Pavement Edge Treatment

WA-RD 798.1

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WSDOT Research Report
Post-Construction Report
Experimental Feature WA 11-01

Pavement Edge Treatment

Contract 8017, SR 395
Lee Road to Junction I-90

Contract 8116, SR 410
Twin Creek to Mather Memorial Park Pull-Off Paving

Contract 8241, SR 21
Curlew State Park to North of Rin Con Creek

Contract 8271, SR 542
Fossil CR to Wells CR RD Vic Paving
# Experimental Feature Report

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## 16. ABSTRACT
Four projects were built over two construction seasons using special devices attached to the paving machine that produces a 30° slope on the outside pavement edge instead of the near vertical drop-off common with conventional paving equipment. This pavement edge treatment allows vehicles that leave the roadway a gentler slope to navigate when remounting the pavement.

The projects used four types of devices; (1) the TransTech Shoulder Wedge Maker™, (2) the Advant-Edge™, (3) the Carlson Safety Edge End Gate, and (4) a contractor built device. All of the devices were able to produce a finished pavement slope that was close to the 30° angle recommended by FHWA.

The projects will be monitored for five years to measure the functional performance of the edge treatment and possible reductions in collisions caused by drivers trying to re-enter the roadway after losing control and running off the road.

## 17. KEY WORDS
Safety Edge™, Slope, HMA, Advant-Edge™, TransTech Shoulder Wedge Maker™, Troxler Safety Slope™, Carlson Safety Edge End Gate, pavement edge treatment

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Introduction

Safety EdgeSM is one of the safety enhancements being promoted through the Federal Highway Administration’s (FHWA) Every Day Counts (EDC) program. The Every Day Counts program identifies and deploys innovative technologies that are aimed at shortening project delivery, enhancing safety, or protecting the environment. The Safety EdgeSM pavement edge treatment enhances safety through a modification to asphalt paving equipment that result in a sloped edge in place of a vertical edge at the outside shoulder. WSDOT is embracing the EDC program by constructing a number of demonstration projects which will be monitored for constructability, pavement edge stability and durability, operational characteristics, and collision reduction.

Safety EdgeSM Description

If a vehicle leaves the roadway in a location where the pavement edge drops off vertically, a driver may overcorrect as they re-enter the roadway and this overcorrection can cause a loss of vehicle control and lead to a serious collision. When drop offs are in the range of four inches, the potential exists for a vehicle’s front tire to scrub against the pavement edge and not be able to return to the road surface (Ivey and Sicking, 1986). In these conditions drivers may increase turning forces in an effort to overcome the pavement edge drop. When the tire overcomes the friction forces created by the tire-pavement interaction, the vehicle may return to the road surface abruptly and with excess angle. Once the vehicle re-enters the roadway the sharp turning angle of the front tires may result in the driver losing control of the vehicle which can cause it to rollover or swerve into oncoming traffic (see Figure 1).
The Safety EdgeSM pavement edge treatment provides a non-vertical wedge at the edge of the pavement which reduces the steering forces needed for re-entering the roadway. With this treatment, the pavement edge is sloped at a 30° angle (see Figure 2). The presence of a slope instead of a vertical face makes it easier for a vehicle to re-enter the roadway after inadvertently driving off the edge of the pavement. Figures 3 and 4 are diagrams of a pavement edge without and with the pavement edge treatment. Figures 5 and 6 are photos of a pavement with a vertical edge and one with the pavement edge treatment. Figure 7 shows a pavement under construction with no edge treatment and with edge treatment.
Figure 3. Without a Safety Edge\textsubscript{SM}. (FHWA Safety Edge PowerPoint)

Figure 4. With a Safety Edge\textsubscript{SM}. (FHWA Safety Edge PowerPoint)

Figure 5. Vertical drop off at pavement edge. (FHWA Safety Edge\textsubscript{SM} PowerPoint)

Figure 6. Sloping edge produced by pavement edge hardware. (FHWA Safety Edge\textsubscript{SM} PowerPoint)
Figure 7. Pavement edge without the Safety Edge™ in foreground and with the Safety Edge™ in the background. (FHWA Safety Edge PowerPoint)

**Need**

The Strategic Highway Safety Plan, adopted in 1998 by the American Association of State Highway and Transportation Officials (AASHTO), identified 22 goals to pursue in order to reduce the number of crashes and fatalities on our nation’s highways. The goals included minimizing the consequences of leaving the road and reducing head-on and across median crashes (AASHTO, 1998). National Highway Traffic Safety Administration (NHTSA) statistics from 2009 showed that of all the fatal accidents, approximately 53% can be attributed to vehicles leaving the roadway (NHTSA, 2009). A reduction in roadway departures fatalities would significantly impact the total number of annual fatalities, which is the goal of FHWA in promoting the use of the Safety Edge™ (FHWA Safety Edge™ Web Site).
Literature Review

Texas Transportation Institute (TTI) did pioneering work in the 1980’s on an improved pavement edge configuration. Their research found that drivers rated a 45° wedge as a much easier pavement edge to remount than either the vertical or rounded edge normally found on pavement edges. The TTI study was criticized as not being representative of real world conditions because the participants were instructed to drive off the pavement edge rather than collecting data from drivers unknowingly putting themselves in the position of remounting a vertical pavement edge (Zimmer and Ivey, 1983).

A Federal Highway Administration (FHWA) pooled fund project initiated the implementation of the Safety EdgeSM. The eight states (California, Colorado, Georgia, Indiana, Mississippi, New York, North Carolina and Utah) constructed projects with the Safety EdgeSM and participated in a multiyear performance evaluation. The effort focused on rural two-lane roadways with paved and unpaved shoulders. A total of 377 sites in Georgia and Indiana were selected and accident data was collected over a three year period. The researchers looked at the effectiveness, cost, and benefit-cost of the Safety EdgeSM treatment (FHWA, 2011).

The analysis of the crash data determined that the use of the safety edge resulted in approximately a 5.7 percent reduction in total crashes. This result was not statistically significant; however, the results obtained were always in a positive direction. The statistical analysis of fatal and injury crashes were too variable to draw conclusions. Overall project costs and the overall cost of asphalt resurfacing materials did not increase for the projects with the treatment as compared to projects without the treatment. Computations based on the volume of asphalt material used to form the safety edge suggest added costs in the range of $536 to $2,145 per lane mile for both sides of the roadway. Benefit-cost analysis based on the estimated 5.7 percent crash reduction effectiveness found that the safety edge treatment is so inexpensive that it is highly cost-effective for application in a broad range of applications on two-lane highways (FHWA, 2011).

Eleven FHWA sponsored demonstration projects were constructed in ten states under the EDC program in 2010 and 2011. The individual field reports from these demonstration projects
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can be seen by clicking here. A brief summary of the field reports follows with more complete information tabulated in Appendix A.

**Device Used**

Five different devices were used on 11 projects to construct the Safety EdgeSM.

- TransTech Shoulder Edge Maker (7 projects)
- Avant-Edge (3 projects)
- Carlson End Gate (2 projects)
- Troxler SafeTSlope (1 project)
- Home Made Devices (2 projects, one Iowa, one North Carolina)

**Device Operation**

The major complaint with the devices, with the exception of the Carlson End Gate, center on the difficulty in quickly raising or lowering the devices when paving across intersections or in areas with higher or lower longitudinal profiles. Contractors and state inspection personnel recommended the development of automated devices to eliminate this problem. Most of the devices now employ a spring mechanism that allows the device to move vertically when encountering obstacles. The Carlson End Gate moves with the screed and therefore does not need to be adjusted.

**Slope Angle**

The end product of the use of the safety edge devices is a sloped edge. The average slope produced by each device was measured to be as follows:

- TransTech (37°) on seven projects
- Avant-Edge (50°) on three projects
- Troxler (28°) on one project
- Carlson (31°) on two projects
- NCDOT contractor built device (36°) on one project
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Compaction

Densities and air void contents immediately adjacent to the Safety EdgeSM are compared to the same measurements three feet away from the safety edge to determine the degree of compaction of the treated pavement. The results are as follows:

- Higher densities and lower air voids near the Safety EdgeSM (4 projects).
- Slightly higher densities and lower air voids near the Safety EdgeSM (2 projects).
- Densities and air voids no difference near the Safety EdgeSM (2 projects).
- Lower densities and higher air voids near the Safety EdgeSM (1 project).

The higher densities and lower air voids were directly correlated to the amount of compactive effort applied to the Safety EdgeSM. On the one project that recorded lower densities the roller operators were instructed to avoid rolling the edge because it caused the slope angle to substantially increase.

Pavement Segregation

Segregation was noted in the safety edge treatment pavement as follows:

- No segregation (6 projects)
- Minor segregation (2 projects)
- Interior segregation (1 project)

Pavement Thickness

The thickness of the pavement for each of the projects was as follows:

- 1.5 inches (4 projects)
- 2.0 inches (4 projects)
- Multiple lifts (1 project)

The thicker the pavement the easier it is to create the safety edge treatment, however, a thicker lift also requires more compactive effort to achieve maximum density.

Summary of Demonstration Projects

The demonstration projects used all of the available Safety EdgeSM devices with the TransTech Shoulder Edge Maker used on the most projects. Two projects used devices developed by the paving contractor. The major complaint on the devices was the difficulty in
quickly adjusting the device when encountering changes in longitudinal profile of the pavement or intersections and as a result automation of the devices was recommended. The edge formed by the various devices varied in slope angle from 28 to 50º with the Avant-Edger producing the highest average angle at 50º and Troxler the lowest average at 28º. The TransTech device, used on seven projects, produced an average slope angle of 37º. The compaction of the pavement at the safety edge was higher or slightly higher than the pavement in the remainder of the mat in six of the nine projects, the same in two of the nine, and lower in one of the nine projects. Segregation of the asphalt material in the Safety EdgeSM area was not found in a majority of the projects (7 out of 9) and only a minor amount in two of the nine projects. The depth of the pavement places on the nine projects was equally split between 1.5 inches and 2.0 inches, with four projects in each category. The remaining project had multiple lifts with the top lift being 1.5 inches.

Montana Department of Transportation (MDT) participated in the demonstration projects by reviewing their 25 years of constructing tapered edges on their roadways. The tapered edge is typically constructed at a 6:1 (9.5º angle) and is formed by attaching a strike-off plate to the paver that strikes off the edge and pulls the excess material back into the screed. The review determined that their practice performs very well and produces pavement edges that are durable with no significant edge breakup. Opportunities were identified for the selective use of the Safety EdgeSM on narrow roads, steep grades and curve widening. The conclusion arrived at by the reviewers was that the MDT tapered edge practice should be acknowledged as being an acceptable alternative to the Safety EdgeSM.

**Application**

WSDOT typically paves the shoulder on state highways to improve the driving surface for errant vehicles. The widths of paved shoulders on WSDOT highways vary between one and ten feet depending on route and location. Surfacing material is then used to finish the shoulder slope flush with the top of the paved surface, which mitigates shoulder pavement edge drop-offs. However, over time a vertical edge may be present due to erosion or wheel encroachment, especially along curves. FHWA has determined that the Safety EdgeSM treatment is particularly
beneficial on two-lane roads with unpaved shoulders. It allows drivers who drift off the highway to return to the road safely. It is expected that as a result the number of crashes and fatal collisions will be reduced. Its benefits are highlighted below:

- Reduces crashes and saves lives by mitigating pavement edge drop-off
- Is a low cost, systematic improvement applied during paving
- Improves durability by reducing edge raveling

**Devices Used to Construct Pavement Edge Treatment**

A number of manufacturers make hardware that forms the sloping pavement edge. All of these devices are adjusted manually; however, the size and coarse threads of the cranking mechanism do not facilitate quick adjustments. Contractors have been making modifications to these devices to better fit their equipment and to simplify the operation of this device. One modification has been to mount an electric drill on the device to quickly adjust the shoe height at driveways, mailboxes and other obstacles. Contractors worry about the adjustment speed because if the toe of the shoe is not above the driveway or other obstacle, the force of the paver will rip the shoe off the paver and likely disrupt the screed alignment. It is a good idea for the operator to give himself a buffer space initially until he gets more familiar with the speed of the crank in relation to the speed of the paver (FHWA Safety EdgeSM Web Site).

**TransTech Systems, Inc.**

The TransTech Shoulder Wedge Maker™ (SWM) mounts directly on the paver screed extension against the end gate (see Figure 8). An internal spring holds the device down on the road surface and this pressure in combination with the compound angled face compacts the mat as the paver moves forward. The SWM is delivered as a pair with both right-hand and left-hand versions for paving with traffic or against traffic. TransTech also markets a notched wedge device for longitudinal joint formation.
The Troxler SafeTSlope™ Edge Smoother is mounted on the paver screed extension against the end gate (see Figure 9). A guide rail with a two-inch radius allows the device to ride along the surface of the road shoulder following its contour. The two-inch radius helps the transition when the device encounters an obstacle such as a driveway cut or road intersection. A self-adjusting internal spring provides downward force to keep the guide rail in contact with the shoulder surface. A 30º forming edge produces the smooth wedge fillet. A 45º compound angle surface forces more asphalt mix under the device. An extended smoothing surface acts as a
trowel to smooth the surface of the wedge fillet. Both left and right-hand devices are available for paving with or against traffic.

![Figure 9. Troxler SafeTSlope™ Edge Smoother.](image)

**Carlson Paving Products, Inc.**

The Carlson Safety Edge End Gate features a spring loaded and heated end gate for the paving screed (see Figures 10 and 11). It utilizes the length of the end gate to apply compaction to the slope face of the pavement edge treatment. The screed operator’s normal end adjustments automatically control the edge. The end gate ski is flat in the front and transitions to 30° at the back of the ski. The relatively long length of the end gate ski results in a smooth/sealed slope face.
Advant-Edge Paving Equipment

The Advant-Edge™ attaches to the screed extension and shapes the edge to a 30° tapered angle (Figures 12 and 14). It automatically adjusts to changes in shoulder elevations (i.e. driveways) via its internal spring. The Advant-Edge™ is reversible so that it may be attached to either side of the paving machine. A new model called the Ramp Champ™ is designed to create either a safety edge or a tapered longitudinal center lane joint (Figure 13). It is also spring loaded to automatically adjust for changes in shoulder elevation. The slope of the safety edge is adjustable from 5° to 30° and its forming surfaces (shoes) are detachable permitting the same unit to create a variety of edge profiles.
Figure 12. The Advant-Edge™ creates a tapered 30° safety edge along the shoulder of the road.

Figure 13. The Advant-Edge Ramp Champ™ forms a tapered safety edge or a longitudinal center lane joint.

Figure 14. Advant-Edge™ mounted on a paver. Unit is designed to automatically adjust to shoulder elevation changes (driveways and intersections).
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(Note: The Safety Edge SM will be referred to as the “pavement edge treatment” from this point on in the report.)

WSDOT Projects

As of September 2012, WSDOT has completed 4 demonstration projects that have incorporated the pavement edge treatment device. Each of the 4 projects used a different device on the paver to create the pavement edge treatment. The projects and the type of devices used on each one are listed in Table 1:

Table 1. WSDOT Projects with pavement edge treatment.

<table>
<thead>
<tr>
<th>Year</th>
<th>Contract No.</th>
<th>SR</th>
<th>Project</th>
<th>Device Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>8017</td>
<td>395</td>
<td>Lee Road to Junction I-90</td>
<td>Contractor built screed and roller hardware</td>
</tr>
<tr>
<td>2011</td>
<td>8116</td>
<td>410</td>
<td>Twin Creek to Mather Memorial Park Pull-Off Paving</td>
<td>TransTech Shoulder Wedge Maker™ and contractor built roller hardware</td>
</tr>
<tr>
<td>2012</td>
<td>8241</td>
<td>21</td>
<td>Curlew State Park to North of Rin Con Creek</td>
<td>Advant-Edge™</td>
</tr>
<tr>
<td>2012</td>
<td>8271</td>
<td>542</td>
<td>Fossil Cr. To Wells Cr. Rd. Vic. Paving</td>
<td>Carlson Safety Edge End Gate</td>
</tr>
</tbody>
</table>

Contract 8017, SR 395, Lee Road to Junction I-90

Contract 8017 improved 22.50 miles of southbound SR 395 from MP 72.36 to MP 94.85 between Connell and the junction of I-90 at Ritzville, Washington as shown in the project location map (Figure 15). The pavement edge treatment was added to the project via a change order. The Contractor (Central Washington Asphalt Inc.) electing to build a special screed and edge rolling hardware. The outside, passing lane was planned 0.15 ft. prior to the placement of an equal amount of HMA Class 1/2 inch. The roadway was then paved shoulder to shoulder with 0.15 ft. of HMA Class 1/2 inch using the pavement edge treatment on both shoulders except where there was guardrail or curbing. The paving occurred in the spring of 2011.
Figures 16 through 25 show the roadway prior to construction, the construction operation and formation of the pavement edge treatment, and the finished product.

Figure 15. SR 395, Lee Road to Junction I-90 location map.

Figure 16. SR 395 before overlay. Note wide stable shoulder.

Figure 17. Paver forming and compacting pavement edge treatment.
Figure 18. Close-up of paver screed.

Figure 19. Close-up of roller hardware.

Figure 20. Close-up of sloped pavement edge showing top of slope at existing pavement edge.

Figure 21. View of rolled pavement edge treatment.

Figure 22. Distant view of paver with edge rolling hardware.

Figure 23. Angle of sloped pavement edge. Note the uniform compaction.
Measurements were taken of the pavement edge angle at various locations before and after compaction of the edge. The results are summarized in Table 2. The average final slope angle of the compacted slopes at 23° misses the 30° goal on the good side since it is a much flatter slope and would be easier to mount by a vehicle running off the road. The FHWA Design and Construction Guide states that the recommended range for the slopes is 26 to 40 degrees (FHWA Safety Edge Web Site).

One of the advantages of this particular roadway was a very firm stable shoulder area that extended well beyond the pavement edge. This allowed the Contractor to retain the full width of pavement by placing the pavement edge treatment on the shoulder area. Figures 37-39 show the pavement edge treatment on top of the stable gravel shoulder area.
The second project using the pavement edge treatment was located on SR 410 between Enumclaw and the junction of SR 123 with its center roughly around Greenwater, Washington. The project limits extended for 9.2 miles; however, two large paving exceptions reduced the total mileage to 5.32 miles. The roadway was paved shoulder to shoulder with 0.15 ft. of HMA Class 1/2 inch using the pavement edge treatment on both shoulders except where there was guardrail or curbing. The pavement edge treatment was added as a Special Provision (Appendix B). The Contractor, Tucci and Sons Inc., used a TransTech Shoulder Wedge Maker™ and a home-made edge roller to form the pavement edge treatment. The treatment was only used between MP 35.50 and MP 37.00. The Contractor started without the roller but the slope was unacceptable so they added the roller to improve compaction of the slope. The paving occurred in the summer of 2011.

### Table 2. SR 395 edge treatment slope angle before and after compaction.

<table>
<thead>
<tr>
<th>Height (in)</th>
<th>Length (in)</th>
<th>Slope (°)</th>
<th>Height (in)</th>
<th>Length (in)</th>
<th>Slope (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.15</td>
<td>7.50</td>
<td>23</td>
<td>1.84</td>
<td>4.25</td>
<td>23</td>
</tr>
<tr>
<td>2.90</td>
<td>7.50</td>
<td>21</td>
<td>2.61</td>
<td>5.25</td>
<td>26</td>
</tr>
<tr>
<td>2.63</td>
<td>6.50</td>
<td>22</td>
<td>2.09</td>
<td>4.50</td>
<td>25</td>
</tr>
<tr>
<td>3.15</td>
<td>7.50</td>
<td>23</td>
<td>2.10</td>
<td>5.00</td>
<td>23</td>
</tr>
<tr>
<td>2.65</td>
<td>7.50</td>
<td>19</td>
<td>2.37</td>
<td>6.00</td>
<td>22</td>
</tr>
<tr>
<td>2.65</td>
<td>7.25</td>
<td>20</td>
<td>2.11</td>
<td>5.25</td>
<td>22</td>
</tr>
<tr>
<td>3.39</td>
<td>7.00</td>
<td>26</td>
<td>1.86</td>
<td>5.50</td>
<td>19</td>
</tr>
<tr>
<td>3.14</td>
<td>6.75</td>
<td>25</td>
<td>2.34</td>
<td>4.50</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.00</td>
<td>4.75</td>
<td>23</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>22</strong></td>
<td></td>
<td><strong>Average</strong></td>
<td><strong>23</strong></td>
<td></td>
</tr>
</tbody>
</table>

Note: Heights have been adjusted for the slope of the pavement surface.

**Contract 8116, SR 410, Twin Creek to Mather Memorial Park Pull-Off Paving**
Figures 27 through 36 show the roadway prior to construction, the construction operation and formation of the pavement edge treatment, and the finished product.

Figure 26. SR 410, Twin Creek to Mather Memorial Park Pull-Out Paving location map.

Figure 27. SR 410 prior to construction.

Figure 28. Side view of TransTech hardware.
Figure 29. End view of TransTech pavement edge hardware without the roller.

Figure 30. Pavement edge formed by the TransTech hardware prior to adding the roller. Note open texture of the HMA.

Figure 31. Pavement edge treatment after addition of a roller behind the paver.

Figure 32. Roller added to compact the vertical edge at the top of the slope.

Figure 33. Roller added to compact the vertical edge at the top of the slope.

Figure 34. Finished pavement with dressed shoulders.
This project had some areas where the pavement edge treatment could be placed outside of the existing paved surface; however, there were some areas that the slope began immediately at the edge of existing slope so this required a slight narrowing of the roadway surface. Measurements were taken to determine the angle of pavement edge treatment at various locations before and after compaction of the edge. The results are summarized in Table 3. The measurements on the uncompacted edge averaged 30º with a range of values between 27 and 33º. Two sets of measurements were made on the compacted slopes. The first set at unknown mileposts averaged 40º with a range of 34 to 43º. The second set taken between MP 40.20 and 40.59 averaged 29º with a range of 26 to 31º.
Table 3. SR 410 edge treatment slope angle before and after compaction.

<table>
<thead>
<tr>
<th>Uncompacted Slopes (MP 41.55 - MP 41.69)</th>
<th>Compacted Slopes (milepost unknown)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (in)</td>
<td>Length (in)</td>
</tr>
<tr>
<td>3.50</td>
<td>7.00</td>
</tr>
<tr>
<td>3.00</td>
<td>5.00</td>
</tr>
<tr>
<td>3.25</td>
<td>5.00</td>
</tr>
<tr>
<td>3.5</td>
<td>6.75</td>
</tr>
<tr>
<td>2.5</td>
<td>4.00</td>
</tr>
<tr>
<td>Average</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>40</td>
</tr>
</tbody>
</table>

Table 4. SR 410 edge treatment slope angle after compaction MP 40.30 to 40.59.

<table>
<thead>
<tr>
<th>Slope Top Surface (°)</th>
<th>Edge Slope (°)</th>
<th>Effective Edge Slope (°)</th>
<th>Slope Top Surface (°)</th>
<th>Edge Slope (°)</th>
<th>Effective Edge Slope (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30</td>
<td>29</td>
<td>4</td>
<td>32</td>
<td>28</td>
</tr>
<tr>
<td>1</td>
<td>30</td>
<td>29</td>
<td>4</td>
<td>30</td>
<td>26</td>
</tr>
<tr>
<td>1</td>
<td>30</td>
<td>29</td>
<td>3</td>
<td>30</td>
<td>27</td>
</tr>
<tr>
<td>1</td>
<td>30</td>
<td>29</td>
<td>3</td>
<td>30</td>
<td>27</td>
</tr>
<tr>
<td>1</td>
<td>30</td>
<td>29</td>
<td>3</td>
<td>30</td>
<td>27</td>
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<td>1</td>
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<td>1</td>
<td>30</td>
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<td>2</td>
<td>30</td>
<td>28</td>
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<tr>
<td>1</td>
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<td>2</td>
<td>30</td>
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<td>1</td>
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<td>1</td>
<td>30</td>
<td>29</td>
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<td>1</td>
<td>30</td>
<td>29</td>
<td>2</td>
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<td>28</td>
</tr>
<tr>
<td>1</td>
<td>30</td>
<td>29</td>
<td>2</td>
<td>30</td>
<td>28</td>
</tr>
<tr>
<td>Average</td>
<td>29</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figures 37 through 40 show the SR 410 pavement edge treatment one year after construction. Some erosion can be seen of the shoulder material exposing the pavement edge treatment.

Figure 37. Pavement edge treatment close-up one year after construction.

Figure 38. Pavement edge treatment on SR 410 one year after construction.

Figure 39. Another photo of the SR-410 pavement edge treatment one year after construction.

Figure 40. Close-up of pavement edge treatment on SR 410 one year after construction. Shows some exposure of pavement edge treatment.
Contract 8241, SR 21, Curlew State Park to N of Rin Con Creek Rd - Paving

The third project was located on SR 21 between Republic, Washington and the border with Canada. The project limits extended from MP 168.58 to MP 183.80 a distance of 15.22 miles. The roadway was preleveled and then paved shoulder to shoulder with 0.15 ft. of HMA Class 3/8 inch. The pavement edge treatment was added as a Special Provision in the contract (Appendix B). The Contractor, Poe Asphalt Paving Inc., used an Advant-Edge™ and a homemade edge roller to form the pavement edge treatment. The paving occurred in the summer of 2012. Figures 42 through 51 show the roadway prior to construction, the construction operation and formation of the pavement edge treatment, and the finished product.

Figure 41. SR 21, Curlew State Park to North of Rin Con Creek location map.
Figure 42. Advant-Edge™ used to produce the pavement edge treatment.

Figure 43. Pavement edge treatment produced by the Advant-Edge™.

Figure 44. Pavement edge treatment on SR 21.

Figure 45. Close-up of edge treatment slope.

Figure 46. Side view of edge treatment.

Figure 47. Another view of the edge treatment.
Measurements were taken at three locations to determine the angle of pavement edge treatment after compaction of the edge. The results are summarized in Table 5. The average of 20° is well below the target value of 30° indicating the slopes are flatter making it easier for vehicles to re-enter the roadway if they exited the pavement.
Table 5. After compaction slope measurements for SR 21.

<table>
<thead>
<tr>
<th>Height (in.)</th>
<th>Length (in.)</th>
<th>Degrees (º)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>15.5</td>
<td>15</td>
</tr>
<tr>
<td>5</td>
<td>13</td>
<td>23</td>
</tr>
<tr>
<td>3</td>
<td>8.5</td>
<td>21</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>20</strong></td>
<td></td>
</tr>
</tbody>
</table>

**Contract 8271, SR 542, Fossil Cr to Wells Cr Rd Vic - Paving**

The fourth project was located on SR 542, the Mt. Baker Highway, between Glacier and the end of the route. The project limits extended from MP 38.65 to MP 41.55 a distance of 2.90 miles, however, the first 0.43 miles were a paving exception; therefore, the total length of paving was only 2.47 miles. The entire roadway was planed 0.15 inches shoulder to shoulder in preparation for the paving. The pavement section consisted of 0.15 ft. of HMA Class 3/8 inch over 0.08 inches of HMA Class 3/8 inch pre-leveling. The pavement edge treatment was added as a Special Provision in the contract (Appendix B). The contract was awarded to Granite Construction Inc. with paving scheduled for August of 2012. The Carlson End Gate was used to form the pavement edge treatment on this project.
Figures 53 through 60 show the construction operation and formation of the pavement edge treatment, and the finished product.
Figure 55. Pavement edge treatment produced by the Carlson end gate.

Figure 56. Slope indicator device on the edge treatment. Slope does not appear to be compacted.

Figure 57. Close-up of slope indicator.

Figure 58. View showing uniform appearance of edge treatment.

Figure 59. Pavement edge treatment next to guardrail.

Figure 60. Pavement edge treatment next to guardrail.
Table 6 lists the slope measurement made of the finished pavement using a slope indicator gauge (Figures 56 and 57). The average of 28º meets the pavement edge goal of 30º and none of the slopes fall out of FHWA’s 26 to 40º recommended range.

<table>
<thead>
<tr>
<th>Station</th>
<th>Milepost</th>
<th>Slope (º)</th>
</tr>
</thead>
<tbody>
<tr>
<td>121+50</td>
<td>40.75</td>
<td>24.0</td>
</tr>
<tr>
<td>122+50</td>
<td>40.77</td>
<td>25.0</td>
</tr>
<tr>
<td>123+50</td>
<td>40.79</td>
<td>39.0</td>
</tr>
<tr>
<td>124+50</td>
<td>40.81</td>
<td>27.0</td>
</tr>
<tr>
<td>125+50</td>
<td>40.82</td>
<td>35.0</td>
</tr>
<tr>
<td>126+50</td>
<td>40.84</td>
<td>31.0</td>
</tr>
<tr>
<td>127+50</td>
<td>40.86</td>
<td>27.0</td>
</tr>
<tr>
<td>129+50</td>
<td>40.90</td>
<td>26.0</td>
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<tr>
<td>131+50</td>
<td>40.94</td>
<td>23.0</td>
</tr>
<tr>
<td>133+50</td>
<td>40.98</td>
<td>24.0</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>28.0</td>
</tr>
</tbody>
</table>

**Summary of Findings**

All of the pavement edge devices were capable of producing a finished pavement that met the FHWA’s goal of 30º (Table 7). The slope angles produced on the four WSDOT projects which ranged from 20 to 30 degrees are generally lower and in the case of the Avant-Edge™ and TransTech significantly lower than those reported on the FHWA demonstration projects. As previously noted, pavement edges produced by the Advant-Edge™ had an average slope angle of 50º, by the TransTech an average of 37º, and by the Carlson End Gate an average of 31º on the trial demonstration projects. It would appear that perhaps the design of the first two devices has changed since the demonstration projects were built, or that contractors have become more adept at using the devices to produce the desired slope angle.
## Table 7. Average compacted slope angle for each project.

<table>
<thead>
<tr>
<th>Project</th>
<th>Average Slope Angle (°)</th>
<th>Device Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR 395, Lee Road to Junction I-90</td>
<td>23</td>
<td>Contractor built</td>
</tr>
<tr>
<td>SR 410, Twin Creek to Mather Memorial Park Pull-Off Paving</td>
<td>31</td>
<td>TransTech Shoulder Wedge Maker™</td>
</tr>
<tr>
<td>SR 21, Curlew State Park to North of Rin Con Creek</td>
<td>20</td>
<td>Advant-Edge™</td>
</tr>
<tr>
<td>SR 542, Fossil Cr. To Wells Cr. Rd. Vic. Paving</td>
<td>28</td>
<td>Carlson Safety Edge End Gate</td>
</tr>
</tbody>
</table>

## Evaluation of the Process and the Devices

On the first two projects the Contractors and project personnel were asked to evaluate the use of the edge forming devices, its effect on rates of production, possible added cost, possible improvement in the quality of the finished pavement edge, challenges in using the devices, and any recommendations that might improve the process. On the last two projects the same questions were posed only to the WSDOT project engineers.

On the first two projects the interviews with WSDOT and the Contractor’s personnel both revealed that the pavement edge treatment was very easy to install and that it resulted in very little to no additional effort. One paving foreman felt that it was a stronger edge by his observations of loaded trucks driving off the edge compare with the traditional edge. On the last two projects, the project engineers indicated that the cost to the contractors of acquiring the edge devices were minor and the actual use of the devices resulted in no additional cost nor did it slow down production. The project engineer on the SR 21 project indicated that the pavement edge treatment provided an improvement since the shoulders were very narrow and the existing slopes were often 3:1 or steeper. The PE on the SR 542 project did not see the benefit of the pavement edge treatment due to the fact that most of SR 542 is winding and narrow and protected by guardrail. It was his opinion that the project did not prove to be a good selection for a trial use of the pavement edge treatment. In fact, the pavement edge treatment turned out to be a liability in that there was slightly less depth of pavement where there should have been full depth at the
edge of the guardrail. The project engineer recommended that future project selection should be based on roadways that have a history of overtracking where the pavement edge and shoulder material are being frequently disturbed by vehicles.

**Future Research**

The experimental feature work plan (Appendix C) calls for annual reports and a final report at the end of a five year monitoring period. The final report will include details of the performance of the pavement edge treatment projects and collision reduction statistics.

**References**


Appendix A

FHWA Demonstration Projects
Summary Data
# Experimental Feature Report

<table>
<thead>
<tr>
<th>Date</th>
<th>Project Name</th>
<th>Device Used</th>
<th>Placement Comments</th>
<th>Safety Edge® Demonstration Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 2016</td>
<td>Fairview, IA</td>
<td>Contractor made device</td>
<td>Edgeing face was slightly concave or convex at some locations, but it was generally not considered a issue with regard to performance at the SE. Additional labor was needed where massive crossed existing roads.</td>
<td></td>
</tr>
<tr>
<td>May 2016</td>
<td>Elizabethown, PA</td>
<td>Advance Edge</td>
<td>Problems adjusting four things at once, Safety Edge device, screwdriver, and plate. Extraordinary results were obtained. New SEs were used in a large area, and only a very small amount of additional labor was needed.</td>
<td></td>
</tr>
<tr>
<td>July 2016</td>
<td>Kimball, NE</td>
<td>TransTech Shoulder Wedge Maker</td>
<td>Spring stiffness is too high and the travel length too short which results in the device raising the screw in paving across intersections or areas where higher longitudinal profile. Construction personnel recommended that an automated system be developed to raise and lower the Safety Edge device.</td>
<td></td>
</tr>
<tr>
<td>July 2016</td>
<td>SR 102, Columbus, MS</td>
<td>TransTech Shoulder Wedge Maker</td>
<td>Automated system needed to raise and lower the Safety Edge device. This device performed very well, and the construction personnel recommended it for future use.</td>
<td></td>
</tr>
<tr>
<td>Aug 2016</td>
<td>Turner, NE</td>
<td>Advance-Edge, TransTech Shoulder Wedge Maker and Natchez Wedge Joint Maker</td>
<td>Construction personnel suggested putting a sleeve around the Safety Edge spring to keep it from moving too far. They also noted that the SEs performed very well.</td>
<td></td>
</tr>
<tr>
<td>Aug 2016</td>
<td>Jasper County, AL</td>
<td>TransTech Shoulder Wedge Maker</td>
<td>Automated adjustment system recommended. Support making the angle of the Safety Edge device align to the straddle so that it can be changed using HMA mixtures by which the slope angle tends to increase when compacted.</td>
<td></td>
</tr>
<tr>
<td>Aug 2016</td>
<td>Stillwell, DE</td>
<td>Advance-Edge, TransTech Shoulder Wedge Maker</td>
<td>Project superintendent indicated that there was no difference in the performance between the two devices. The screw driver and the Advance-Edge seemed to work better, but the safety edge was not recommended.</td>
<td></td>
</tr>
<tr>
<td>Sept 2016</td>
<td>Monomnin Co., WI</td>
<td>TransTech Shoulder Wedge Maker, Cedar End Exit</td>
<td>The Contractor's and pave driver agreed to the lead structure in that the screw operated's typical and adjustments automatically controlled the edge. The TransTech device required periodic vertical adjustment.</td>
<td></td>
</tr>
<tr>
<td>April 2011</td>
<td>Bragg's Road, NC</td>
<td>TimberSaw®/Cutter and NCDOT device</td>
<td>Service life of devices could be extended by using a more wear-resistant steel in the shoe contacts the road. The point of the shoe wear was significantly after only a few miles of service. Vertical adjustment screw is easily tested during normal use and should be made of stronger material and/or improved design.</td>
<td></td>
</tr>
<tr>
<td>April 2011</td>
<td>Little Dixie Road, NC</td>
<td>Carlson Paving Products, Inc.</td>
<td>Carlson device was simple to operate and the Operator was able to produce a uniform and stable edge. A slight increase in speed was observed during compaction.</td>
<td></td>
</tr>
</tbody>
</table>

### Results:

- **Average slope:** 31.5° with a maximum value of 24.9° and a minimum value of 14.5°.
- **Composition:** Higher and air voids lower adjacent to the edge of the SE sections as compared to the non-SE sections. However, the air void content of the entire mat was higher than desirable for long-term performance.
- **HMA Mixture:** N.A.
- **Pavement Section:** N/A.
Appendix B

Contract Special Provisions
(Retyped from original)
Section 5-04.3(21) is supplemented with the following:

(******)

Pavement Edge Treatment

A Pavement Edge Treatment shall be constructed to the dimensions shown and at locations designated in the plans. This edge treatment shall not be used along curbing, barrier, or guardrail sections.

The Pavement Edge Treatment device shall provide a sloped and compacted HMA wedge that is constructed monolithically with the pavement. Short sections of handwork will be allowed when necessary for transitions and turnouts or as approved by the Project Engineer.

The Contractor shall submit for approval to the Project Engineer a Pavement Edge Treatment device. An approved device may be available at the Engineer’s project office and the Contractor may call the project office to check on availability. Other acceptable devices are the TransTech Shoulder Wedge Maker and the Advant-Edge.

Contact information for these devices is the following:

1. TransTech Systems, Inc.
   1594 State Street
   Schenectady, NY 12304
   1-800-724-6306
   www.transtechsys.com

2. Advant-Edge Paving Equipment LLC
   P.O. Box 9163
   Niskayuna, NY 12309-01 63
   Ph. 518-280-6090
   Contact: Gary D. Antonelli
   Cell 518-368-5699
   email: garya@nycap.rr.com
   Website: www.advantedgepaving.com

If an alternate device is submitted for approval the Contractor shall provide proof that the device has been used on projects with acceptable results or construct a test section at the beginning of the Pavement Edge Treatment Work and demonstrate to the satisfaction of the Project Engineer that it meets these requirements.

All cost in the Pavement Edge Treatment shall be included in the prices for other Work.
Appendix C

Experimental Feature Work Plan
WORK PLAN

Evaluation of the Pavement Edge Treatment

SR 395 Lee Road to Junction I-90 Decreasing
MP 72.36 to MP 94.85

and

SR 410 Twin Creek to Mather Memorial Park Pull-Off Paving
MP 38.50 to MP 47.70

Mark A. Russell
Pavement Design Engineer
Washington State Department of Transportation

Terry L. Berends
Assistant State Design Engineer
Washington State Department of Transportation
Introduction

Vehicles leaving the roadway in locations of vertical pavement drop offs may overcorrect when re-entering the roadway which can lead to serious collisions. The overcorrection occurs when a vehicle leaves the roadway and uses sharp steering maneuvers to return to the road surface. The potential exists, when drop offs are in the range of 4 inches\(^1\) that a vehicle’s front tire will scrub against the pavement edge and not immediately be able to return to the road surface. In these conditions drivers may increase turning forces in an effort overcome the pavement edge drop. When the tire overcomes the friction forces created by the tire-pavement interaction the vehicle will return to the road surface abruptly and with excess angle. Once the vehicle re-enters the roadway the sharp turning angle of the front tires may result in the vehicle losing control which can cause it to rollover or swerve into oncoming traffic. The pavement edge treatment provides a non-vertical wedge at the edge of the pavement which reduces the forces needed in steering for re-entering the roadway in comparison to a near vertical face.

The pavement edge treatment is a wedge of pavement placed by a device bolted to the screed of the paving machine (Figure 1). FHWA recommends an angle of 30° to 35° between the roadway slope and the slope of the wedge (Figure 2). After completion of paving the gravel is graded back flush with the new pavement just as when a conventional vertical pavement edge is constructed.

\(^1\) Transportation Research Record 1084 “Influence of Pavement Edge and Shoulder Characteristics on Vehicle Handling and Stability” by Don L. Ivey and Dean L. Sicking
Scope

The pavement edge treatment will be constructed at the edge of paved shoulder in accordance with the attached plan detail. Unlike the FHWA detail (Figure 2) the pavement edge treatment will be placed over the existing paved surface and will result in a minor reduction in shoulder width. This is to avoid the need to construct a stabilized flat area outside the existing edge of paved shoulder. In areas where there is an existing stabilized flat area outside the existing pavement, the pavement edge treatment may be placed so that the top of the slope is equal to the edge of the existing pavement.
Staffing

These installations will be constructed as a Region programmed pavement rehabilitation projects. Therefore the assigned Region project office will coordinate and manage all construction aspects. Representatives from the WSDOT Materials Laboratory (1 – 2 people) and WSDOT HQ Design will also be involved with the process.

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Testing

No testing other than that normally conducted on a paving project will be required for the pavement edge treatment.

Reporting

A “Post Construction Report” will be written following completion of the demonstration projects. This report will include construction details, cost of the treatment, and other details concerning the overall process. Annual summaries will also be conducted over the next five years. At the end of the five-year period, a final report will be written which summarizes the performance characteristics and future recommendations for use of this process.
**Cost Estimate**

Construction Costs

Providing the pavement edge shoe is estimated at $3,000. The pavement edge will result in a slight reduction in HMA use which should result in a very minor cost savings.

Testing Costs

No additional testing will be required

Report Writing Costs

Initial Report – 16 hours = $1,600
Annual Report – 4 hours (1 hour each) = $400
Final Report – 32 hours = $3,200

**Schedule**

Construction: Spring/Summer 2011

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<th>Post Const. Report</th>
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