Make Traversable
Opening Wider than 36”

- 30” between pipes on sideslopes up to 3:1.

Pipe diameter is greater than 36”, so requires use of pipe runner

Cut to match the sideslope
Option 2: Make Traversable
Option 4: Breakaway Supports

• Reduce severity by providing breakaway hardware
  – Sign supports
  – Luminaire supports
  – Utility Poles

• MUTCD requires crashworthy sign supports on all public roads (Section 2A-19)
Delineate
Local Road Safety Plan

• Also called **LSRP**, provides a framework for identifying, analyzing, and prioritizing roadway safety improvements on local roads.

• The LRSP development process and content are tailored to local issues and needs.

• The process results in a prioritized list of issues, risks, actions, and improvements that can be used to reduce fatalities and serious injuries on the local road network.
Why Develop an LRSP?

• While local roads are less traveled than State highways, they have a much higher rate of fatal and serious injury crashes.

• Developing an LRSP is an effective strategy to improve local road safety for all road users and support the goals of a State's overall strategic highway safety plan.
Aspects common to LRSPs include:

- Stakeholder engagement representing the 4E's—engineering, enforcement, education, and emergency medical services, as appropriate.
- Collaboration among municipal, county, Tribal, State and/or Federal entities to leverage expertise and resources.
- Identification of target crash types and crash risk with corresponding recommended proven safety countermeasures.
- Timeline and goals for implementation and evaluation.
Local Road Safety Plan

• Local road agencies should consider developing an LRSP to be used as a tool for reducing roadway fatalities, injuries, and crashes. The plan should be viewed as a living document that can be updated to reflect changing local needs and priorities.

• Developing Safety Plans: A Manual for Local Rural Road Owners, FHWA-SA-12-017, provides guidance on developing an LRSP.
Local Road Safety Plans

Local roads experience 3x the fatality rate of the Interstate Highway System.

Source: FARS and FHWA Highway Statistics Series (2014)

Safety improvements on local roads can be determined through the LRSP process.
Developing an LRSP

• In developing an LRSP, local and rural road owners should first consider addressing the following questions:
  • What is the purpose or goal?
  • Which agencies are critical to include during plan development?
  • How will safety problems be identified?
  • How will improvement strategies be identified? Prioritized? Implemented?
  • How will the plan be monitored and updated?
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<th>Developing an LRSP</th>
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<tr>
<td>• Establish a working group.</td>
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<td>• Review crash, traffic, and roadway data.</td>
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<tr>
<td>• Establish goals, priorities, and countermeasures.</td>
</tr>
<tr>
<td>• Implementation and Assessment of the plan</td>
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<tr>
<td>• Federal Highway Administration, &quot;Strategic Highway Safety Plan (SHSP)&quot; website. Available at: <a href="http://safety.fhwa.dot.gov/hsip/shsp/">http://safety.fhwa.dot.gov/hsip/shsp/</a></td>
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Road Safety Audits

A road safety audit is a proactive formal safety performance examination of an existing or future road or intersection by an independent and multidisciplinary team.

SAFETY BENEFIT:

10-60%
Reduction in total crashes
Road Safety Audits

• While most transportation agencies have established traditional safety review procedures, a road safety audit (RSA) is unique.

• RSAs are performed by a multidisciplinary team independent of the project.

• RSAs consider all road users, account for human factors and road user capabilities, are documented in a formal report, and require a formal response from the road owner.
Benefits of an RSA

• Reduced number and severity of crashes due to safer designs.
• Reduced costs resulting from early identification and mitigation of safety issues before projects are built.
• Improved awareness of safe design practices.
• Increased opportunities to integrate multimodal safety strategies and proven safety countermeasures.
• Expanded ability to consider human factors in all facets of design.
The 8 Steps of a Road Safety Audit

1. Identify project
2. Select RSA team
3. Conduct start-up meeting
4. Perform field reviews
5. Conduct analysis and prepare report
6. Present findings to project owner
7. Prepare formal response
8. Incorporate findings
RSA in progress – Field Review with a multi-disciplinary team
A Road Safety Audit is different

**What is the difference between RSA and a Traditional Safety Review?**

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<th>Road Safety Audit</th>
<th>Traditional Safety Review</th>
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<tbody>
<tr>
<td>Performed by a team independent of the project</td>
<td>The safety review team is usually not completely independent of the design team.</td>
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<tr>
<td>Performed by a multi-disciplinary team</td>
<td>Typically performed by a team with only design and/or safety expertise.</td>
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<tr>
<td>Considers all potential road users</td>
<td>Often concentrates on motorized traffic.</td>
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<td>Accounting for road user capabilities and limitations is an essential element of an RSA</td>
<td>Safety Reviews do not normally consider human factor issues.</td>
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<tr>
<td>Always generates a formal RSA report</td>
<td>Often does not generate a formal report.</td>
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<tr>
<td>A formal response report is an essential element of an RSA</td>
<td>Often does not generate a formal response report.</td>
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Road Safety Audit Resources

• Ohio LTAP will offer a Road Safety Audit Workshop in 2020

• Other RSA resources:
  
  • **FHWA Road Safety Audit Guidelines**
  • **Model RSA Policy**
  • **RSA Newsletter**
  • **Road Safety Audits: Case Studies**
Which of these 20 Proven Countermeasures are applicable to 2-Lane Rural Roads?

• Enhanced Delineation and Friction at Horizontal Curves
• Systemic Application of Multiple Low-Cost Countermeasures at Stop-Controlled Intersections
• Longitudinal Rumble Strips and Stripes on 2-Lane Roads
• The Safety Edge
• Roadside Design Improvement at Curves
• Local Road Safety Plan
• Road Safety Audits
Questions and Discussion