Constructability Review
of
The Safety Edge Construction Technique
2011 WisDOT Pilot Projects

WisDOT Project I.D. 0657-45-14
CMSC Work Order 3.6

Final Report
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Executive Summary

Safety edge is a paving detail for Hot Mix Asphalt (HMA) pavement that calls for constructing the outside pavement edge at a 30-degree angle slope to mitigate the impact of pavement-edge drop-offs. Drop-offs can occur over the life of the pavement as the material adjacent to the pavement settles, erodes or is worn away. This pavement-edge drop-off creates problems after a vehicle drifts off the pavement and drops onto the unpaved surface and tries to re-enter the roadway. While attempting to steer back on to the pavement, the tires can start to rub against the vertical edge of the pavement, causing tire-scrubbing. Drivers attempting to return immediately to the paved roadway can over-steer and lose control of their vehicle because of the tire scrubbing. Constructing a sloped pavement edge requires use of a “shoe” that is attached to the HMA paving machine and forms the sloped safety edge during normal paving operations. Use of the safety edge was required by specification on six pilot HMA overlay projects in Wisconsin in 2011. The Construction and Materials Support Center (CMSC) was retained to evaluate the constructability of the safety edge on the pilot projects. Questionnaires were developed for the consultant project management staff and the contractor’s project managers and/or paving foremen to complete regarding construction aspects of the safety edge. In addition several projects were visited to observe the construction operations first hand and measure the slope angle of the constructed edge. Numerous photos of the safety edge units, the paving operation, rolling of the mat, and the placement of the safety edge for each project are available, but not included in the report. Also, a field review of a safety edge overlay project constructed in 2010 was conducted to observe the pavement and shoulder material condition after one year.

There was no negative impact on the paving operation at the six 2011 project locations due to the safety edge unit. Two types of commercially available “shoes” were used on the projects and there was little difference in performance of the final constructed safety edge. There was a wide range of constructed slope angles on the projects. The mean average slope angle measurement for the single lift projects and the binder lift of the two lift projects was 35.8 degrees. While the mean average slope angle measurements on the surface lift of the two lift projects was 37.3 degrees. These measurements are somewhat higher than the desired range of 30 to 35 degrees recommended by FHWA. Nuclear density test results showed adequate compaction was being achieved at the pavement edge, but it was somewhat lower than that achieved in the middle of the driving lane.
Based upon the results of the 2011 pilot projects it is suggested that the safety edge specification be modified to identify both a target slope range of 30 to 35 degrees and an acceptable tolerance slope range of 30 to 45 degrees. It is also suggested that a second safety edge pilot program be conducted in 2012 to investigate the relationship and impact mix design, rolling pattern, and final density have on construction of the safety edge. Other recommendations regarding paving operations are provided that will help project personnel and contractors achieve the desired safety edge slope.
Constructability Review

of

The Safety Edge Construction Technique

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Safety Edge Background

The USDOT Federal Highway Administration (FHWA) through its Every Day Counts initiative is recommending that State Highway Agencies (SHAs) adopt a Hot Mix Asphalt (HMA) paving construction technology called Safety Edge. Safety edge is a paving detail that consolidates the pavement edge into a 30-degree angle to mitigate pavement-edge drop-offs. The FHWA notes that one cause of roadway departure crashes, particularly on rural two-lane highways with unpaved shoulders, is vertical pavement-edge drop-offs. The drop-offs occur over the life of the pavement as the materials adjacent to the pavement settles, erodes or is worn away. This pavement-edge drop-off creates problems after a vehicle drifts off the pavement and drops onto the unpaved surface and tries to re-enter the roadway. While attempting to steer back on to the pavement, the tires can start to rub against the vertical edge of the pavement, causing tire-scrubbing. Drivers attempting to return immediately to the paved roadway can over-steer and lose control of their vehicle. The Wisconsin Department of Transportation (WisDOT) attempts to mitigate this drop-off by grading the adjacent unpaved material so that it is flush with the top of the pavement. However, frequent maintenance is required due to recurring issues of settling material, tire wear and shoulder material erosion. FHWA contends that an effective and inexpensive counter-measure to pavement edge drop-offs is to construct the pavement initially with an angled edge. Their studies have shown that providing a 30-degree angled edge eliminates tire-scrubbing, making the pavement edge safer for drivers and cyclists.

Figure 1 shows a graph that was developed as a result of the findings of research at the Texas Transportation Institute and published in TRB first State of the Art Report The Influence of Roadway Surface Discontinuities on Safety January 1, 1984.
The relative degree of safety for each edge shape was based on an average of subjective ratings by four drivers with varying driver skills from professional to novice, driving three sizes of sedans and a pick-up truck (tires from 12” to 15”) at speeds of 35, 45, and 55 mph. The research was also published in TRB 10th State of the Art Report Influence of Roadway Surface Discontinuities on Safety, May 2009 (CIRCULAR E-C134). Shape B is typical of conventional HMA overlay edge condition. And Shape A is typical of concrete pavements and new HMA pavement. As a result of the field demonstrations it was found that a 30 degree edge profile was easier to construct and had better performance than the 45° (Shape C) edge. However, the 45° edge angle still produced a reasonably safe edge and was much preferable to the 90° vertical edge of Shape A.

Constructing such a 30 degree edge requires use of a “shoe” that is attached to the HMA paving machine that forms the Safety Edge during normal paving operations. As the HMA paving material extrudes from the paver, the shoe forms a consolidated pavement edge at the
appropria\nt shape and angle. There are several commercially available shoes that can be adapted to various HMA pavers. A list of manufacturers is provided in Appendix H.

The Federal Highway Administration has established a safety edge web site in order to collect and provide pertinent information on the safety edge technique. The web site address is http://www.fhwa.dot.gov/everydaycounts/technology/safetyedge/intro.cfm. The web site includes an introduction to the safety edge and its safety advantages, case studies, frequency asked questions and answers, related publications, brochures, videos and resources.

The FHWA “Every Day Counts” web site referred to in the previous paragraph includes Field Reports for nine HMA overlay projects constructed in 2010 using the safety edge feature, including a Wisconsin project on STH 55 in Menominee County. A brief summary of the observations made on those projects is provided in Appendix A.

The following sources also include information on the safety edge feature used on HMA overlay projects:

   http://www.fhwa.dot.gov/publications/focus/11jun/11jun00.cfm

2) Wisconsin Transportation Information Center, Crossroads Newsletter, “Closer Look at the Safety Edge”, Winter 2011

   Final Report will be available in 2012.

4) FHWA “Safety Evaluation of the Safety Edge Treatment” Report, April 2011

**Project Scope**

The Wisconsin Department of Transportation (WisDOT) requested that the Construction and Materials Support Center (CMSC) at the University of Wisconsin – Madison assist in the evaluation of the pilot program for construction of the safety edge in Wisconsin. The scope of the project involved obtaining information on six WisDOT projects constructed in 2011 to document how the contractor constructed the safety edge, what equipment modifications were required, if there were any construction problems encountered and how successful they
were in construction the recommended 30-degree angled edge. Information on the projects was obtained by conducting field reviews during paving operations on three projects and having project management personnel complete surveys for the other three projects. Contractor’s personnel were asked to complete surveys at the end of the paving operations for all six projects. In addition, a field review was done on the one safety edge project constructed by WisDOT in 2010 to observe the condition of the shoulder material adjacent to the pavement edge.

The six WisDOT projects involved in the 2011 pilot effort were distributed among the five WisDOT Regions and represented reconstruction projects, preventative maintenance projects and 3R overlay projects. Locations, features and details for each of the pilot projects are shown in Table 1.

**Project Objectives**

The objectives of the study were as follows:

1. **Evaluate Constructability of Safety Edge Technique**

   Based on observations and comments from the project engineer and paving contractor representatives, determine the ease of installing the safety edge feature on a HMA overlay project.

2. **Identify Performance Requirements**

   Recommend installation requirements for the safety edge feature that should be included in special provisions for future projects that include the safety edge related to tangent sections, curvilinear sections with superelevation transitions, variable thicknesses and number of lifts, pavement density, safety edge density and impact on ride.

3. **Recommend Language for Future Performance Specifications**

   Special Provisions and Detail Drawings used on the six 2011 safety edge projects are included in the Appendix. Based on observations of these projects and comments by the project engineers and paving contractor’s representative, develop recommendations for future specifications.
<table>
<thead>
<tr>
<th>Region</th>
<th>County</th>
<th>Project I.D.</th>
<th>STH #</th>
<th>Project Limits</th>
<th>Project Length (mi.)</th>
<th>A.D.T. (Year)</th>
<th>Project Type</th>
<th>Existing Pavement</th>
<th>HMA Mix Design</th>
<th>Overlay Thickness (inches)</th>
<th>Paving Contractor</th>
<th>Safety Edge Device</th>
</tr>
</thead>
<tbody>
<tr>
<td>SE</td>
<td>Washington</td>
<td>4010-05-70</td>
<td>144</td>
<td>West Bend-</td>
<td>8.373</td>
<td>4,500 (south end)-7,500 (north end) (2010)</td>
<td>Resurfacing with profile milling of existing surface</td>
<td>HMA Pavement over Concrete</td>
<td>19mm E3 (binder)</td>
<td>3 (binder); 1 3/4 (surface)</td>
<td>Payne &amp; Dolan</td>
<td>Carlson Paving Products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Monroe State Line</td>
<td></td>
<td>8.3 (est.)</td>
<td>Reconstruction with rubblizing of existing surface</td>
<td>Concrete</td>
<td>19mm E3R Superpave (binder)</td>
<td>1 3/4 or 2 1/2 (binder); 1 3/4 (surface)</td>
<td>Rock Road</td>
<td>&quot;Shoulder Wedge Maker&quot;</td>
</tr>
<tr>
<td></td>
<td>Sheboygan</td>
<td>4570-06-60</td>
<td></td>
<td></td>
<td></td>
<td>5,050 (2011)</td>
<td>Resurfacing with milling of existing surface</td>
<td>HMA</td>
<td>19mm E3 Superpave (binder)</td>
<td>1 3/4 (surface)</td>
<td>Northwoods Paving</td>
<td>&quot;Shoulder Wedge Maker&quot;</td>
</tr>
<tr>
<td>NW</td>
<td>Ashland</td>
<td>1180-00-73</td>
<td>USH 2</td>
<td>36th Ave.-Government Road</td>
<td>6.845</td>
<td>2,300 (2011)</td>
<td>Preventive Maintenance</td>
<td>HMA</td>
<td>19mm E1 Superpave (binder)</td>
<td>2 (surface)</td>
<td>Northeast Asphalt</td>
<td>Carlson Paving Products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Preventive Maintenance with milling of existing surface</td>
<td>HMA</td>
<td>12.5mm E1 Superpave (binder)</td>
<td>2 (surface)</td>
<td>American Asphalt</td>
</tr>
<tr>
<td>NC</td>
<td>Green Lake</td>
<td>6064-02-72</td>
<td>73</td>
<td>S.C.L.-Jct. STH 44</td>
<td>4.311</td>
<td>2,300 (2011)</td>
<td>Preventive Maintenance</td>
<td>HMA</td>
<td>12.5mm E3 Superpave (binder)</td>
<td>2 (surface)</td>
<td>Carlson Paving Products</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Preventive Maintenance with milling of existing surface</td>
<td>HMA</td>
<td>2 (surface)</td>
<td>&quot;Safety Edge End Gate&quot;</td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 1: 2011 Safety Edge Projects-Locations and Features**
Field Review Approach

Information obtained for each of the six pilot projects during the field reviews included the following information:

1. **Asphalt Mix Design.**

   Copies of the asphalt mix design forms for each project were collected from the project engineers and filed.

2. **Project Engineer and Contractor’s Questionnaires.**

   Questionnaires were developed by the study team for use on the project. Project personnel from the consulting engineering firms managing the projects and the contractor’s project managers and/or paving foremen were asked to complete a safety edge project questionnaire upon the completion of the mainline paving operations.

3. **Observations and Photos.**

   There project sites were visited (STH 73, STH 69, and STH 144) to observe the paving operation and the safety edge feature. Photos were taken of the safety edge unit, the paving and rolling operation, and the installed safety edge feature. The project engineers on the other three projects (STH 13, USH 2, and STH 42) were requested to closely observe the paving operation and safety edge feature and record their observations on the project engineer’s questionnaire and obtain photos of the observation to provide to the author.

4. **Field Testing**

   a) Nuclear density testing on the in-place surface lift was performed at the standard location in the middle of the traveled lane by the contractor (QC readings) and the consultant (QV). Additional nuclear density tests performed at the edge of the traveled lane were performed by WisDOT Statewide Bureau staff.

   b) Slope angle measurements were obtained for the safety edge on the binder lift and the surface lift both before and after the breakdown roller passed over the HMA pavement. A straight edge and wooden ruler were used to measure the vertical and horizontal dimensions of the safety edge feature. The slope angle was then calculated using these
measurements. Slope angle measurements were subjective based on the location of the starting point of the safety edge at the outside edge of the traveled lane and at the low point of the safety edge slope selected by the various inspectors performing the measurement.

c) International Roughness Index (IRI) ride measurements were obtained for the projects by WisDOT staff using a high speed profiler.

Field Review Findings and Observations

A summary of the findings from the field reviews and contractors comments are provided below.

1. Field Review Findings

   a) Asphalt Mix Design Information from the asphalt mix design form for each project is included in Table 1: 2011 Safety Edge Projects-Locations and Features.

   b) Project Engineer and Contractor’s representative comments provided on the questionnaire can be found in Appendix D. A summary of those comments follows:

   Project Engineers Questions and Comments

   1) Ease of installation and start up issues? Device was installed in about one hour. No issues with the installation.

   2) Any negative impact? Additional time required by the paving crew to make adjustments to insure that safety edge was placed properly. On a thin overlay (two-inches), initially the safety edge tended to create a longitudinal crack along the edge. With power brooming of the shoulder area to eliminate loosed fines and aggregate prior to paving, the safety edge held together better with any longitudinal cracking.

   When the safety edge feature overhung the width of the binder lift, occasionally longitudinal cracking occurred.

   3) Any segregation of the bituminous material? None noted.

   4) Any adjustments of the screed or paver required? None observed. Some adjustment of TransTech or Carlson unit noted on three projects.

   5) Observations of material compaction or consolidation at safety edge? On two projects, the two-inch thick overlay caused some longitudinal cracking where the safety edge overhung
the base material. On some projects, the rolling pattern was modified to prevent the edge from deforming when rolled.

6) Consistency of the shape & slope of safety edge? The safety edge was of a consistent shape after placement and before the mat was rolled. On most of the projects, the shape and slope of the safety edge after rolling became more consistent as the contractor had more experience with the rolling of the safety edge break point.

7) Observations of density and air voids adjacent to the edge? No changes noted on five projects. On one project, density at the edge appeared to be better and air voids appeared to have decreased compared to a non safety edge project (air void measurements were not obtained).

8) Any effect on project material yield? Minor (< 1 percent) changes noted.

9) Any negative impact on placement of gravel shoulders? None noted.

10) Does gravel shoulder stay in place on top of safety edge? Too early to determine on five projects. Shoulder material will not be placed until 2012 on one project.

11) Overall impression of the safety edge? Works well for loaded asphalt trucks during the paving operation and before shoulder material is placed. Placement of the safety edge needs some “fine tuning”. No issues during the placement of the gravel shoulder material. The finished product should function as designed.

12) Suggestions for safety edge specifications on future projects? No comments from two projects. Installation of safety edge should be discussed in detail at the preconstruction conference. Specifications should require the contractor to use a safety edge device that can install the safety edge on a multiple lift project in order to match up the safety edge formed on each lift. No comments were noted on use of the safety edge on tangent sections vs. curvilinear sections with super elevation transitions.

13) Recommendations for inspectors on future safety edge projects? Focus on the safety edge during the rolling operation. Check the safety edge slope angle after rolling. Observe for longitudinal cracking and “breaking off” of the edge. Avoid rolling over the break point of the edge. Make adjustments of the width of paving and the side plate to match up with the safety edge on the previous lift.

14) List three keys to constructing a successful safety edge? Use a safety edge unit with adjustable slope, bituminous mix design, rolling of the mat, adequate binder width to support the safety edge with a level and stable surface, cooperative contractor, close monitoring of the safety edge installation, paving operator to adjust the outside edge of the paver when needed.

Paving Contractor’s Comments
1) Additional project costs considered when bidding project? Cost of safety edge unit ($3,000-$5,000) plus cost of time for initial set up on the paver.

2) Time required to install safety edge unit? Varied from 10-15 minutes to 1-3 hours.

3) Ease of installing safety edge unit? Only had to drill a few holes on the paver end gate and bolt on safety edge device.

4) Where and how is safety edge unit installed on paver? Carlson unit is installed on screed extension next to the gate with four bolts. TransTech unit is installed on the outside of the paver screed. Had to drill and tape holes to mount a ½-inch spacer plate on the back of the safety edge.

5) Paver and safety edge used on project? STH 13-Terex/Cedar Rapids paver with a Versascreeed 10 and Carlson safety edge unit; USH 2-paver unit not reported and TransTech safety edge unit; STH 42-Blaw Knox paver with Carlson screed and Carlson safety edge unit; STH 73-Blaw Knox paver with Carlson screed and Carlson safety edge unit; STH 69-Cat AP1000D paver and TransTech safety edge unit; STH 144-Blaw Knox 3200 paver and Carlson safety edge unit.

6) Any negative impact on the paving operation? One project reported... Only if gravel shoulder is too high. Other five projects reported no other issues.

7) Any modifications to the safety edge unit during paving operations? Nothing reported on four projects. Constant adjustments to get the bit material to flow and compact reported on one project. Had to raise the safety edge up over gravel shoulders reported on one project.

8) Any situations where the safety edge had to be removed or disengaged? Only when paving through intersections reported for three projects.

9) Any segregation of bit material? None reported.

10) Does device require vertical adjustment of the screed? None reported.

11) Difficult to maintain the desired shape of the safety edge? No reported on two projects. Sometime reported on one project due to single lift. Yes reported on three projects due to density requirements, the type of roller required, or with a “tender” mix, the mat being pushed out further by the roller.

12) Any difference in the consolidation of the material in the safety edge? None reported on four projects. Less compaction on the safety edge slope reported on one project. Could be improved reported on one project.

13) Any affect the paving production rate? None reported on six projects.

14) Any impact on the ride quality? None reported on two projects. Will find out when the IRI readings are taken reported on two projects. Only if the mat gets thin and the safety edge “hits bottom” (gravel or binder material) reported on two projects.

15) Describe the roller operation? Normal pattern used reported on five projects. Left edge pass to last to allow to cool before rolling reported on one project.
16) Describe how safety edge is installed on thicker overlays? Add additional width to compacted base course or binder lift to provide a solid base for safety edge. Form the safety edge on each lift reported on three projects. Only use on the surface lift reported on one project.

2. Field Review Observations

Based on the three projects visited, the following observations were made:

a) STH 73. The binder lift of 3-foot-3 width that was placed on the existing three foot wide bituminous shoulder that was milled was not adequate to support the safety edge installed with the surface lift in some areas due to a variation in the width of the driving lane. Without adequate support under the safety edge, there were some locations where a longitudinal crack developed in the surface mat after the break down roller compacted the edge of the pavement.

b) STH 69. The TransTech safety edge device that was used could not be adjusted and could only form the safety edge feature at a slope angle of 30 degrees. The roller pattern not changed from the normal three pass starting at the center line and moving towards the edge of pavement. No movement or shoving of the mat was noted at the edge of pavement when it was rolled. The first and second binder lifts were placed at a wider width than the 12-foot driving lane width to provide support for the safety edge feature. The paving foreman had a crew member assigned to watching the safety edge being installed with the surface lift and making adjustments so that the safety edge feature of the surface lift matched the safety edge feature of the second binder lift. A laborer was also used to hand rake the bituminous mix at the surface lift safety edge to match the previously placed safety edge.

c) STH 144. Only observed placement of binder lift. Surface lift will be placed in 2012. Binder lift was placed at an additional eight-inch width to provide support for surface lift safety edge feature. Due to the placement of the binder lift at a 3 ½ -4-inch thickness to produce a finished thickness of three inches, the safety edge unit was not always riding on the aggregate base producing a one-inch vertical lip at the top of the safety edge. There was no up or down adjustment of the Carlson safety edge unit possible to eliminate the lip. The breakdown roller compacted most of the lip after rolling the edge. The roller operator left approximately a six-inch width at the edge to be rolled last after the pavement had cooled. A seven pass rolling
pattern was used with the roller passing over the entire width two times. The ambient air temperature seemed to affect how much the mat moved or compacted when rolled. The safety edge shape stayed as it had been placed by the paver and then rolled during the afternoon paving operation.

d) The TransTech safety edge unit needs to be installed tightly to the end plate to prevent bituminous material from getting between the device plate and the end plate.

e) The Carlson safety edge unit can be adjusted to form various slope angles from 30 to 90 degrees.

NOTE: STH 13, USH 2, and STH 42 projects refer to the project engineer questionnaire summary in the Field Review Findings section of the report and Appendix D for observations made by the project engineers and paving foremen for these three projects.
3. **Field Test Results**

   a) A summary of nuclear density testing results is shown in the following Table 2:

<table>
<thead>
<tr>
<th>STH</th>
<th>Tests Performed By</th>
<th>Test Performed on Lift</th>
<th>Test Location</th>
<th>N</th>
<th>Mean (%)</th>
<th>Std. Dev.</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>144</td>
<td>QC</td>
<td>Binder</td>
<td>Driving Lane</td>
<td>51</td>
<td>93.3</td>
<td>1.03</td>
<td>91.3-95.4</td>
</tr>
<tr>
<td></td>
<td>QV</td>
<td>Binder</td>
<td>Driving Lane</td>
<td>18</td>
<td>94.0</td>
<td>1.02</td>
<td>92.6-95.4</td>
</tr>
<tr>
<td></td>
<td>WisDOT</td>
<td>Binder</td>
<td>N.B.L. (0.0&quot; from edge)</td>
<td>30</td>
<td>86.3</td>
<td>1.57</td>
<td>83.2-91.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Binder</td>
<td>N.B.L. (9.0&quot; from edge)</td>
<td>30</td>
<td>88.8</td>
<td>1.29</td>
<td>86.3-92.5</td>
</tr>
<tr>
<td>69</td>
<td>QC</td>
<td>Surface</td>
<td>Driving Lane</td>
<td>66</td>
<td>92.7</td>
<td>1.14</td>
<td>86.4-94.9</td>
</tr>
<tr>
<td></td>
<td>QV</td>
<td>Surface</td>
<td>Driving Lane</td>
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<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>WisDOT</td>
<td>Surface</td>
<td>S.B.L (4.5&quot; from edge)</td>
<td>50</td>
<td>88.6</td>
<td>1.58</td>
<td>84.0-90.9</td>
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<td></td>
<td></td>
<td>Surface</td>
<td>S.B.L (9.0&quot; from edge)</td>
<td>50</td>
<td>90.9</td>
<td>1.32</td>
<td>87.2-94.1</td>
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<td>42-Sheboygan Co.</td>
<td>QC</td>
<td>Surface</td>
<td>Driving Lane</td>
<td>12</td>
<td>92.8</td>
<td>1</td>
<td>91.6-94.8</td>
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<td></td>
<td>QV</td>
<td>Surface</td>
<td>Test Not Available</td>
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<td></td>
<td>WisDOT</td>
<td>Binder</td>
<td>N.B.L. (4.5&quot; from edge)</td>
<td>30</td>
<td>88.1</td>
<td>0.93</td>
<td>85.8-90.0</td>
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<td></td>
<td></td>
<td>N.B.L. (9.0&quot; from edge)</td>
<td>30</td>
<td>90.4</td>
<td>0.74</td>
<td>88.8-91.7</td>
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<tr>
<td>42-Manitowoc Co.</td>
<td>QC</td>
<td>Surface</td>
<td>Driving Lane</td>
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<td>93.8</td>
<td>0.76</td>
<td>92.7-94.6</td>
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<td>Tests Not Available</td>
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<td>92.9-98.0</td>
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<td></td>
<td>QV</td>
<td>Surface</td>
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<td></td>
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<tr>
<td>73</td>
<td>QC</td>
<td>Surface</td>
<td>Driving Lane</td>
<td>30</td>
<td>93.8</td>
<td>1.11</td>
<td>91.7-96.0</td>
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<tr>
<td></td>
<td>QV</td>
<td>Surface</td>
<td>Driving Lane</td>
<td>15</td>
<td>92.3</td>
<td>1.05</td>
<td>89.9-94.0</td>
</tr>
<tr>
<td></td>
<td>WisDOT</td>
<td>Surface</td>
<td>S.B.L. (0.0&quot; from edge)</td>
<td>29</td>
<td>87.2</td>
<td>2.21</td>
<td>83.6-92.0</td>
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<tr>
<td></td>
<td></td>
<td>S.B.L. ( 18.0&quot; from edge)</td>
<td>29</td>
<td>90.1</td>
<td>1.14</td>
<td>88.1-92.3</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>QC</td>
<td>Surface</td>
<td>Driving Lane</td>
<td>19</td>
<td>94.1</td>
<td>1.04</td>
<td>92.3-96.1</td>
</tr>
<tr>
<td></td>
<td>QV</td>
<td>Surface</td>
<td>Driving Lane</td>
<td>26</td>
<td>93.4</td>
<td>1.46</td>
<td>91.2-95.9</td>
</tr>
<tr>
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<td>WisDOT</td>
<td>Surface</td>
<td>N.B.L. (4.5&quot; from edge)</td>
<td>15</td>
<td>92.5</td>
<td>0.7</td>
<td>91.5-93.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S.B.L. (4.5&quot; from edge)</td>
<td>15</td>
<td>89.8</td>
<td>1.42</td>
<td>88.2-93.1</td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 2: Nuclear Density Test Results**
Per WisDOT Standard Specifications, the target minimum required density in traffic lanes for the binder lift is 89.5 percent and 91.5 percent for the surface lift.

b) A comparison of the QC nuclear density tests taken in the driving lane and the tests taken at the safety edge is shown in the following Table 3:

<table>
<thead>
<tr>
<th>Project</th>
<th>Avg. QC</th>
<th>QC Range</th>
<th>Avg. 4.5&quot; From Edge</th>
<th>Range 4.5&quot; From Edge</th>
<th>Edge/Driving Lane (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>STH 144</td>
<td>93.3*</td>
<td>91.3-95.4*</td>
<td>86.3*</td>
<td>83.2-91.6*</td>
<td>92</td>
</tr>
<tr>
<td>STH 69</td>
<td>92.7</td>
<td>86.4-94.9</td>
<td>88.6</td>
<td>84.0-90.9</td>
<td>96</td>
</tr>
<tr>
<td>STH 42</td>
<td>92.8</td>
<td>91.6-94.8</td>
<td>88.1</td>
<td>85.8-90.0</td>
<td>95</td>
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<tr>
<td>USH 2</td>
<td>95.5</td>
<td>92.9-98.0</td>
<td>No Tests</td>
<td>Performed</td>
<td>-</td>
</tr>
<tr>
<td>STH 73</td>
<td>93.8</td>
<td>91.7-96.0</td>
<td>87.2</td>
<td>83.6-92.0</td>
<td>93</td>
</tr>
<tr>
<td>STH 13</td>
<td>94.1</td>
<td>92.3-96.1</td>
<td>91.2</td>
<td>88.2-93.8</td>
<td>97</td>
</tr>
</tbody>
</table>

TABLE 3: Comparison of Nuclear Density Tests

* = Tests performed on binder lift.

Nuclear density tests obtained by WisDOT staff were taken at points 4.5”, 9.0”, and 18.0” in from the break point of the safety edge feature. Density tests on the slope of the safety edge were not attempted.

c) A summary of slope angle measurements is shown in Table 4. All measurements were made by the project engineer unless noted.

The Carlson Paving Products unit was used on the STH 13, STH 42, STH 73 and STH 144 projects and the TransTech Systems unit was used on the USH 2 and STH 69 projects. The mean average slope angle measurement on the binder lift of the projects using the Carlson
unit was 31.4 degrees and on the surface lift was 35.8 degrees. The average on the binder lift using the TransTech unit was 38.9 degrees and on the surface lift was 43.0 degrees.

<table>
<thead>
<tr>
<th>STH</th>
<th>Lift</th>
<th>Before / After Hot Roller</th>
<th>N</th>
<th>Mean Value (%)</th>
<th>Std. Dev.</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>144</td>
<td>Binder (3&quot;)</td>
<td>Before (by author)</td>
<td>4</td>
<td>39.0</td>
<td>0.92</td>
<td>38.2-39.8</td>
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<tr>
<td></td>
<td></td>
<td>1st Day (by author)</td>
<td>5</td>
<td>28.7</td>
<td>3.55</td>
<td>24.4-33.7</td>
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<tr>
<td></td>
<td></td>
<td>2nd Day (by author)</td>
<td>5</td>
<td>25.5</td>
<td>5.30</td>
<td>19.6-33.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3rd Day (by author)</td>
<td>8</td>
<td>36.7</td>
<td>4.04</td>
<td>31.0-45.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Surface (1 3/4&quot;)</td>
<td></td>
<td>To Be Paved in 2012</td>
<td></td>
<td></td>
</tr>
<tr>
<td>69</td>
<td>Binder (1 3/4&quot; or 2 1/4&quot;)</td>
<td>Before (by author)</td>
<td>6</td>
<td>48.4</td>
<td>2.45</td>
<td>45.0-51.6</td>
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<tr>
<td></td>
<td></td>
<td>After (by author)</td>
<td>12</td>
<td>43.2</td>
<td>5.02</td>
<td>36.0-53.1</td>
</tr>
<tr>
<td></td>
<td>Surface (1 3/4&quot;)</td>
<td>Before (by author)</td>
<td>3</td>
<td>36.6</td>
<td>2.77</td>
<td>35.0-39.8</td>
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<td></td>
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<td>36.6</td>
<td>2.98</td>
<td>33.0-39.1</td>
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<tr>
<td>42</td>
<td>Surface-Sheboygan Co. (1 3/4&quot;)</td>
<td>After</td>
<td>17</td>
<td>34.9</td>
<td>4.61</td>
<td>27.6-45.0</td>
</tr>
<tr>
<td></td>
<td>Surface-Manitowoc Co. (2 1/4&quot;)</td>
<td>After</td>
<td>37</td>
<td>33.0</td>
<td>4.27</td>
<td>27.6-45.0</td>
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<tr>
<td>USH 2</td>
<td>Binder (2 1/4&quot;)</td>
<td>After</td>
<td>13</td>
<td>34.0</td>
<td>7.87</td>
<td>19.6-45.0</td>
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<td>Surface (1 3/4&quot;)</td>
<td>After</td>
<td>20</td>
<td>44.6</td>
<td>6.46</td>
<td>26.6-53.1</td>
</tr>
<tr>
<td>73</td>
<td>Surface (2&quot;)</td>
<td>After (by author)</td>
<td>7</td>
<td>33.5</td>
<td>8.04</td>
<td>26.6-50.2</td>
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<tr>
<td></td>
<td></td>
<td>Before (by Project Engineer)</td>
<td>8</td>
<td>30.8</td>
<td>2.54</td>
<td>26.6-34.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>After (by Project Engineer)</td>
<td>24</td>
<td>36.7</td>
<td>3.68</td>
<td>28.6-45.0</td>
</tr>
<tr>
<td>13</td>
<td>Surface (2&quot;)</td>
<td>After</td>
<td>30</td>
<td>38.6</td>
<td>3.42</td>
<td>32.0-47.0</td>
</tr>
</tbody>
</table>

TABLE 4: Safety Edge Slope Angle Measurements
The mean average slope angle measurement for the single lift projects and the binder lift of the two lift projects was 35.8 degrees. While the mean average slope angle measurements on the surface lift of the two lift projects was 37.3 degrees. These measurements are somewhat higher than the desired range of 30 to 35 degrees recommended by FHWA.

The range of measurements that were taken on the six projects varied from a low of 19.6 degrees to a high of 53.1 degrees on the single lift or binder lift and from a low of 26.6 to a high of 45.0 degrees on the surface lift of two lift projects. The reasons for these wide ranges needs further study. The consultant’s staff on three of the projects felt that some of the variation in the wide range of slope angle measurements on those projects could be attributed to:

1) STH 42 project—measurements were made by different members of the project management team on the north and south sections of the project and measurement locations, and vertical and horizontal measurements were somewhat subjective in were they were taken and a small measurement difference could make a large difference in the angle calculation. Also, different breakdown rollers were used with slightly different rolling patterns and rolling or the edge on the north and south sections of the project.

2) USH 2—the bituminous mat was compressed vertically by the breakdown roller creating lateral movement at the edge of the pavement. As a result, the finished edge was not a crisp, uniform slope. Attempting to form a sharp edge detail on a two inch overlay thickness using very large equipment and a bituminous mix aggregate that is large compared to the dimensions of the edge detail can be problematic.

3) STH 73—variation in the width of the existing driving lane and paved shoulder caused the safety edge to overhang the milled shoulder and binder lift in some areas of the project. This caused variation in the finished dimensions of the safety edge feature.

d) A summary of average International Roughness Index (IRI) ride measurements of the mainline are shown in the Appendix F for informational purposes. Readings at intersections, bridges, and railroad crossings we not included in the summary. No attempt was made to analyze the effect on the ride quality of the mat from the safety edge feature for this report due to the number of variables that could affect the ride quality.
4. **Photos**

Numerous photos of the safety edge units, the paving operation, rolling of the mat, and the placement of the safety edge for each project are available on C.D. discs provided to WisDOT. Samples of the photos are included in Appendix G.

5. **2010 Safety Edge Project-STH 55, Menominee County**

A field review of the project was conducted on October 6, 2011, approximately one year after the completion of the project. The entire 18.5 mile length of the project was inspected in the northbound and southbound lanes. Gravel shoulder width on the project varied from zero to three feet. Observations of the asphalt pavement and shoulder material were recorded.

   a) Shoulder material that was placed on tangent sections was compacted or washed away to exposed from half an inch to three-quarters of an inch of the safety edge feature as measured on the slope of the safety edge.

   b) Shoulder material that was placed at the junction of the driving lane and side road tapers has been washed away to expose approximately two inches of the safety edge feature as measured on the slope of the safety edge feature.

   c) Shoulder material that was placed at the junction of the driving lane and “slow vehicle turnouts” has been removed to expose from one and a half to three inches of the slope of the safety edge feature.

   d) Shoulder material that had been placed on the inside of curve sections, especially sharper curves, has been washed away to expose from two to three inches of the safety edge slope.
Conclusions

1. **2010 Project on STH 55, Menominee County**

The aggregate shoulders have remained in place with only minimal displacement or washing away of the aggregate after one year. Tangent sections exhibited very minor exposure of the safety edge slope. The low sides of sharp curves exhibited the greatest exposure of the safety edge slope.

2. **Asphalt Mix Design**

No segregation of the bituminous mat was observed. No difference in air voids was observed at the safety edge (no testing for air voids was performed). Some lateral movement of the mat under the breakdown roller during compaction on some projects may be due to the HMA mix design for that project. The tenderness of the mix may affect the compaction of the mat at the edge and the final shape of the safety edge.

3. **Project Engineer and Contractor’s Observations of Equipment, Placement, and Results of Safety Edge Feature**

The Safety edge shoe can be easily installed on the paver screed. There was no negative impact on the paving operation due to the safety edge unit. No adjustments of the paving screed were required. Some adjustments of the safety edge was needed to have the HMA material flow, to rise up over gravel shoulder, or when paving through an intersection. The safety edge feature was a consistent shape and slope upon placement by the paver. No segregation of the material was reported. Some difference in the density or air voids of the mat at the safety edge compared to the driving lane was noted. A compacted base and/or a wider binder lift is needed to provide a solid base for the safety edge feature on the binder or surface lift to prevent longitudinal cracking at the break point of the safety edge. For two lift overlay projects, the width of the first lift should be increased to support the safety edge installed with the surface lift. Matching up the safety edge slope formed during placement the two lifts should be monitored by the paving crew. Only a minor (< 1 percent) effect on the project material yield was noted. The tenderness of the HMA mix design can affect the optimum rolling pattern of the mat and the safety edge. Rolling patterns were modified on some projects to delay the rolling of the safety edge in order to preserve the shape and slope of the edge. The safety edge feature does not interfere with the placement of the gravel shoulder material. Inclusion of the safety edge with a HMA overlay does not appear to affect the ride quality of the pavement if the mat is placed at the proper thickness. The installation of the safety edge should be discussed in detail at the pre-paving conference. Paving inspectors need to be more observant of the
safety edge installation, the rolling pattern used on the mat and the slope angle of the safety edge. Keys for a successful safety edge installation include use of a safety edge unit with an adjustable slope, an appropriate HMA mix design, occasional adjusting of the outside edge of the paver when needed, an adequate binder width to support the safety edge, proper rolling of the mat, close monitoring of the safety edge installation, and a cooperative paving contractor.

4. **Field Observations**

Proper installation of the TransTech tight to the end gate is critical to placement of the safety edge feature at the desired 30 degree slope angle. The Carlson safety edge unit can be adjusted to produce the desired slope angle. A properly compacted base and/or an adequate lower lift width are important to provide support for the safety edge feature when the mat is rolled. The rolling pattern used by the breakdown roller needs to be adjusted so that the rolling of the mat edge is delayed to preserve the dimensions of the safety edge. During late season paving operations, the ambient air temperature affects the mat temperature, compaction of the pavement edge and the safety edge slope.

5. **Nuclear Density Tests**

The mean nuclear density value at the safety edge were lower but compared favorable to the QC average nuclear density value obtained in the driving lane and the WisDOT target minimum density value for the surface and binder lifts. Nuclear density values at the edge of non-safety edge pavements were not available for comparison.

6. **Slope Angle Measurements**

The Carlson and the TransTech safety edge units produced similar results. Although the mean slope angle measurements for each project compared favorably with the slope angle of 30-35 percent recommended by FHWA, there was a wide range of measurements on each of the projects. The mean slope angle of the safety edge produced by the Carlson unit was closer to the FHWA recommended slope angle (the Carlson unit can be adjusted to produce various slope angles).

7. **IRI Ride Measurements**

Based on the observations of the project engineers and contractor’s crew, installation of the safety edge did not appear to affect the ride on the pavement. No in depth analysis of the IRI ride data was conducted due to the presence of other variables that could affect the IRI ride measurements.
8. **Future Projects**

Inspections and observations should be considered for and future pilot HMA overlay projects that incorporate the safety edge feature to confirm the conclusions drawn from the 2011 projects. Inspection of safety edge projects constructed in 2010 and 2011 should also be considered in 2012 to observe the condition of the gravel shoulders and the safety edge slope.

**Recommendations**

1. **2010 Project on STH 55, Menominee County**

Inspect the pavement condition, gravel shoulder material condition, and safety edge feature exposure in 2012.

2. **Specifications and Detail Drawing for 2012 Safety Edge Projects**

Indicate a “target” safety edge slope angle of 30 to 35 degrees and an “acceptable” safety edge slope tolerance of 30 to 45 degrees in the specifications. Indicate a safety edge slope of 1.8:1 (30 degrees) to 1.4:1 (35 degrees) on the detail drawing. Longer term, it may be desirable to develop specification language that specifies that the safety edge unit used must be adjustable in order to be adaptable to various paving operations conditions. Another option is to develop a strong performance specification that holds the contractor accountable for constructing the desired safety edge slope and allows them to choose the type of safety edge device used.

3. **Pre-paving Construction Conference**

Conduct a pre-paving construction conference for a detailed discussion of the safety edge feature including safety edge equipment, proper installation, base preparation, pavement width to accommodate the safety edge, paver adjustments, rolling operation and safety edge target slope angle. On multiple lift projects, discuss options for placement of the safety edge feature on both lifts or only on the surface lift.

4. **Asphalt Mix Design**
Further study of the relationship of the mix design, rolling pattern used on the mat, final density of the mat, and the dimensions of the safety edge is needed. A second round of pilot projects will help in investigating what impact each of these factors have on the constructed safety edge slope.

5. **Safety Edge Equipment and Installation**

Project paving inspectors should inspect the condition of the safety edge unit and check for proper installation on the paver screed in accordance with the manufacture’s detailed instructions.

6. **Paving Operation**

Screed operators should continually monitor the screed, edge plate, and safety edge unit and make adjustments as necessary to install the safety edge at the proper shape and slope. Prevent HMA material from getting between the safety edge unit and the end plate. Keep the end plate ski in contact with the surface being paved to prevent material from moving out under the end plate ski and affecting the slope of the safety edge. Monitor the texture and shape of the safety edge. Raise the safety edge or change the angle to 90 degrees when paving through side road intersections.

7. **Rolling Operation**

If necessary, the rolling pattern should be adjusted so that the rolling of the pavement edge does not produce lateral movement of the safety edge and change the dimensions and slope of the safety edge without affecting the compaction of the mat. If necessary, delay rolling of the outer six to 12 inches of the mat until the last pass of the roller.

8. **Paving Inspector Responsibilities**

Inspect installation of the safety edge on the paver screed at the beginning of the paving operation. Daily check the set angle of the unit. Daily check for aggregate wedged between the safety edge plate and the screed end plate. Check the dimensions and slope angle of the safety edge before and after rolling at the start of daily paving operations and periodically during the paving day. Monitor adjustments made to the safety edge and screed by the screed operator. Monitor location of safety edge break point on binder and surface lifts. Inspect rolling pattern operation checking for lateral movement of the safety edge affecting the dimensions and slope to ensure that the targeted slope angle of the safety edge is maintained.

9. **Safety Edge Slope Angle Measurements For Future Safety Edge Pilot Projects**
Perform slope angle measurements of the safety edge using a straight edge and ruler or a protractor according to the FHWA Design and Construction Guide (Refer to Safety Edge References). Perform measurements during the first 1,000 feet of paving each day before and after rolling of the mat and during the daily paving operation. The frequency of measurement points to be determined in the field based on the consistency of the placement and rolling of the safety edge. Further investigate the safety edge slope angle produced by the various safety edge units.

10. Nuclear Density Testing For Future Safety Edge Pilot Projects

Perform nuclear density tests at the safety edge break point for comparison to QC/QV nuclear density tests. The frequency of measurements points to be determined in the field based on the consistency of the QC test results. Obtain nuclear density test results taken at the edge of non-safety edge pavements for comparison.

11. Inspection of 2011 Safety Edge Projects

Inspect the pavement condition, gravel shoulder material condition and safety edge feature exposure in 2012 of all projects constructed in 2011. Inspect the installation of the surface lift with the safety edge feature on the STH 144, Washington County project.

12. Pre-paving Considerations

Provide a compacted base of adequate width to support the safety edge feature. Increase the width of the base, or the lift under the lift to be paved with the safety edge feature by six to eight inches to provide a base for placement of the safety edge to prevent longitudinal cracking at the safety edge break point during the rolling operation. On multiple lift projects when the safety edge feature is placed on both lifts, widen the first lift to allow for the matching up of the safety lift slope of the safety edge installed with the second lift.
APPENDIX

A. Field Reports for Safety Edge Projects Constructed Nationally in 2010
B. 2011 Safety Edge Specification and Detail Drawing
C. FHWA Notes and Photos of 2010 STH 55, Menominee County Safety Edge Project
D. Questionnaire Responses from Project Engineers and Contractor
E. Representatives for 2011 Safety Edge Projects
F. IRI Ride Measurements Summary
G. Photos of Safety Edge Unit, Paving Operations, and In place Safety Edge Feature
H. List of Safety Edge Equipment Manufacture’s Web Sites
APPENDIX A
Field Reports for Safety Edge Projects Constructed Nationally in 2010

1) Route F62, Jasper County, Iowa The slope of the safety edge varied throughout the project. The average slope was 38 degrees. The safety edge was incorporated into all three lifts on the project with the lower lifts extended out slightly farther to accommodate the lifts above resulting in more HMA being used to build the edge. The slope of the safety edge tended to increase with increased lift thickness. The safety edge was formed by using the TransTech “Shoulder Wedge maker” attached to the paver screed. The device required some elevation adjustments by the screed operator when approaching turnouts and intersections. In order to maintain the slope of the safety edge, the breakdown roller and finishing roller were kept from overhanging the edge and applying maximum compaction force. When the roller overhung the edge of the mat, the edge would shift and increase the slope of the safety edge. On future projects, to increase performance, automatic adjustment of the vertical profile of the safety edge device would be of benefit to the paving operator. Since the angle of this safety edge device is currently not adjustable, it would be beneficial on future projects to be able to decrease the angle of the device when using HMA mixes for which the slope angle tends to increase when compacted.

2) State Route 117, Androscoggin County, Turner, Maine The average slope of the safety edge using the Advant Edger “Safety Edge” device was 54 degrees rolling. The average slope of the safety edge using the TransTech “Shoulder Wedge Maker” was 45 degrees after rolling. Both devices produced an edge with a slope of 30 degrees immediately behind the screed. The HMX mix for the surface lift was “normal”, not too tender or too stiff. Using a mix with a different level of stiffness could result in different values for the slope. The contractor originally used nine passes of the breakdown roller for the section paved using the Advant Edger unit. With this number of passes, the HMA was pushing, shoving and tearing under the breakdown roller. The contractor then reduced the number of breakdown roller passes to six for the section paved with the TransTech device to avoid this problem. The compaction of the HMA mat averaged 93 percent in the travel lane and 84 percent near the safety edge break point.

3) State Route 182, Columbus, Mississippi The average slope of the safety edge after rolling was 37 degrees. Before rolling the slope of the safety edge was 40 degrees. The safety edge unit used was the TransTech “Shoulder Wedge Maker”. The paving crew suggested that the device should have an automated system for raising and lowering the device. The HMA mix density was higher adjacent to the safety edge than in the section that did not include the safety edge feature. It was thought that the presence of the safety edge had a confining effect when the mat was rolled. No segregation was observed in any areas of the mat or the safety edge.
4) **Brogden Road, Johnston County, North Carolina** The safety edge feature increased the density and lowered air void content adjacent to the edge compared to the control section. Two breakdown rollers were used behind the paver. One roller was positioned on the longitudinal joint and the other was dedicated to rolling the edge. Lateral movement under the rollers and at the edge was insignificant. The average slope of the safety edge produced by the Troxler device was 28 degrees and 26 degrees by the device fabricated by the North Carolina DOT. The edge of the pavement was not damaged by asphalt hauling trucks during the paving operation.

5) **Little Divine Road, Johnston County, North Carolina** The Carlson device was simple to operate. The contractor was able to produce a uniform and stable edge. The average slope of the safety edge was 29 degrees. The density of the finished pavement was no different than in the control section both adjacent to the edge and three feet from the edge. Lateral movement of the mat produced with a HMA mix was minor under passes of the breakdown roller.

6) **State Route 10, Kearney, Nebraska** The safety edge did not have a detrimental impact on the contractor’s paving operation during mainline paving. The average slope of the safety edge was 34 degrees. The paving crew felt that the slope of the safety edge device would need to be approximately 20 to 25 degrees in order to produce a final 30 degrees desired slope. The safety edge was formed using a TransTech “Shoulder Wedge Maker” unit bolted to the screed. The paving crew recommended that device have an automated system for raising and lowering the device. The spring stiffness of the current device is too high and the travel length too short so that when the paver passed through intersections or areas with a higher longitudinal profile, the safety edge unit would raise the screed relative to the profile set by the longitudinal ski. The HMA density of the safety edge section was the same as the non-safety edge section when using the same rolling pattern. The sections where the rolling pattern was revised to overhang the roller over the edge of the unconfined mat resulted in slightly lower air voids and higher densities compared to the sections where rolling the safety edge was delayed and only one pass of the breakdown roller was used. No segregation of the mat was observed in any areas of the mat or the safety edge.

7) **State Route 2009, Elizabethtown, Pennsylvania** The safety edge feature did not have a detrimental impact on the paving operation during mainline paving. The average slope of the safety edge was 48 degrees. The safety edge was formed using the Advant-Edger device bolted to the screed of the paver. In several areas where paving extended beyond the HMA base, the material upon which the safety edge was placed had not been prepared prior to paving and it is expected that the safety edge within these areas may break off from the mat due to local traffic loading along the edge. Proper preparation of the base for the edge needs to be considered on future projects. At intersections, driveways and changes in longitudinal elevations or profile, it was difficult for the screed operator to adjust the safety edge by raising or lowering, adjust the height of the screed end plate, extend or retract the screed extension, and adjust the height of the screed at the same time. The paver crew
recommended that an automated system could reduce these issues. Monitoring the downward pressure of the safety edge device was important to keep the bottom of the device in contact with the surface being paved. In some locations the safety edge was hung up on coarse aggregate of the HMA base mix that was used to widen the roadway. When this occurred, the screed would vibrate or jerk. NO segregation of the mat or the safety edge was observed. Air voids content of the HMA mat along the safety edge varied from eight to 18 percent which was higher than desired for long term performance.

8) Old Furnace Road, Seaford, Delaware The average slope of the safety edge varied from 37 to 50 degrees. The paving crew felt that the safety edge device would have to be 20-25 degrees in order to produce a finished slope of 30 degrees. The TransTech and Advant-Edger devices were used on the project. Both units were bolted to the screed. The screed operator felt that the Advant Edger unit seemed to work better resulting in a smoother finished edge. When paving across intersections or areas with a higher longitudinal profile, the safety edge devices raised the screed relative to the profile set by the longitudinal ski. The WMA density at the edge was higher with the safety edge than in the non-safety edge sections due to the confining effect of the safety edge when the edge was rolled. Air voids along the edge of the mat were higher than desired, varying from 8.6 to 13.5 percent, which may have a detrimental impact on long term pavement performance. Longitudinal segregation, or different surface texture, was observed along the edge of the paver.

9) 2010 Safety Edge Project-STH 55, Menominee County In 2010, the Wisconsin Department of Transportation (WisDOT) constructed a bituminous overlay project specifying the safety edge feature. The project started at the STH 55 intersection with STH 47 near Keshena and extended north for 18.5 miles to the Langlade County line. The TransTech Shoulder Wedge Maker and two Carlson devices (Prototype #2 and Prototype #3) were demonstrated on this project. All three devices had varying degrees of success. None of the devices had a negative impact on the paving operations. The average slope of the safety edge was 35, 33, and 36 degrees for the TransTech, Carlson Prototype #2 and Prototype #3 respectively. The shape of the slopes was relatively consistent in the observed test sections but in all cases the slopes were higher than the targeted 30 degrees. The HMA mix density was slightly higher and the air voids slightly lower adjacent to the edge of the mat for the non-safety edge section in comparison to the safety edge sections. This result is contrary to other projects where the safety edge sections had slightly higher in-place density or similar density when compared to the non-safety edge section. No problems were observed or expected regarding the shoulder and the Safety edge. Segregation was not observed on this project, either at the longitudinal joint or at the edge. Also refer to the field reports filed by Bill Bremer, Wisconsin FHWA Safety Engineer provide in Appendix C.

The full case study reports for these project are available at
APPENDIX B
2011 Safety Edge Specification and Detail Drawing

Pavement Safety Edge

A Description

(1) This special provision describes providing a sloped safety edge at the locations the plans show for pavements and pavement overlays placed adjacent to aggregate shoulders. Conform to details within the plan.

(2) Department is conducting research on the safety edge. Cooperate with research activities as requested.

B (Vacant)

C Construction

C.1 General

(1) Construct the safety edge monolithically with the pavement extending beyond the edge of pavement. Prepare the foundation material underlying the extended safety edge as the engineer directs. Place the finished shoulder material to the top of the safety edge conforming standard spec 305.3.3.

C.2 Equipment

(1) For HMA pavement and overlays use a paver with an engineer-approved safety edge system capable of constructing the specified edge cross section compacted conforming to standard spec 450.3.2.6. Do not use a single plate strike off. Before paving, provide documentation that the proposed system met these specifications on other projects or construct a test section. The engineer may allow a conforming test section to be incorporated into the work.

(2) For concrete pavement and overlays use slip-form paver modified to form the required edge.

(3) The engineer may allow hand placement for short sections where machine placement is not practicable. The engineer may also allow full depth sawing to remove formed edges integrally placed with pavement where the plans do not show safety edge.

(4) The engineer may eliminate safety edge work from the contract if at any point the contractor fails to construct conforming work.

D Measurement
The department will include the tonnage of material acceptably placed in the edge in the tonnage for the associated HMA pavement or overlay bid items.

The department will include the plan-view area of material acceptably placed in the edge in the yardage of the associated concrete pavement bid items.

E Payment

Payment for providing safety edge as well as full depth sawing to remove integrally placed edge is incidental to the associated pavement or overlay bid items.

The department will make no compensation under standard spec 109.5 if the safety edge work is eliminated due to the contractor’s failure to produce conforming work.
CONCRETE PAVEMENT AND CONCRETE OVERLAYS

HMA PAVEMENT AND HMA OVERLAYS

FOR H 5" OR LESS

CONSTRUCTED WITH FINAL TWO LAYERS

SHOULDER AGGREGATE PLACEMENT

CONCRETE OR ASPHALT SAFETY EDGE

CONSTRUCTED WITH FINAL LAYER

EDGE OF PAVEMENT

5' APPROX.

2' MIN.

FOR H GREATER THAN 5"

CONSTRUCTED WITH FINAL TWO LAYERS

CONSTRUCTED WITH FINAL LAYER

EDGE OF PAVEMENT

5' APPROX.

2' MIN.
Paving for the surface lift on STH 55 began at 7:00 am on 9/9/10. The TransTech safety edge maker (SEM) shoe was attached to the paver screed on the shoulder side for paving in a southerly direction on the northbound lane at the Menominee/Langlade County Line. During the morning paving the foreman for Northeast Asphalt (NEA) only lowered the SEM to create an approximately one to two inch 30 degree slope. The shoe was not extended down to the roadway surface and the spring was not compressed at all. The shoe adjusting screw cotter pin was tight against the surface of the mounting bracket. This resulted in the shoe appearing to act like a strike off plate. In addition, the foreman was concerned if the paver end gate ski was lowered to touch the uneven shoulder surface, the pavement ride would be adversely affected. The manufacturer’s instructions indicate for the SEM to work properly, the end gate ski must be kept riding directly on the surface(not elevated). The initial run for the majority of the day was over an edge/scratch surface that had been placed on 9/8. Throughout the day, our communication/discussions always involved the WisDOT project engineer representative, Adam Gaugh, and we made no attempt ourselves to direct NEA staff.

This project has a pavement ride incentive, and NEA is working hard to achieve this incentive, and this is reflected in their reluctance/refusal to fully comply with the manufacturer’s instruction for adjusting the SEM. The safety edge technology was added to the project contract as a special provision through the addendum process. See attachment. The manufacturer’s SEM manual is attached and operating instructions are on the last two pages.

I was accompanied on the project by Cathy Satterfield and Mark Sandifer, from FHWA Washington office. After contacting FHWA national representatives familiar with the safety edge makers at mid-day, we returned to the paving operation and further discussions with Adam. Adam requested NEA to try to increase the compression on the spring by tightening the screw. The paving foreman did comply until there was approximately x inches of float between the cotter pin and the mounting bracket, the minimum amount recommended by the manufacturer. This change immediately could be seen in the length of the safety edge slope and probably the compaction of material on the slope. However, material was still being extruded below the end gate ski, which is basically waste material and increasing the material used on the project (reducing the yield).

Adam indicated he would have further discussion with NEA to see if anything can be done to lower the ski, and I indicated I would contact Jim Volkmann, WisDOT project supervisor, on my 9/10 observations.

On the morning of 9/10 I was contacted by Andy Mergenmeier, FHWA Resource Center pavement engineer, to inform me that NEA managers have been contacted by a company that has a different technology to create the safety edge, and NEA is considering requesting WisDOT to allow NEA to change the safety edge hardware. FHWA has no objections if WisDOT agrees with a switch.
contacted Jim Volkmann about the 9/9 paving experience and heads-up on a possible request from NEA. I also contacted Steve Krebs to give him a heads-up on this new development and to discuss drilling at/near the edge to extract cores for density testing.

Submitted by   Bill Bremer  
Safety Engineer  
FHWA Wisconsin Division

I arrived on the project at 5 pm on 9/14/10 and observed the contractor, Northeast Asphalt (NEA) using the Trans-Tech safety edge (SE) maker paving the northbound lane approximately seven miles from the Menominee/Langlade County line. The SE was fully engaged and producing the planned safety edge shape. There is occasionally some material “spillage” that is getting under the end gate ski. The ski and SE maker require considerable adjusting to keep the ski on the shoulder since the shoulder elevation varies (uneven) as the paver proceeds down the road. When the end gate ski elevation is adjusted, the slope and shape are very good, and minimum spillage occurs. The ski needs to be raised when the shoulder becomes higher. I was joined by Adam Gaugh, WisDOT project leader, and Frank Alfaro, WisDOT CO Oversight Engineer to discuss the results achieved to date and events for Thursday’s paving.

Adam indicated Carlson Paving Equipment Company had arrived from Michigan with a new prototype device that works on a different principle than the Trans-Tech SE maker. The Trans-Tech SE maker is bolted to the screed and the Carlson device is incorporated onto the end gate ski and therefore less chance of affecting the pavement smoothness (ride). FHWA had informed WisDOT Region last week that we were expecting NEA to request permission to try the Carlson equipment to produce the safety edge, and we would be very supportive of trying the new prototype(s). Anna Wisner, Jim Volkmann, and Adam Gaugh were involved and concurred in trying the new equipment experiment. The prototype equipment would be added during the night and used with the beginning of the paving operations today, Wednesday, 9/15/10. Andy Mergenmeier, FHWA national Safety Edge paving engineer arrived Tuesday evening to be present for the testing with the new prototype equipment, and to obtain density testing data, etc.

Paving began this morning at 7 am (09/15/10) on the southbound lane, approximately four miles from the county line. The first Carlson prototype was installed and was tried for approximately 200 feet. Representatives from Carlson Paving Equipment (Tom Travers) was on the project working with the NEA paving crew. The first prototype was not obtaining the desired shape and was discontinued. The Trans-Tech SE was then re-engaged and again was producing the optimum shape for that device that was observed on Wednesday evening. Tom Travers indicated the second prototype needed to be adjusted in order to fit the NEA Blaw-Knox paver (NEA had modified the paver, including the electrical system which Tom had not anticipated.) At approximately 9am the second prototype was installed with better results. The shape more closely resembled the Trans-Tech product and the sloped edge had a smoother, sealed appearance (after the paint on the ski was burnt off by the hot asphalt and the ski became hot in approximately 300 to 400 feet). The prototypes include the ability to use a heat strip capable of heating the end gate ski to approximately 600 degrees, but this feature could
not be tested because the electrical system on the paver had been previously modified by NEA. The second prototype was used until 10 am, when paving operations were stopped in anticipation of rain. All paving operations had been completed (rolling and temporary transverse joint) by the time rain started at 10:30 am. I would call today’s experiments very positive and Carlson will now further modify the prototypes back at their plant in Washington State to flatten the slope on the ski to get the final sloped angle closer to 30 degrees, and to modify the electrical system on the heat strip to adapt to the NEA paver. The next prototype will be returned to the project, probably no sooner than next week, for further testing.

The WisDOT has verbally agreed to allow FHWA obtain test cores using drilling services from Ayres & Associates as a change order to the Ayres contract. The test cores, and other test data will be collected to include both the Trans-Tech and Carlson areas. Andy Mergenmeier will layout the areas where the core testing will be collected. NEA was assisting Andy to collect extra density tests today for Andy’s national test report at locations the two types of equipment were used.

In my opinion, while the prototype equipment will require additional modification and testing, it is clear the new device will exceed the capability of the Trans-Tech device to produce a tighter, sealed, sloped edge that can be adjusted to produce various slopes. This report does not try to cover all of the technical modifications Carlson Paving Equipment is developing.

We very much appreciate the support and assistance WisDOT and NEA is providing to test and pilot the safety edge, especially the new prototype equipment. If I have misstated any of the technical information, please correct me. Thanks. Pictures were taken by several of us today, but I do not have the capability of transferring them off my camera while I am in the field. Nathan Fregien, from Menominee College has taken professional video and photos, as part of the WI LTAP project, on this past Tuesday, of the Trans-Tech device, but was not able to get to the project today before the rain. Adam will keep Nathan informed on the project progress to try to obtain video of the next prototype and when shoulder graveling begins, as well as opportunities to record the hardware mounting process.

Bottom line- a very successful day, despite the rain.

Submitted by   Bill Bremer
                Safety Engineer
                FHWA Wisconsin Division

I conducted a site visit on 9/29/10 & 9/30/10 on STH 55 Menominee County to review the status of installing the Safety Edge technology, including using Carlson Paving Company’s prototype #3 edge maker. The WisDOT paving contractor, Northeast Asphalt (NEA) was successfully using the FHWA provided-contract specified Trans-Tech edge maker on 9/29/10, with very good results. Carlson Paving Company had completed modifications to their equipment and had made arrangements to use prototype #3 starting on the morning of 9/30/10. The principle difference between the existing/conventional safety edge hardware that is currently available is that the Carlson safety edge
technology creates the 30 degree slope under the end gate ski by extruding the asphalt into the safety edge shape gradually from no slope near the front of the ski to 30 degrees at the end where the asphalt leaves the paver.

During the startup operations for the days paving on 10/1/10 at 7 a.m., on the southbound lane approximately five miles north of STH 47, the representative from Carlson Paving (Kevin), installed their end gate. The conventional end gate was removed and the new prototype end gate was installed. Estimated time to complete the operation was two minutes and involved only removal of three bolts, swapping end gates, and re-fastening the gate to the paver. See the first two photos of installing the new end gate. The current version does not include any heating element since the NEA paver generator was not compatible with Carlson’s equipment (this was known and no attempt was made to modify the paver.) During the initial 200 feet, the end gate extrusion ski was at air temperature and the material on the safety edge slope was only slightly smoother than the material on the Trans-Tech slope. Once the paver had traveled approximately 200 feet, the underside of the end gate ski appeared to approach the temperature of the asphalt, and the slope appeared to have a much tighter/smooth/er sealed appearance. I think this will be a significant advantage of the Carlson edge maker, since this additional sealing should enhance the ability of the edge slope to keep water from entering the pavement and enhance the edge durability. After the first several hundred feet of paving, the contractor only had to make minor, normal operating adjustments to the end gate ski elevation, and the paving crew on the paver only consisted of the normal size crew consisting of the driver/operator and one screed operator (see the last photo.)

WisDOT’s consultant, Ayres, collected supplemental nuclear density Readings and drilled density cores at three 1,000 foot test sections laid out on 9/16/10 by Andy Mergenmeier, FHWA HQ and Adam Gaugh, WisDOT project leader. The sections included no safety edge, Trans-Tech, and Carlson Prototype #2. Adam had already laid out a 1,000 foot test section for the Carlson Prototype #3 paving on 9/30/10, and drill cores were scheduled to be collected today, 10/1/10. A change order is being prepared for all of the extra Ayres density work, and I verbally concurred in FHWA participation, although our approval is not needed since this is not an oversight project. I have additional photos of the previous core sites and will supply them to Andy at a later date.

Currently Carlson only has the prototype for the right side (as shown in the photos). It was not known at the time of my departure on 9/30 at 8:30 am how long Carlson will keep the equipment with NEA on this project and the Menominee STH 47 project (also specified to use a safety edge) where paving will start next week. The 18 miles of mainline paving on STH 55 is expected to be completed on 10/1/10.

An additional interesting piece of information on this project is that the asphalt design mix submitted by NEA and approved by WisDOT, includes using recycled asphalt shingles, in addition to RAP. I learned that NEA had successfully used recycled asphalt shingles last year on the CTH M project in Menominee County.
Adam Gaugh is keeping Nathan Fregien from Menominee College informed about the project progress. The College has the FHWA funded contract with the Wisconsin LATP to videotape, photograph, and produce a short CD on the safety edge technology used on STH 55 and STH 47. Adam said Nathan was hoping to visit the project again on 9/30/10, but he had not arrived at the time of my departure.

Submitted by Bill Bremer
Safety Engineer
FHWA Wisconsin Division
APPENDIX D
Questionnaire Responses from Project Engineers and Contractor

Survey Questions and Responses for Project Engineer

1) Ease of installation of safety edge device? Was there any start up issues that had to be corrected during paving operation?

STH 13….Device was installed & ready to go prior to paver arriving on site. No start-up delays related to device.
USH 2….After discussion with the contractor, there was no problems with installation and just a little adjustment at start up.
STH 42….Installation took about one hour, but no issues created by safety edge device during operation.
STH 73….The contractor attached the Carlson Endgate to the paver prior to start-up. This took approximately one hour.
STH 69….The safety edge device installed in a matter of a couple minutes. We did not see any issues at start up.
STH 144….No issue that I was aware of.

2) Does the use of the safety edge device create any negative impact on the paving operation/constructability?

STH 13….Yes, refer to question #5. Also noted, we encountered only one issue with the safety edge on our project. We noticed that on a thin overlay (2”) as our project, the safety edge tends to crack longitudinally along the edge of the existing pavement. After further trails, we found that power brooming the shoulder, specifically, the portion where the safety edge overhangs into it (the shoulder), eliminated loose fines and material, and the safety edge tended to hold together better without the cracking. It appeared that on a thin mat, the asphalt tended to shove where it overhung into the shoulder under the pressure of the rollers. I would suspect that thicker mats would not have this problem.
USH 2….None that was observed.
STH 42….Additional time by paving crew spent making sure safety edge is being installed at correct angle.
STH 73….The contractor did have constructability issues with the safety edge device on this project, but I think that constructability would be project specific. The STH 73 paving project required a change order to increase the depth of the shoulders from 1.5-2.0 inches existing to 4 inches proposed. This was not part of the original plan and specials. The original plans and specials showed a 2 inch mill with a 2 inch overlay.
The contractor milled out a 4 foot wide pass along the shoulders and used a shoulderer machine to pave the lower shoulder binder lift. The lower lift did not include the safety edge, but was paved wider (3.33 ft.) to account for the safety edge on the upper lift. However, when paving the upper lift with the safety edge, the edge would occasionally overhang the lower lift, causing the safety edge to fall off. If the shoulder binder was not required on the project, the safety edge would likely have been more successful.

STH 69….We did not see any negative impact to the paving operation. All of our density tests were good and very few issues came from having the safety edge added to the paving operation.

STH 144….Only time required for set-up and additional paving time due to increased quantity.

3) Is any segregation of bit. material created by the use of the safety edge device?

STH 13….None noted.
USH 2….None.
STH 42….None noted.
STH 73….No segregation of the bit. material was noticed by field staff.
STH 69…..No segregation noticed on the mat.
STH 144….None that I observed.

4) Does use of the device require vertical adjustment of the screed or any other adjustments on the paver?

STH 13….None noted.
USH 2….It (Trans Tech safety edge unit) has its’ own adjustment device.
STH 42….No comment.
STH 73….Yes, occasionally the contractor would need to adjust the Carlson Endgate and/or the wing to produce the desired safety edge. I don’t believe any adjustments to the screed were required.
STH 69….It was very important for someone to be making constant adjustments at the safety edge side of the paver. They had to adjust in/out to keep the second lift in line with the first lift. They also had to keep adjusting the side plate of the paver to keep it in contact with the ground so that material did not flow out from underneath. If they did not have somebody on the paver making the adjustments as they went along, the safety edge would not turn our correctly.
STH 144….None that I am aware of.

5) Observations on material compacting/consolidation at edge of paved lane?
STH 13….Project used 2” HMA Type E-3 overlay. It was observed that the thin nature of the overlay and safety edge caused longitudinal cracking at the overhang point onto the gravel shoulder after rolling. The contractor swept one half foot of the shoulder free of loose sand & gravel & millings to hard pan underneath, which solved the issue.

USH 2….Uniform slope before compaction. After compaction with hot roller, the (safety edge) portion would push outward.

STH 42….Rolling techniques needed to be modified to not squash edge and to try to keep edge shape and angle.

STH 73….When the contractor achieved the desired safety edge, the edge compaction appeared to be increased relative to previous operations with the safety edge that I have observed.

STH 69….The material was compacting fine and density tests were very good. We did have a few spots where the edge tore but I think it was a base compaction issue and would have happened even if the safety edge was not being installed.

STH 144….I think that the (safety edge) product would be better on a project where the binder was placed in two lifts to reduce rolling differential.

6) Consistency of the shape & slope of the safety edge?

STH 13….Very consistent. But shape & distinctiveness of safety edge is visually unremarkable on a thin overlay like we have (2”).

USH 2….Uniform slope before compaction. When (hot) roller rolled edge, this seemed to make (safety ) edge un-uniform, in some areas.

STH 42….As long as rolling didn’t squash edge ruining angle, very consistent.

STH 73….The loose (uncompacted) safety edge from the Endgate was very consistent and held the desired safety edge dimensions. When the safety edge was paved on a stable surface (i.e. when the shoulder binder lift was wide enough to accommodate the safety edge), the rolled safety edge also held the desired dimensions. However, if the base underneath the safety edge was not stable, the edge would fall off after rolling.

Occasionally, the Endgate would produce a lip of bit. material along the top slope of the safety edge. When this material was then rolled, the lip would be pushed out and produce an undesirable safety edge shape.

STH 69….The contractor and I were on a learning curve on this safety edge so the consistency was not great at the beginning. Once we had somebody keeping the paver adjusted as they went and a laborer doing some small handwork, the consistency got better. With the Rock Road roller operator rolling the safety edge as the last pass, we did not see any difference before or after the rolling of the safety edge. We did average closer to a 45 degree angle. I am not sure why this happen. I
am not sure if the initial slope of the (safety edge) attachment should be closer to 25
degree to help the final (safety edge) slope end up at 30 degrees.
STH 144….Some deviation due to rolling.

7) HMA mixture specifications (request copy of asphalt mix design)?
Refer to report Section III-Field Reviews.

8) Observations of density and air voids of the bituminous material adjacent to the edge?

STH 13….Density and air voids are within target. Shoulder paved integrally with travel
lane. (12’ travel lane and 3’ shoulder).
USH 2….Observed no difference.
STH 42….Did not seem to affect it much.
STH 73….When the contractor achieved the desired safety edge, the edge density
appeared to be increased relative to previous paving operations with the safety edge
that I have observed. Air voids along the edge of the pavement appeared to be
decreased relative to a standard paving operation.
STH 69….Bob Schiro, WisDOT, was on site taking density tests. He said that
everything was looking good. Our density testing summary was included in the file that
I mailed.
STH 144….None. I have requested (density) information from the SE Region Materials
Section. WisDOT Central Office did the testing.

9) Affect of material used for safety edge on project yield?

STH 13…..Yield seems to have very minor increase. Hardly noticeable.
USH 2….Observed none.
STH 42….Minimal.
STH 73….The safety edge had a minimal effect on the project yield (<1 %).
STH 69….We probably went overboard on the widths of our lowest layer to make sure
we had the proper width at the top of the safety edge but I figured we used an extra
600-800 tons (of bituminous material) by going wider on the first and second lift than
we probably would have if we did not have the safety edge. We did still end up under
plan quantity (of bituminous material) so design must have taken this into
consideration.
STH 144….Increase due to the extra (binder) width (to accommodate the safety edge
on the surface lift)

10) Any negative impact from safety edge on placement of gravel shoulder?
11) Does gravel shoulder stay in place on top of safety edge?

STH 13....No comments.
USH 2....No, actually placed very well.
STH 42....Gravel shoulder does not seem to stay as flush with edge of lane.
STH 73....No
STH 69....No, placement of shoulder aggregate material went very easy.
STH 144....None.

STH 13....No comments.
USH 2....Yes.
STH 42....Too soon to tell, but appears to not stay all the way to top of edge.
STH 73....The gravel shoulder has remained in place several weeks after its installation.
STH 69....Initially there has been no problem but shoulder is only a few weeks old.
STH 144....We have not shouldered yet. I am concerned about (shoulder) raveling due to the thickness of the gravel (shoulder).

12) What is your overall impression of the safety edge?

STH 13....Works well with loaded trucks driving on it. Does not divot pavement. Very impressed.
USH 2....Uncompacted material fine but finishing methods (rolling) could be developed better.
STH 42....Seems to affect gravel shoulder integrity, but able to drive on and off shoulder easily prior to graveling.
STH 73....Overall, I think that the safety edge shows promise. When the contractor was able to produce the desired safety edge, the finished shoulder appeared more stable than standard paving operations. Also, the contractor did not have issues with the installation of the gravel shoulders, which was a concern prior to paving.
STH 69....Needs some fine tuning to make the whole process work better but it is a nice idea. I think that it helps with our edge of pavement drop offs during construction by making this edge a more gradual slope. (The safety edge) decreases risks during construction. I have not seen it on a finished road long enough to have an opinion.
STH 144....I believe that it will function as designed to increase safety.

13) Any suggestions on what should be included in the safety edge specification on future projects?
STH 13....Discuss overlay application more.
USH 2....No.
STH 42....Include roller pattern requirements to endure safety edge shape not compressed.
STH 73....Future specifications should include corrective actions for the contractor. The contractor applied a large effort to adjust the safety edge the first day of paving, but with subsequent days this effort lessened. A friendly reminder to the contractor to adjust the device often not enough. The specifications should require the contractor to provide a safety edge device that can install the safety edge on multiple lifts, if required, as shown in the construction details.
STH 69....On multiple lifts, the matching up of the two or three lifts was the hardest part and made the final product difficult to achieve. If possible, I would suggest looking into having the safety edge be added in the final lift. My thought was to have the lift under the surface course be narrower by six inches, or so. This would cause the final 1 ⅞" surface lift to have 3 ½" placed at the outer six inches of pavement but allow the safety edge to be placed in one lift.
STH 144....No Comments.

14) What would you recommend to future project inspectors that they should be looking for when inspecting the installation of the safety edge feature?

STH 13....Cracking at shoulder point should be watched on overlay.
USH 2....No particular recommendations.
STH 42....Roll along edge, not over the edge, as much as possible.
STH 73....(a.) I would recommend that future inspectors focus on the safety edge after it has been rolled. For the most part, the loose (unrolled) safety edge had the correct dimensions and looked acceptable after the material passed through the Endgate. However, once the material was rolled, that is when problems were noticeable. If problems occur after the rolling, corrective actions should be taken to resolve the issues.
(b.) The base aggregate shoulder should be level with the existing paving surface prior to paving. This will help prevent the edge from falling off after the rolling.
(c.) Superelevation corrections, if necessary, should be wedged prior to mainline paving with the safety edge. The contractor milled in the superelevation corrections for the STH 73 project. This was successful for the most part, but occasionally, the shoulder slope varied from the mainline causing a thicker edge. If the paving depth becomes too thick, the safety edge has a larger likelihood of failing (The contractor’s device could only produce the safety edge on one lift, so other devices may be able to accommodate additional paving thicknesses). It was more successful with regards to
the safety edge installation, to have the contractor wedge the superelevation correction instead of milling the superelevation correction. STH 69….The contractors are not used to having to make adjustments to the outside edge of the paver but this is important to achieve the proper safety edge. Adjusting the width to match up correctly with the previous lift and also adjusting the side plate are both important. My suggestion on #13 would eliminate the contractor having to make so many adjustments and end up with a cleaner safety edge. STH 144….Check the (safety edge slope) angle after rolling.
15) What are the three keys to constructing a successful safety edge feature?

   STH 13….No comments.
   USH 2….Adjustable slope for safety edge (unit), material used.
   STH 42….Rolling, wide enough binder, and cooperative contractor.
   STH 73…. (a.) Make sure that there is a level and stable surface, suitable for paving, adjacent to the safety edge installation.
   (b.) If the safety edge is not placed on the lower lift, the contractor should provide a device able to produce the edge on two lifts. If this is not feasible, make sure the lower lift is wide enough for the safety edge and apply a (width) factor of safety.
   (c.) Closely monitor the safety edge product throughout the paving operations. The contractor applied a large effort to adjust the safety edge the first day of paving, but with subsequent days this effort lessened.
   STH 69….a) Make sure to go wide enough with the initial lifts to end up with the correct lane width at the top.
   b) Have a contractor appoint an operator to keep the adjustments to the outside of the paver correct to achieve the proper safety edge.
   c) Rock Road assigned a laborer to do handwork to areas that didn’t come out looking correct.
   STH 144….Placement, rolling, and (slope) angle.

16) Measure the safety edge slope (rise & run) before and after the roller operation in accordance with the FHWA recommendations

   Refer to report Section III-Field Reviews.

17) Request nuclear density test results at the normal locations in the driving lane, at the outer most edge of the paved surface, and on the sloped safety edge surface

   Refer to report Section III-Field Reviews.
Survey Questions and Responses for Contractor/Superintendent/Paving Foremen

1) Additional project costs considered when bidding the project?

   STH 13....Just for the equipment-safety edge unit. Also, figured cost for initial set-up.
   USH 2....$5,000=purchase price plus cost to install onto the paver. $0.00 to mobilize and set-up.
   STH 42....Additional time to set-up safety edge unit.
   STH 73....We had to purchase safety edge side gates for left and right sides for the Carlson screed.
   STH 69....Yes.
   STH 144....None.

2) Length of time needed to install safety edge unit?

   STH 13....Initial set-up = 3 hrs. (had to touch holes in screed extension). After that, minutes to set-up.
   USH 2....2 hours x 2 men.
   STH 42....1 hour of set-up and removal.
   STH 73....1.5 hrs. extra time per set-up.
   STH 69....10 minutes.
   STH 144....15 minutes.

3) How easy is it to install the safety edge unit?

   STH 13....Very, only a couple minutes.
   USH 2....Drill holes placed onto paver. Then bolt on the safety edge unit.
   STH 42....No comments.
   STH 73....Three men to lift and install the side gate.
   STH 69....Not bad.
   STH 144....Exchange side plates-4 bolts.

4) Explain where on the paver/how the unit is installed? What modifications had to be made to the paver to accommodate the safety edge?
5) What paver unit/manufacturer is being used on this project? What safety edge device is being used on this project?

STH 13….Paver was a Terex/Cedar Rapids w/Versascreed 10. Safety edge was a “Safety Wedge” made by Carlson Paving Products.
USH 2….Paver unit—no comment. Safety edge was “Shoulder Wedge Maker” made by Trans Tech.
STH 42….Paver was a Blaw Knox with a Carlson screed. Safety edge was made by Carlson.
STH 73….Blaw Knox paver with a Carlson IV screed.
STH 69….Cat-AP1000D paver; TransTech “Shoulder Wedge Maker”.
STH 144….Blaw-Knox 3200 Paver; Carlson Safety Edge Unit.

6) Does use of the safety edge device create any negative impact on the paving operation, handling of the paver, etc. ?

STH 13….No.
USH 2….Handling is no issue. One hour and one man needed to clean device daily at end of day.
STH 42….Convenience more than anything.
STH 73….Only if gravel shoulder is too high.
STH 69….Not really.
STH 144….No.

7) Did you have to make any modifications to the safety edge unit during the paving operations? Why?

STH 13….No.
USH 2….No.
STH 42….Constant adjustments to the safety edge unit to get the material to flow the best and compact the best.
STH 73….Had to raise edge up over gravel (shoulder)
STH 69….No.
STH 144….No.

8) During the paving operation, where there any situations where the safety edge had to be removed or disengaged?

STH 13….Just through intersections. We just cranked it up.
USH 2….No.
STH 42….Not applicable.
STH 73….We had to raise it when paving through intersections and driveways.
STH 69….Yes, intersection work.
STH 144….None.

9) Is any segregation of bituminous material created by the use of the safety edge device?

STH 13….Not seen on this job.
USH 2….No.
STH 42….No.
STH 73….I don’t think so.
STH 69….No.
STH 144….None.

10) Does use of the device require vertical adjustment of the screed?

STH 13….No.
USH 2….Only if the mat got thinner. This did not happen here. However, you would need to take off if the layer thickness was variable and potentially thin.
STH 42….No.
STH 73….Not really; this mix was a good mix.
STH 69….No.
STH 144….None.

11) Is it difficult in maintaining the finished shape of the edge?
STH 13….Sometimes, due to the project being a one lift overlay. Would work much better on a two lift project.
USH 2….No.
STH 42….Yes, due to density requirements across the mat and the type of rollers needed to compact the material.
STH 73….I think that with a tender mix, the edge will push out more.
STH 69….Yes.
STH 144….No.

12) Is there any difference in the consolidation of the material in the safety edge?

STH 13….No.
USH 2….It will be compacted less on the bevel.
STH 42….No.
STH 73….May be improved.
STH 69….No.
STH 144….No.

13) Does the safety edge affect the paving production rate?

STH 13….No.
USH 2….No.
STH 42….No.
STH 73….Not really.
STH 69….No.
STH 144….No.

14) Does the installation of the safety edge have an impact on the ride quality?

STH 13….Will find out when IRI is run.
USH 2….Only if mat gets thin and safety edge “hits bottom”.
STH 42….Not enough information to make that decision.
STH 73….No
STH 69….No.
STH 144….If the safety edge (unit) would hit gravel or base material (when paving), it could possibly have an impact.
15) Describe the roller operation (compare sections with & without the safety edge)

   STH 13....No difference.
   USH 2....Roller is not on the bevel. Only a “cl___ hand roller”.
   STH 42....Leave edge pass last to cool shortly before rolling.
   STH 73....No difference.
   STH 69....No different.
   STH 144....Same pattern. 10” to 12” off edge on pass #1. On pass #2, moves over and hits the remaining unrolled pavement.

16) Describe how the safety edge is installed on thicker overlays. What is the best way to construct the safety edge on thicker, multi-lift cross sections (i.e. form the safety edge on each lift or pave the 1st lift with a vertical edge and then form the safety edge on the 2nd, and 3rd lift, if necessary)

   STH 13....This was a one lift overlay, so we did not run into this. Would think to form on each lift, so a crack doesn’t form at the vertical edge of the first lift.
   USH 2....For Mathy, we would need to add gravel to edges greater than 2” drop off. Therefore, better to use safety edge on both layers.
   STH 42....Widen road. Put in at no more than 2” max.
   STH 73....You have to have the binder course 4” to 5” wider on each lane for the safety edge to sit on top of.
   STH 69...(Install a) vertical edge on the bottom lift(s); then just use it on the final lift. It seems to work better on a thicker lift.
   STH 144....Can be used on all lifts. Need to add 5” of width to each lift to get the desired width when finished. Example: On a three lift job, you need to be 12-15” wider on the bottom lift to support the edge.
APPENDIX E

Representatives for 2011 Safety Edge Projects

STH 13- Chad Schroder, Project Engineer
    MSA Professional Services
    Rhinelander, WI

USH 2- Bill Maki, Project Engineer
    Chequamegon Bay Engineering
    Ashland, WI

STH 42- Jon Vogt, Project Engineer
    Kapur & Associates, Inc.
    Green Bay, WI

STH 73- Paul Glasser, Project Engineer
    Strand Associates
    Madison, WI

STH 69- Ken Plowman, Project Engineer
    Fehr-Graham & Associates
    Monroe WI 53566

STH 144- Richard Nelson, Project Engineer
    SEH
    Milwaukee, WI
### APPENDIX F

IRI Ride Measurements Summary

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<th>STH</th>
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<th>N</th>
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<th>Std. Dev.</th>
<th>Range</th>
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<th>Mean (%)</th>
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NOTE: STH 144 IRI ride measurements will be conducted on the surface lift to be placed in 2012.
APPENDIX G
Photos

TransTech “Shoulder Wedge Maker” Used on STH 13 Project
Carlson “Safety Edge End Gate” Used on STH 55 Project

Placement of Safety Edge Using Carlson Unit
APPENDIX H
List of Safety Edge Equipment Manufacture’s Web Sites

1) Shoulder Wedge Maker, Transtech Systems, Inc., http://www.transtechsys.com,
   1-800-724-6306 (Requires separate shoe for right and left side of paver)

2) Safety Edge End Gate, Carlson Paving Products, http://www.carlsonpavingproducts.com,
   1-253-278-9426 (Device must be ordered to fit specific screed it will be used on. Angle is adjustable)

3) Advant–Edge Paving Equipment LLC, “Advant-Edger” and “Ramp Champ”,
   http://www.advantedgepaving.com, 1-814-422-3343 (Shoe is reversible to fit right and left side. “Ramp Champ” has adjustable angle)

4) Troxler Electronic Laboratories, Inc., “Safe-T-Slope Edge Smoother”,
   http://www.troxlerlabs.com/products/paving.php, 1-877-876-9537 (Requires separate shoe for right and left side of paver)