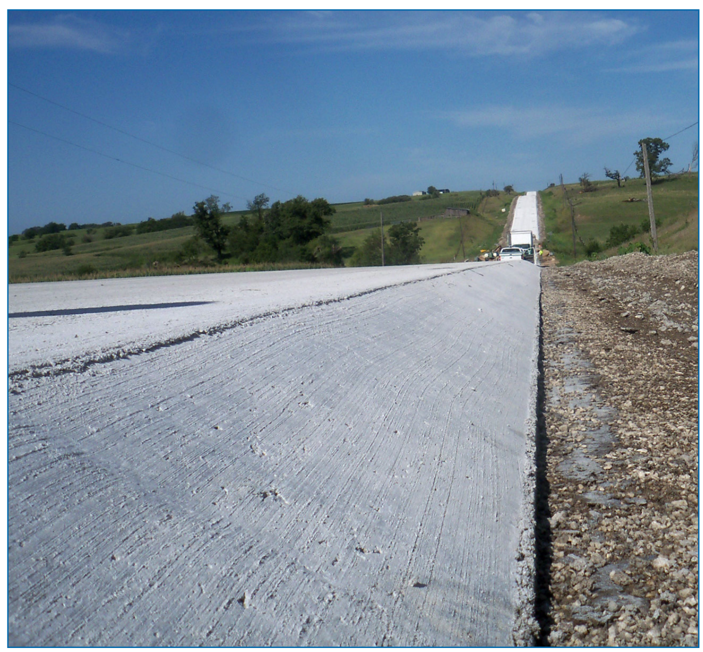
Evaluation of the Safety Edge in Iowa: Phase II

Final Report
December 2012



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16. Abstract

Roadway departure crashes are a serious traffic safety concern. These crashes account for about 53 percent of US highway fatalities and one million injuries annually. The Iowa Department of Transportation (DOT) estimates approximately 52 percent of roadway-related fatal crashes in Iowa are lane departures. The Federal Highway Administration (FHWA) estimated in 2010 that 160 fatalities and more than 11,000 injuries related to unsafe pavement edges occur annually.

The Safety Edge is a design feature that creates a 30 degree fillet along the outside edge of a roadway during paving operations. The FHWA developed the Safety Edge based on research that indicated vehicles attempting to remount the pavement after leaving the paved roadway surface could traverse a sloped pavement edge surface more easily.

In this Phase II study, researchers observed and documented advances in design and utilization of Safety Edge equipment, sampled, tested, and assessed consolidation of the Safety Edge, inspected field conditions on previously-installed Safety Edge projects, evaluated changes in shoulder settlement/erosion, and assessed any deterioration of sloped HMA pavement edges.

Based on observations and measurements, the research team concluded that, even considering that not all results were consistent and didn't meet the "ideal" 30 degree slope angle, almost all Safety Edge slopes included in this evaluation project resulted in more durable and passable slopes than what would be expected with conventional pavement edges.

This Phase II report documents the evaluation of Safety Edge projects and results in Iowa and includes an array of conclusions and practical recommendations.

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ACKNOWLEDGMENTS

The authors would like to thank the Iowa Department of Transportation (DOT) and the Federal Highway Administration (FHWA) Accelerating Safety Activities Program (ASAP) for sponsoring this research. The funding and cooperation of all agencies involved has helped promote and advance the better application of the Safety Edge in the rehabilitation and re-construction of many Iowa roads.

The authors especially want to thank Jerry Roche with the FHWA–Iowa Division and Nicole Fox with the Iowa DOT Office of Local Systems for all of their advice and assistance. In addition, the authors thank the 10 Iowa county engineers who agreed to complete Safety Edge projects and permitted evaluation of the performance of that safety feature on their roads.

EXECUTIVE SUMMARY

Roadway departure crashes are a serious traffic safety concern. These crashes account for about 53 percent of US highway fatalities and one million injuries annually. The Iowa Department of Transportation (DOT) estimates approximately 52 percent of roadway-related fatal crashes in Iowa are lane departures. The Federal Highway Administration (FHWA) estimated in 2010 that 160 fatalities and more than 11,000 injuries related to unsafe pavement edges occur annually.

When an errant vehicle leaves the surface of a paved roadway, a resulting crash can be exacerbated by presence of pavement edge drop-off, which is a vertical elevation difference between two adjacent roadway surfaces, usually a paved roadway and an unpaved shoulder. A typical pavement edge drop-off-related crash occurs when the driver attempts an immediate return to the roadway and tire scrubbing occurs.

The Safety Edge is a design feature that creates a 30 degree fillet along the outside edge of a roadway during paving operations. The FHWA developed the Safety Edge based on research that indicated a sloped pavement edge surface could be traversed more easily by vehicles attempting to remount the pavement after leaving the paved roadway surface.

The intent of the Safety Edge is not to replace regular shoulder maintenance. Rather, the purpose of the Safety Edge is to provide an additional safety measure should drop-off form in the interim before regular maintenance occurs.

The Safety Edge is placed most commonly with hot-mix asphalt (HMA) paving using a device that shapes the asphalt material at the pavement edge. Highlights of this Phase II evaluation of Safety Edge paving in Iowa center around what was found sampling, testing, and assessing edge construction on HMA projects as well as inspecting shoulder and Safety Edge conditions on previously-constructed roadway projects in the state.

Based on observations and measurements, the research team concluded that, even considering that not all results were consistent and didn't meet the "ideal" 30 degree slope angle, almost all Safety Edge slopes included in this evaluation project resulted in more durable and traversable slopes than those that would be expected with conventional pavement edges.

A summary of study conclusions and research recommendations includes the following:

- No current Safety Edge shoe will produce a desirable product all the time for HMA pavements and overlays, so the common practice of "set it and forget it!" does not work
- The contracting authority and contractor must *both* agree before work begins what final result is desired and comply by making adjustments as necessary *throughout* the project
- Inconsistent Safety Edge results occur even on the same projects from day to day or on nearby projects constructed with the same materials by the same contractor, with no reliable means found to predict when problems might occur

- Agencies and contractors must rely on proven techniques and close monitoring to assure that the desired Safety Edge slope is attained
- Contractors and/or agency inspectors need to check and adjust (if necessary) crew procedures several times a day and demand the best work possible
- Especially on narrow roadways, existing shoulders must be brought flush with the edge of pavement *before* paving is started to provide a stable base for the Safety Edge
- For efficiency of operation and an acceptable final Safety Edge, a plan must be devised in advance to establish a base width necessary to accommodate the width of succeeding upper layers, while also following the pavement centerline as closely as possible
- Outreach should continue to be made to Iowa county engineers to promote the Safety Edge concept as part of the scheduled program at workshops and conferences

The final chapters of this report provide additional discussion and details of the research team's conclusions and recommendations. A tech brief entitled Recommendations for Achieving Safety Edge Consistency during Paving was also developed for this Phase II project.

Finally, over the course of monitoring the Phase I and II Safety Edge construction projects, project extents were recorded to permit a crash analysis to be conducted when sufficient years of after data are available.

PROJECT BACKGROUND, PURPOSE, AND DESCRIPTION

Roadway departure crashes account for approximately 53 percent of US highway fatalities and one million injuries annually with pavement edge drop-off thought to be a contributing cause of many of these crashes. Edge drop-offs are potential safety hazards because significant vertical differences between surfaces can reduce vehicle stability and affect a driver's ability to control a vehicle when inadvertently leaving the paved driving area. In addition, scrubbing between the pavement edge and tire can result in loss of control. The Federal Highway Administration (FHWA 2010) estimates 160 fatalities and more than 11,000 injuries that occur annually are related to an unsafe pavement edge.

The Safety Edge is a design feature that creates a 30 degree fillet along the outside edge of a roadway during paving operations. The Safety Edge is placed most commonly with hot-mix asphalt (HMA) paving using a device that shapes the asphalt material at the pavement edge.

The FHWA developed the Safety Edge based on research that indicated a sloped pavement edge surface could be traversed more easily by vehicles attempting to remount the pavement after leaving the paved roadway surface.

Because use of the Safety Edge was relatively new to Iowa, the Iowa Department of Transportation (DOT) and the FHWA–Iowa Division commissioned the Center for Transportation Research and Education (CTRE) at Iowa State University to evaluate the Safety Edge concept and conduct early analyses of the performance of this innovation.

The CTRE team worked with a number of counties during the 2010 construction season to provide information to agencies and contractors as well as to provide technical assistance before and during construction. The team developed materials to educate counties and contractors who had not used the Safety Edge previously.

In addition, the team worked with agencies during the roadway construction season to resolve a number of problems that occurred. Further discussions with other state DOTs and local agencies indicated similar problems had been experienced, but resources were not available to assist in examining and addressing those issues. The final report for that project, Evaluation of Safety Edge Benefits in Iowa, was published in March 2011.

At the commencement of the project task of marketing the Safety Edge in Iowa, the CTRE researchers and advisory team members were not aware of any properly-designed applications of the Safety Edge for portland cement concrete (PCC), nationally. With encouragement from the FHWA, the CTRE team and Iowa DOT worked to develop PCC Safety Edge design standards and specifications. This initiative resulted in the first national demonstration of the Safety Edge with PCC on County Road (CR) E-34 in Jones/Linn County, Iowa.

However, the one year completion schedule for the evaluation study did not allow sufficient time to analyze potential long-term performance of the Safety Edge fully, including possible aggravated settlement of the adjacent granular shoulders due to the sloped edge, reduction in frequency and severity of run-off-road crashes with the Safety Edge, and possible separation of the bottom thinner section of the Safety Edge section. In addition, difficulties in maintaining a desired degree of slope during HMA compaction were observed on several projects.

Second-generation versions of the safety "shoes" were being produced by manufacturers and models were being modified or fabricated by contractors. In addition, other, as yet unknown, impacts of the Safety Edge innovation could become apparent over time and these could be examined and reported with a Phase II project as well.

All of these issues were to be considered under the current project. Another objective of this project was to develop additional educational materials about the Safety Edge that could be used by the Local Technical Assistance Program (LTAP) or other organizations for state and local agency training. The training materials could include PowerPoint presentations and videos. In addition, tech briefs could be developed, distributed, and shared on the FHWA website to provide supplemental information learned and documented in the final report for the Safety Edge evaluation project completed by CTRE in 2010.

The training materials could include recommendations for agencies to consider during the construction process to assure that the final Safety Edge shape will closely resemble desired design following compaction. Issues such as adverse impacts from differing mix designs and various rolling patterns during the compaction efforts would continue to be reviewed and evaluated. Information and advice would also be included for use of the Safety Edge with PCC pavements.

Throughout the earlier evaluation project, the team worked with an advisory panel that included the FHWA, the Iowa DOT, Iowa counties, the Asphalt Paving Association of Iowa, the Iowa Concrete Paving Association, and several construction companies. A similar but smaller guidance panel was formed for this follow-up project. As a result, the information that was used to develop the training materials has also been vetted by a group of experienced and knowledgeable professionals.

Project Tasks

The following list summarizes the 10 tasks or activities identified for the Phase II project:

1. Literature review – Update the Phase I report with recent references about the Safety Edge
2. Advisory committee – Form an experienced and knowledgeable group of professionals to provide input and advice
3. Consider additional open houses
4. Provide assistance to local agencies as needed
5. Observe and document advances in design and utilization of Safety Edge equipment
6. Devise and implement methodology for sampling, testing, and assessing consolidation of the Safety Edge
7. Inspect field conditions on previously-installed Safety Edge projects
8. Evaluate changes in shoulder settlement/erosion
9. Assess any increased deterioration of sloped edge of HMA pavements
10. Outreach – Report and develop technical presentations/briefs of conclusions and recommendations

INTRODUCTION

Roadway departure crashes are a serious traffic safety concern. These crashes account for about 53 percent of US highway fatalities and one million injuries annually. The Iowa DOT estimates approximately 52 percent of roadway-related fatal crashes in Iowa are lane departures. When vehicles leave the roadway, the crash can be exacerbated by presence of pavement edge drop-off, which is a vertical elevation difference between two adjacent roadway surfaces, usually a paved roadway and an unpaved shoulder.

Edge drop-offs can pose a safety hazard because significant vertical differences between adjacent surfaces can reduce vehicle stability and affect the driver's ability to handle their vehicle when inadvertently leaving the paved driving area. A typical pavement edge drop-off-related crash occurs when the driver attempts an immediate return to the roadway and tire scrubbing occurs.

Scrubbing is a condition in which the tire sidewall is forced against a vertical pavement edge, resulting in friction between the tire and pavement. Some drivers compensate for scrubbing by increasing the steering angle. When the right front tire finally remounts the pavement, a sudden decrease in friction between the tire and the surface of the pavement edge occurs, resulting in a loss of control (Ivey and Sicking 1986).

The FHWA (2010) estimated 160 fatalities and more than 11,000 injuries related to unsafe pavement edges occur annually. A study by Dixon (2004) evaluated 150 fatal crashes on rural two-lane roads in Georgia and found that edge drop-off was present in 55 percent of the crashes. A study by Hallmark et al. (2006) evaluated crashes in Iowa from 2002 to 2004 and found that pavement edge drop-off may have been a contributing factor in about 18 percent of rural run-off-road (ROR) crashes on paved roadways with unpaved shoulders. The study also found that pavement edge drop-off-related crashes were two times more likely to result in a fatal crash than other crashes on similar rural roadways.

The FHWA indicated drop-offs of three or more inches can be considered potentially dangerous (Roche 2009). Hallmark et al. (2006) suggested a similar result with drop-offs of 2.5 inches or more having a higher relationship to edge drop-off-related crashes.

The Safety Edge

The FHWA began a demonstration project of the Safety Edge concept based on research results that indicated a sloped pavement edge surface could be more easily traversed by a vehicle leaving its lane and attempting to remount the pavement edge. The Safety Edge is a design feature that creates a fillet along the outside edge of the paved section of a roadway.

The Safety Edge is placed during HMA paving most commonly using a device called a shoe that shapes and consolidates the asphalt material at the pavement edge into an approximate 30 degree fillet as shown in Figure 1.

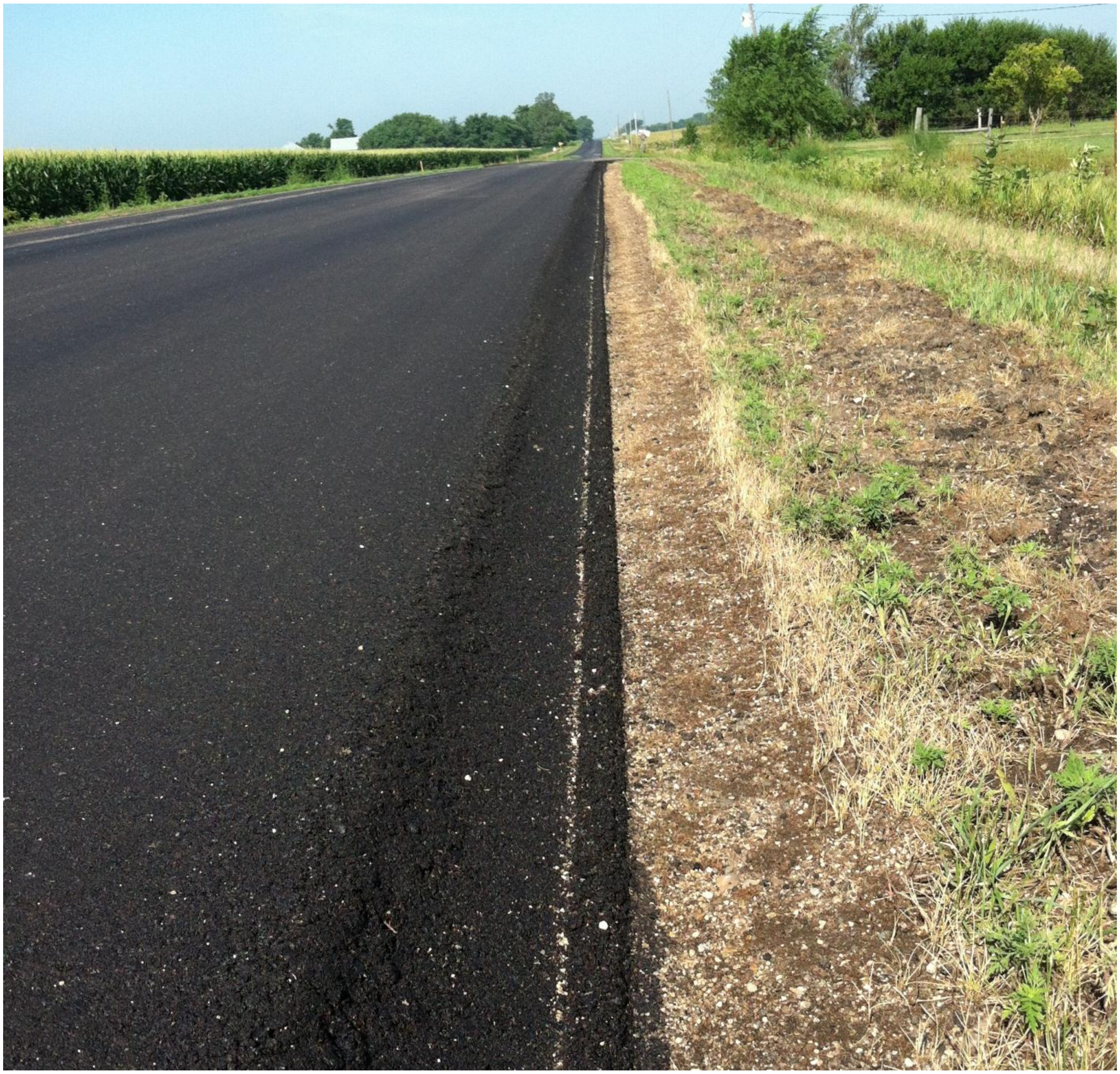

Figure 1. HMA Safety Edge in Kossuth County, Iowa

The Safety Edge shape reduces the likelihood that scrubbing will occur and provides a gradual rather than abrupt transition back to the roadway as an errant vehicle remounts the pavement surface. The Safety Edge provides this benefit before unpaved shoulders have been restored after resurfacing, as well as when the shoulder material has migrated away from the pavement edge over time due to wear or erosion.

The intent of the Safety Edge is not to replace regular shoulder maintenance. Rather, the purpose of the Safety Edge is to provide an additional safety measure should drop-off form in the interim—before regular maintenance occurs. As a result, it is expected that the edge will only be exposed intermittently both in terms of height and location of the exposed edge. With proper shoulder maintenance, the edge will be re-covered with graded material periodically over the life of the pavement.

Safety Edge Effectiveness

Little information is available describing the actual effectiveness of the Safety Edge in reducing crashes, given the feature has not been used widely. However, the concept of a Safety Edge has been suggested by researchers for nearly 20 years.

Humphreys and Parham (1994) suggested that a 45 degree angle asphalt fillet placed at the pavement edge would be useful in addressing vehicle over-corrections on unpaved or eroded shoulders. Neuman et al. (2003) also suggested creation of a 45 degree wedge during pavement resurfacing in a National Cooperative Highway Research Program (NCHRP) 500 series report, A Guide for Addressing Run-off-Road Collisions. However, it was also indicated that more data are necessary to determine if the wedge is effective.

Ivey and Sicking (1986) evaluated the relationship between drop-off height and a driver's ability to recover using simulation and analytical relationships. They evaluated 2, 4, and 6 inch drop-offs with a 45 degree wedge and found that even with drop-offs of 6 inches, recovery within a 12 foot lane was possible. In another study, they found a relationship between drop-off face shape and ability to recover.

Olson et al. (1986) found that drivers were able to recover from negotiating drop-offs of up to 4.5 inches at 55 mph with a 45 degree edge. Finally, Delaigue (2005) used computer-based simulation to assess the effectiveness of different edge slopes. Delaigue's simulation suggested that a passenger vehicle would be able to recover from up to a 5.0 inch drop-off at 60 mph with a slope face of 45 degree or flatter.

A pooled fund study by the Midwest Research Institute (MRI) evaluated the effectiveness of using the Safety Edge with pavement resurfacing projects (Graham et al. 2011a). The study included two-lane rural roads and multi-lane roads with paved shoulders of 4 feet or less. The study evaluated treatment sites that were resurfaced with a Safety Edge and comparison sites that were paved without the Safety Edge.

To evaluate drop-off after the treatments were in place, the MRI team measured drop-off along both control and treatment sections before and during the first year after resurfacing in each study state. Drop-offs of 2 inches and greater were noted. A logistic regression was conducted to compare whether a drop-off was less likely to occur with the Safety Edge in place. Results at one year after the sites were resurfaced suggested that projects with the Safety Edge are slightly more effective in reducing the proportion of extreme drop-offs than those without that feature.

The MRI team also conducted a crash analysis using crash data for six years before resurfacing and three years after resurfacing for study sites in Georgia and two years before and three years after in Indiana (Graham et al. 2011b). A total of 606 treatment and control sites were included.

A before-and-after analysis using Empirical Bayes (EB) was used to develop crash modification factors (CMFs). Results indicate that use of the Safety Edge resulted in a 5.7 percent reduction in total crashes. Although the results were not statistically significant, a CMF of 5.7 percent was suggested and, using this information, the MRI team calculated a benefit to cost ratio from 2.8 to 62.8, suggesting that the Safety Edge is highly cost effective.

Other benefits of the Safety Edge include the following (Roche 2009):

- Provides temporary safety during construction while pavement edge face is exposed
- Some states do not require contractors to restore unpaved shoulders immediately after paving, which results in increased production for contractors since shoulder work can be done after the entire overlay project is completed
- Provides a permanent solution for pavement edge drop-off
- Can reduce tort liability by showing “due care”
- Minimal hardware, labor, or material costs are required
- Potential increased pavement edge durability

ADVISORY COMMITTEE

A large group of professionals was invited to serve on an advisory committee for the earlier evaluation project. The group represented a wide variety of interests, including contractors, associations, state and local agencies, and the FHWA. For this follow-up evaluation, a smaller but knowledgeable and experienced team was invited to provide advice and guidance to the research team throughout the study.

Jerry Roche of the FHWA–Iowa Division was consulted throughout the project work for guidance and direction, as well as for making contacts with equipment manufacturers regarding the use of their latest devices for evaluation.

Input and opinions from the advisory group are included in the conclusion and recommendations of this report.

OPEN HOUSES

As part of the 2010-2011 evaluation activities, several open houses were conducted around the state to showcase the Safety Edge. Two were held in September 2009, near Clinton on CR Z-36 and near Marcus in Cherokee/O'Brien County on IA 143. In May 2010, an open house was held in Louisa County for a project on CR X-99. Two other open houses were also held in 2010; one near Creston on CR H-24 and another for a PCC overlay near Anamosa in Jones and Linn Counties on CR E-34. The latter project was the first PCC Safety Edge in Iowa and possibly the nation.

Because of the wide exposure achieved with state and local agencies in Iowa with these five open houses and considering the fact that the Iowa DOT had adopted a policy for using the Safety Edge on suitable projects, no further open houses were scheduled as part of this follow up project. All of the counties that were contacted for their consideration of Safety Edge use on 2012 projects were aware of the potential benefits and agreed to try the technique if no additional costs were incurred.

ASSISTANCE TO LOCAL AGENCIES

Through presentations made to county engineers and their staffs at association meetings (Iowa State Association of Counties/ISAC) and annual conferences (Iowa County Engineers Association/ICEA), design and construction information regarding the Safety Edge was provided.

In addition, assistance was furnished when requested to individual local agencies during site visits to construction projects by providing suggestions and recommendations that might improve the quality and consistency of the Safety Edge construction. Recommendations included more inspection and oversight of the contractor's work, but both agencies and construction crews were commonly short of staffing and generally unable to provide this additional oversight.

Proposed changes to "normal" compaction procedures may not have been followed consistently, often resulting in some degree of Safety Edge roll-over and steepening of the final slope, thereby producing inconsistent results.

ADVANCES IN DESIGN AND UTILIZATION OF SAFETY EDGE EQUIPMENT

Several types of the original design shoes used on the projects evaluated in 2010 were again employed for the 2011 and 2012 projects described in this report, but some new and modified designs were also evaluated. Some of the new models incorporated a design feature that offered an approximate extrusion process that seemed to add consistency to the Safety Edge and overall improved production of the desired slope. However, some performance concerns were noted that will be discussed in this report. Models that were observed for this follow-up project are shown in Figures 2 through 7 and brief descriptions also follow.

TransTech Shoulder Wedge Maker

This is a first-generation shoe that was used on many of the construction projects evaluated with the earlier study. This design was also used for eight projects that were reviewed for this report.

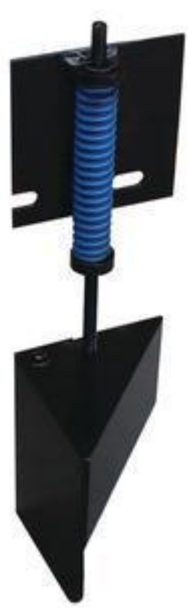

Figure 2. TransTech Shoulder Wedge Maker

Troxler SafeTSlope Edge Smoother

This is a first-generation shoe that is designed very similar to the TransTech model listed above. It was reported to have been used on a DOT project in eastern Iowa, but upon further review, it appeared that the TransTech shoe was the model actually used. It is believed that the Troxler shoe might have been manufactured by TransTech for the Troxler company but apparently no further distinctive improvements to that design have been made.

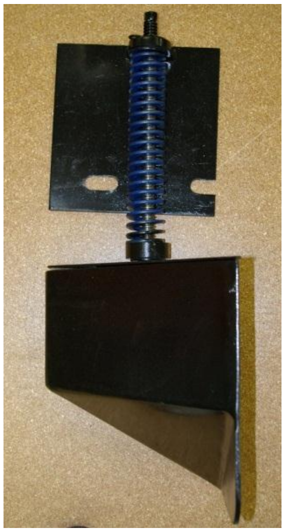

Figure 3. Troxler SafeTSlope Edge Smoother

TransTech Notched Wedge Joint Maker

This shoe design has been used successfully for three years by one local Iowa agency and many of those projects have been reviewed by the research team. Although the consistency of the final slope angle seems to vary with the depth of HMA lifts, the design appeared to have worked well.

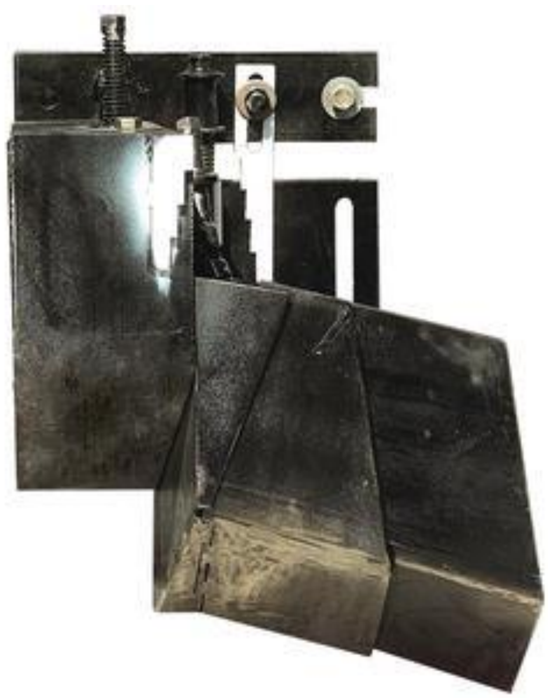

Figure 4. TransTech Notched Wedge Joint Maker

Advant-Edger

Work performed with this first-generation shoe was reviewed and reported in the 2010 evaluation, and this shoe was also utilized again on a 2011 project, which is included in this report.

Figure 5. Advant-Edger

Advant-Edge Ramp Champ

This is a second-generation shoe. Work performed on six projects in two separate counties was evaluated in 2011/2012 and found to provide more consistent and desirable results than the earlier model for the most part.

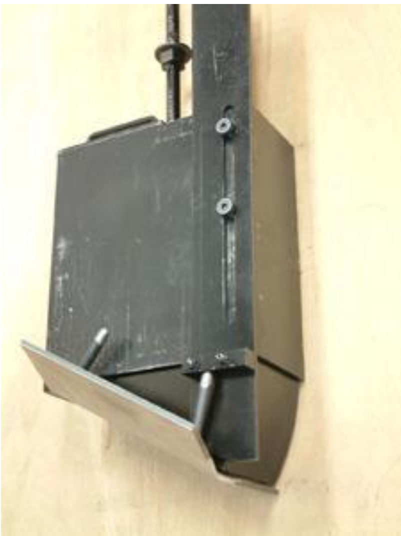

Figure 6. Advant-Edge Ramp Champ

Carlson Safety Edge EndGate

This differently designed Safety Edge device could be considered a second-generation model, although it is the first by this company. It was used on only one 2012 project that was reviewed and appeared to have potential for producing a good product.

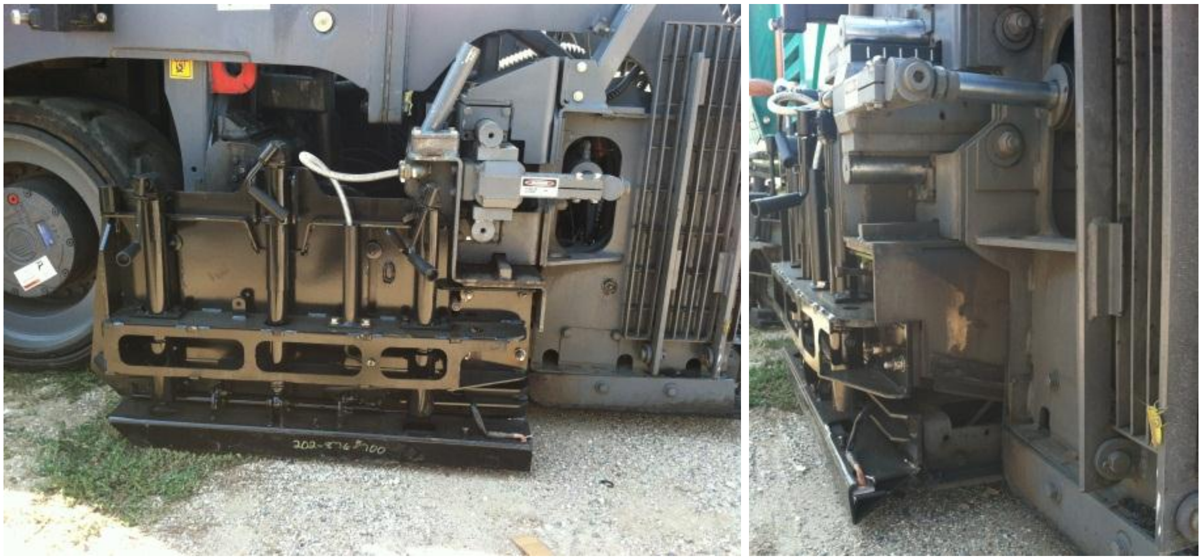

Figure 7. Carlson Safety Edge EndGate

METHODOLOGY FOR SAMPLING, TESTING, AND ASSESSING CONSOLIDATION

Field density testing of core samples of HMA material in the Safety Edge slope for this follow-up study compared well with similar testing performed under the earlier evaluation project. The Safety Edge produced by a shoe equipment design that results in some degree of "extrusion" appeared to produce a tighter and better sealed surface appearance of the slope than other models, but the calculated density was almost identical to previous results (average of 83.5 percent in 2012 compared to an 84.1 percent average in 2010).

Measurements of the finished safety slope angles for this evaluation as well as the 2010 study were made at selected intervals longitudinally along the roadway, with the number of samples determined to provide a statistically-valid result. Slope angle measurements were recorded to the nearest degree for the top lift of HMA or of the entire overlay slope if individual layers were well matched. Sampling of PCC pavement included the entire thickness of the new layer.

Safety Edge slope measurements for this 2011/2012 evaluation were obtained from 25 additional projects for 10 different agencies as shown in Table 1.

When examining slope measurements among different projects, the researchers found a wide variance between individual readings might exist, while the overall average of measurements might yield a similar result, thereby producing misleading conclusions. To counter this possible deduction, the standard deviation for the total series of measurements for each side of a roadway on a given project might be computed to provide a better appraisal of the consistency of the overall Safety Edge product an agency is attaining. The standard deviation may also prove useful in establishing a more realistic "range of allowable values" than the single "target slope" now specified.

Table 1. Safety Edge slope data 2011-2012

County	Site	Year Paved	Contractor	Activity	Avg Measurement-Slope/Settlement Std Dev Left	Avg Left	Avg Right	Std Dev Right	Length (Miles)	Shoe Used
Montgomery	H54	2011	Cedar Valley	PCC SE Slopes	1.42	29	30	1.05	8.8	Self Fabricated
Lee	J40	2011	Cessford Const.	SE Slopes	5.14	44	42	5.08	8	AdvantEdge
Story	Arrasmith Trl	2011	Manatts	SE Slopes	4.23	27	21	2.52	1	Ramp Champ
Story	E15 **	2011	Manatts	SE Slopes	3.83	31	31	3.05	4	Ramp Champ
Guthrie	N70	2011	Henningsen	SE Slopes	8.74	26	22	8.46	8.5	Self Fabricated
IA DOT	IA 175-Webster	2011	F D Asphalt	SE Slopes	4.20	36	38	4.66	4.5	Self Fabricated
Webster	D20	2011	F D Asphalt	SE Slopes	11.03	41	37	8.17	3.5	Self Fabricated
Webster	D26	2011	F D Asphalt	SE Slopes	7.17	41	38	8.06	6.0	Self Fabricated
Webster	P29	2011	F D Asphalt	SE Slopes	9.55	46	48	12.33	5.0	Self Fabricated
Kossuth	P60	2011	Heartland	SE Slopes	4.83	34	34	5.75	5.0	Trans Tech
Kossuth	P66	2011	Heartland	SE Slopes	6.51	33	29	5.37	3.0	Trans Tech
IA DOT	IA 38 - Jones	2011	Manatts	SE Slopes	4.05	29	28	3.85	4.2	Trans Tech - Troxler
Black Hawk	Union Road	2011	Aspro	SE Slopes	4.39	23	23	3.11	5.0	TTCLJM *
Black Hawk	V51	2011	Aspro	SE Slopes	3.23	21	28	5.00	7.0	TTCLJM*
Carroll	E26	2012	Manatts	SE Slopes	5.09	36	33	6.035	2.97	Carlson Screed
Dickinson	A43-M54-A48	2012	OMG-Tri State	SE Slopes	5.02	37	40	8.70	11.0	Modified AdvantEdge
Dickinson	A31	2012	OMG-Tri State	SE Slopes	5.71	35	34	4.96	3	Ramp Champ NB & Modified AdvantEdge SB
Kossuth	A38	2012	Mathy Const.	SE Slopes	3.25	24	24	4.14	4.4	Ramp Champ
Kossuth	P30	2012	Mathy Const.	SE Slopes	5.37	25	23	3.74	8	Ramp Champ
Kossuth	P20	2012	Mathy Const.	SE Slopes	3.02	25	23	2.40	7	Ramp Champ
IA DOT	IA 146	2012	Manatts	SE Slopes	8.38	31	32	5.74		Trans Tech
Carroll	E63	2012	Manatts	SE Slopes	6.28	42	38	3.91	2.1	TransTech
Carroll	E37-East	2012	Manatts	SE Slopes	5.169	35	37	9.505	1.86	TransTech
Carroll	E37-West-71	2012	Manatts	SE Slopes	6.398	40	37	9.551	1.28	TransTech
Carroll	US30 S to Airport	2012	Manatts	SE Slopes	6.9	42	43	7.706	1.24	TransTech
				2011 Averages	5.915	33.231	32.231	5.801		
				Averages	**5.728**	**34**	**33**	**5.908**		
				2012 Averages	5.507	33.818	33.091	6.035		
** Core tested- Normal - 92.6% density; Safety Edge - 83.5% density						Trans Tech Centerline Joint Maker				TTCLJM*

INSPECTING SHOULDER AND SAFETY EDGE CONDITIONS ON PREVIOUSLY-CONSTRUCTED PROJECTS

This task consisted of two objectives: Evaluate changes in shoulder elevation degradation from settlement or erosion and determine any increase in deterioration of the sloped Safety Edge with HMA pavements.

Differences in surface elevations of granular or earth shoulders adjacent to recently paved or resurfaced pavement sections can be attributed generally to three major causes: natural settlement in the granular or earth shoulder section, erosion from rainfall runoff, or displacement of fine material due to turbulence from large passing vehicles. In addition, frequent passage of oversized and/or heavy commercial or agricultural equipment can accelerate the rate of settlement. It was opined that the sloped Safety Edge may experience a higher rate of shoulder deterioration than a vertical or near vertical edge presented with other pavement designs.

To evaluate differences in the degree of shoulder elevation changes on Safety Edge projects, elevation differential measurements were made on 11 projects that were completed in 2010 and 2011. These projects were completed by 8 different contractors in 9 individual counties on both state- and county-owned roadways.

As seen in Table 2, shoulders on both PCC and HMA projects were measured, with all projects showing a minimal degree of settlement, comparable to what would be anticipated to occur with conventional paving or overlays. However, when a sloped pavement edge is presented, a safer re-entry onto the driving surface by errant vehicles is provided.

One of the projects evaluated under this project was on Montgomery CR H-54, which included concurrent segments with and without the Safety Edge that provided an opportunity for a side-by-side comparison of settlement rates.

The images shown in Figures 8 and 9 are typical of the edge drop offs observed and measured on both HMA and PCC pavements with and without the Safety Edge. Although the average settlement magnitudes were nearly identical with and without the Safety Edge, it was obvious that an errant driver’s ability to remount the pavement would be drastically different with or without the Safety Edge.

Table 2. Shoulder settlement data 2010 and 2011 projects

				Average Measurement-Dropoff or Settlement									
County	Site	Year Paved	Contractor	Std Dev	PCC Avg Left	PCC Avg Right	Std Dev	Std Dev	HMA Avg Left	HMA Avg Right	Std Dev	Length (Miles)	Shoe Used
Delaware	D34	2010	Mathy Const.					0.150	0.920	0.950	0.160	5.0	AdvantEdger
Guthrie	W70	2011	Henningsen					0.238	0.940	0.927	0.236	8.0	Self Fabricated
Jasper	F62	2010	Manatts					0.303	0.611	0.819	0.226	4.5	Trans Tech
Jones-Linn	E34	2010	Horsfield Const.	0.485	0.790	0.730	0.290					2.2	Self Fabricated
Keokuk	V63	2010	Wicks Const.	0.345	1.750	2.100	0.450					1	Self Fabricated
Montgomery	H54	2011	Cedar Valley	0.203	0.859	0.898	0.205					7.0	Self Fabricated w/Safety Edge
Montgomery	H54	2011	Cedar Valley	0.267	1.250	1.000	0.259					1.8	Self Fabricated w/o Safety Edge
Union	H24	2010	Henningsen					0.373	1.018	0.821	0.309	2.5	Self Fabricated
IA DOT	IA 21-Benton	2010	OMG	0.217	0.938	0.750	0.177	0.358	1.125	1.000	0.264	4.25	??Maint Contract-
IA DOT	IA 38-Jones	2011	Manatts					0.510	0.988	0.857	0.374	4.2	Troxler - TT
IA DOT	IA 175-Webster	2011	F D Asphalt					0.211	0.375	0.500	0.296	4.5	Self Fabricated
			Averages	**0.303**	**1.117**	**1.096**	**0.276**	**0.306**	**0.854**	**0.839**	**0.266**		

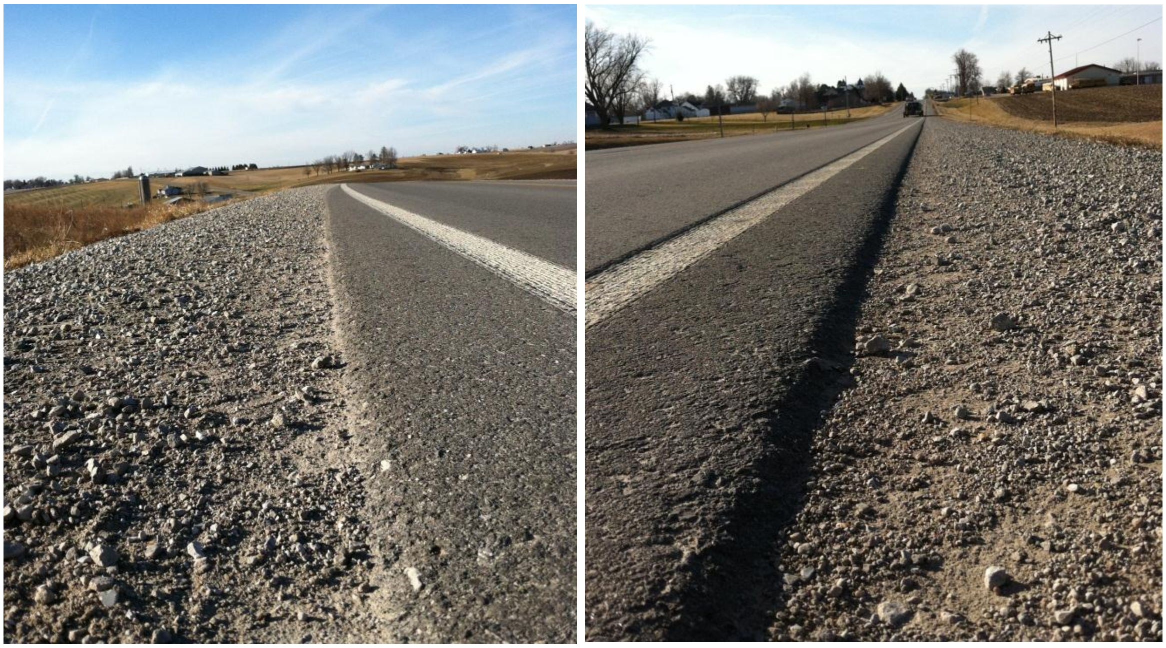

Figure 8. Typical shoulder degradation for HMA pavements with the Safety Edge (left) and with less than 30 degree slope (right)

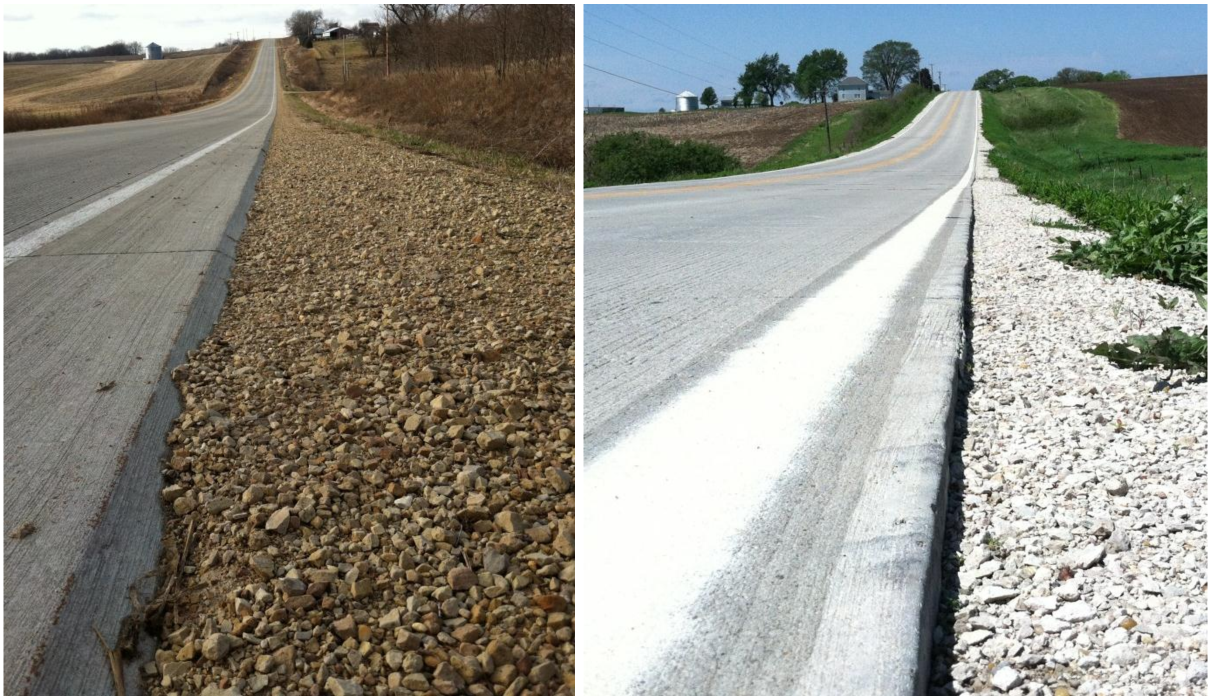

Figure 9. Typical shoulder degradation for PCC pavements with the Safety Edge (left) and without it (right)

The second objective under this task was to evaluate any increased deterioration of sloped edge versus an edge constructed without the Safety Edge for HMA pavements. Since the roadway improvements had been completed before slope measurements were taken in some locations, removal of the granular shoulder material was necessary, which also presented the opportunity to examine the sloped edge for deterioration, as illustrated in Figure 10.

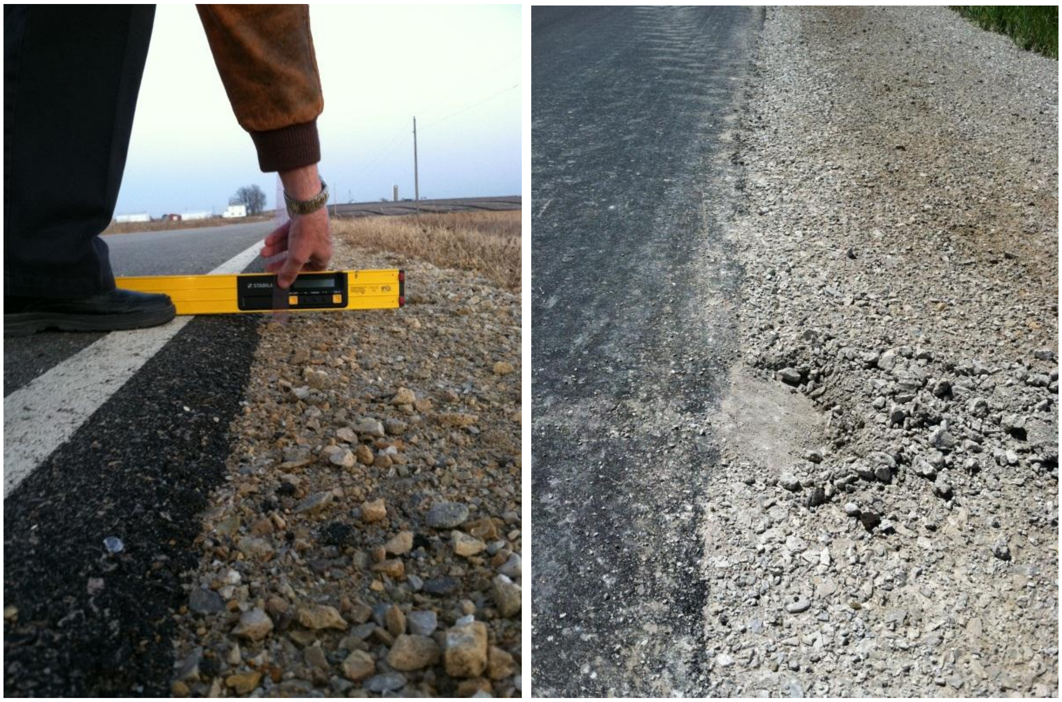

Figure 10. Exposed Safety Edge slope faces

During these investigations, no areas were observed that showed evidence of any increased deterioration. However, in some locations, pavement cracking (Figure 11) was evident, indicating probable construction problems, such as inadequate base width and/or support, that were not related to the Safety Edge.

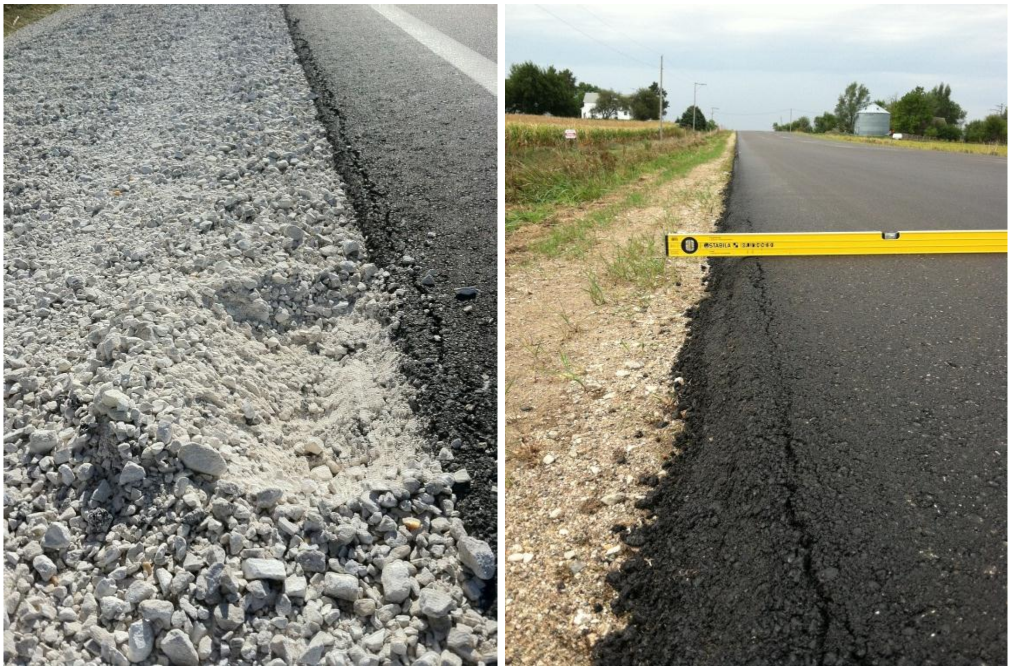

Figure 11. Edge cracking from apparent lack of shoulder support

CONCLUSIONS

Based on observations and measurements, the research team concluded that, even considering that not all results were consistent and didn't meet the "ideal" 30 degree slope angle, almost all Safety Edge slopes included in this evaluation project resulted in more traversable slopes than those that would be expected with conventional pavement edges.

Consistency of Final Product

For HMA pavements and overlays, the team concluded that no current Safety Edge shoe will produce a desirable product all the time. Although the newer design shoes did appear to perform more consistently than earlier models, a common practice of "set it and forget it!" does not work. Many factors, including mix design, compaction rolling pattern used, thickness of layer(s), plus the base width and shoulder conditions, might have an influence on the final edge slope no matter how satisfactory the slope appears immediately behind the paver.

The contracting authority and the contractor *both* must agree before work begins, probably at the pre-construction conference, what final result is desired and comply by making adjustments as necessary *throughout* the project to achieve that level of success. Obviously, this goal must be made clear to the field inspector, paver operator, and crew, as they are the ones actually inspecting and performing the work.

HMA Mix Characteristics

Throughout the conduct of the previous 2010-2011 evaluation and the observations made with this project, inconsistent Safety Edge results have been viewed and documented even on the same projects from day to day or on nearby projects constructed with the same materials by the same contractor.

Several possible causes of this variation have been suggested and considered, including ambient and mix temperatures, variation in compaction activities, asphalt content, aggregate type, and gradation. Moisture content of the aggregate has been known to impact stability during compaction, but the extraordinarily dry Iowa summer in 2012 made that unlikely.

In an effort to identify an item in the job mix factors that might impact stability, a list of gyratory mix design elements for 2012 HMA projects was examined for variations that could predict resultant stability of the mix in the field, but none could be identified.

Without a reliable means to predict when problems with HMA distortion under compaction to the degree that the integrity of the Safety Edge slope might be impacted, agencies and contractors must rely on proven techniques and close daily monitoring to assure that the desired Safety Edge slope is attained.

Base Conditions

Especially on narrow roadways, existing shoulders must be brought flush with the edge of pavement *before* paving is started to provide a stable base for the Safety Edge.

For efficiency of operation and an acceptable final Safety Edge, a plan must be devised to establish a base width necessary to accommodate the width of succeeding upper layers, while also following the pavement centerline as closely as possible. If the base width is too great, the results could be wasted material as shown in Figure 12.

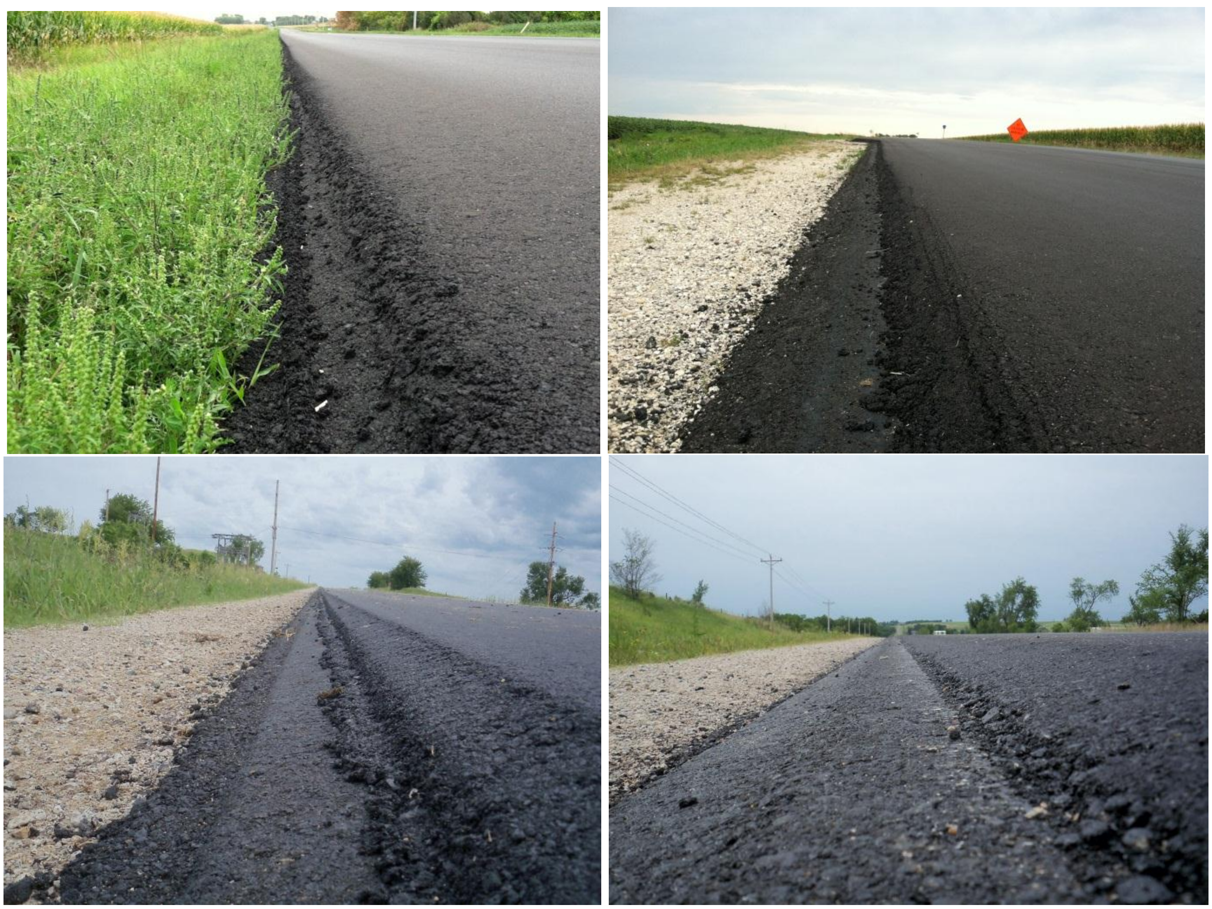

Figure 12. Excess base width examples

Conversely, if the base width is insufficient, the upper layer width could extend beyond the base resulting in lack of proper support for the Safety Edge as shown in Figure 13.

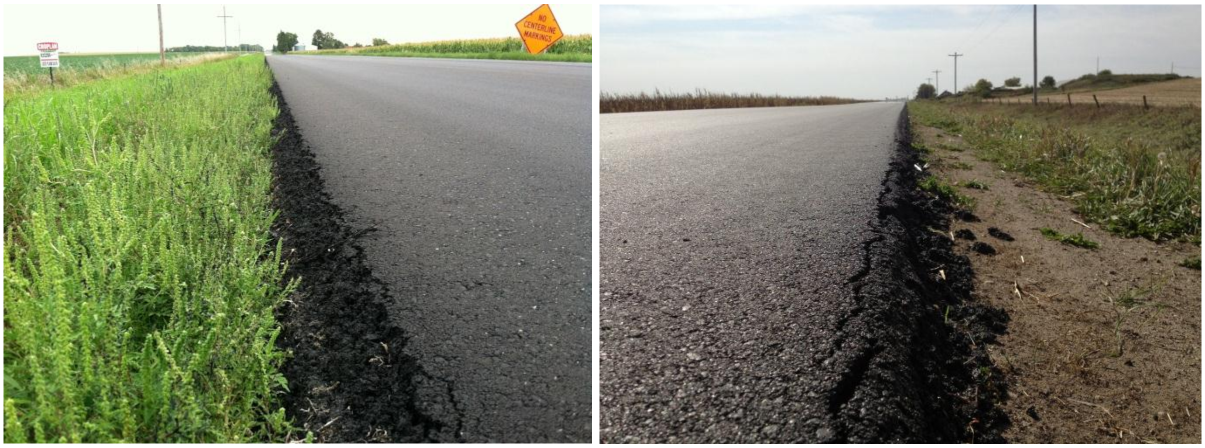

Figure 13. Insufficient base width examples

Design and Construction Guidelines

The Iowa DOT has produced several design and construction guidelines to address these issues and two of these are available online as follows:

www.iowadot.gov/design/dmanual/03C-06.pdf
www.iowadot.gov/design/SRP/IndividualStandards/epv03.pdf

A tech brief entitled Recommendations for Achieving Safety Edge Consistency during Paving was also developed for Phase II of this project.

Outreach

Results from this Safety Edge evaluation project were discussed with attendees at the annual Iowa DOT Fall Safety Workshops around the state. Special mention was made of both the preliminary findings and that a final report and a technical brief would be issued at project completion.

Future Crash Analysis

Over the course of monitoring the Phase I and II Safety Edge construction projects, project extents were recorded that will permit a crash analysis to be conducted when sufficient years of after data are available.

RECOMMENDATIONS

The type of equipment used to produce the Safety Edge, while not of negligible importance, does not seem as influential toward achieving desired results as the approach taken by the production crew and inspection staff. Although improved performance was observed with some of the newer design Safety Edge placement equipment, to assure a consistent end product on a continuing basis, it appears that performance measures may need to be adopted to obtain desired results.

These measures, with or without non-compliance penalties, should encourage both contractor crews and agency inspectors to exert more effort in monitoring the production of a desired Safety Edge product. A minimum sampling frequency could be required with desired results of a 30 degree slope as a target with a 10 degree variance allowed.

Contractors and/or agency inspectors need to check and adjust (if necessary) crew procedures several times a day and demand the best work possible. Measurements could be accomplished with a common, inexpensive device to which both the owner and contractor have access. (Smart levels can be purchased in the $150 to $200 range.) Unacceptable results should be discussed as quickly as possible with the grade superintendent or supervisor so everyone is aware of both poor and acceptable results and prompt adjustments are made as needed.

In addition, if the roadway is open to traffic during construction, attention must be given to the drop-off height created in super-elevated locations, even if the Safety Edge slope is acceptable. Figure 14 shows a large elevation difference in a tangent section, which can also occur outside of curved areas, where the vertical alignment of a segment is being improved or corrected.

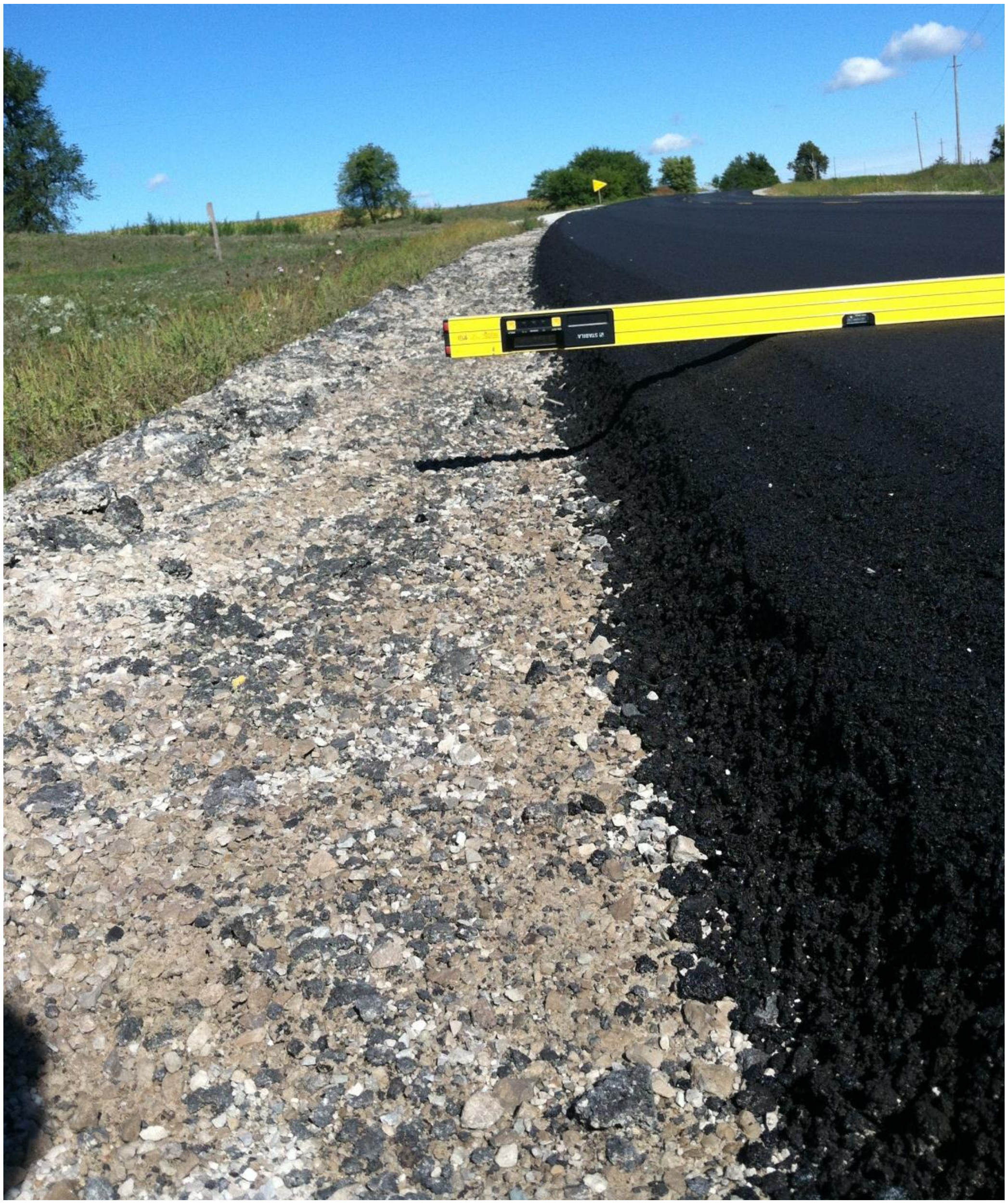

Figure 14. Severe pavement edge drop-off near outside of curve

An interim degree of shouldering should be required where excessive vertical differences in the shoulder and pavement elevations have been created. As illustrated in Figure 15, even with a perfect 30 degree Safety Edge slope, smaller vehicles could easily high center when leaving the pavement and lose control.

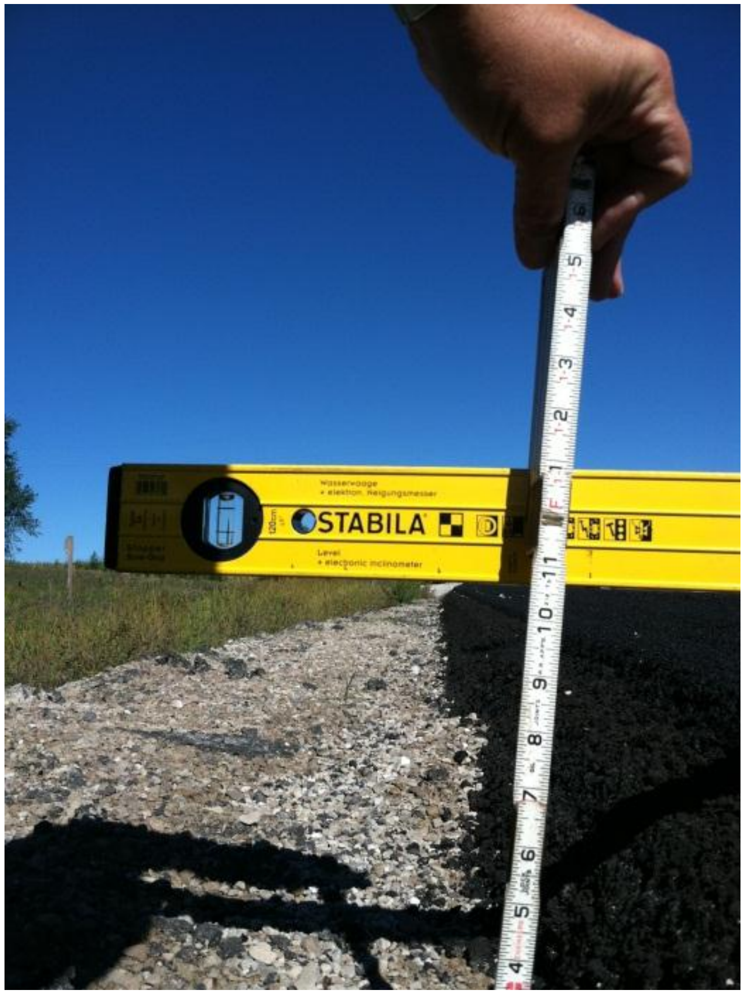

Figure 15. Severe pavement edge drop-off

Although improved performance did appear evident with some of the new designed shoes, other improvements, such as a vibratory plate addition to the Safety Edge placement equipment, might also be worthwhile to consider to further aid in compaction of the Safety Edge material. As noted earlier, Safety Edge slope density samples did not yield a measurable difference in density between the original and newly designed shoes.

Another improvement that would benefit contractors would be a shoe design that could be modified to produce either a Safety Edge or a lane-matching shoe without removal from the paving machine.

The Safety Edge has been shown to be a valuable asset in providing safer re-entry to the driving surface for errant vehicles, but known applications have been to driving surface pavements only, not shoulders. While the addition of paved shoulders has been found to reduce edge maintenance and some lane departure incidents, the potential benefits of a Safety Edge on narrow-width paved shoulders has not been investigated thoroughly. Considering the low cost of this safety enhancement and the possibility of lane departure crashes even with a paved shoulder, the research team recommends that a Safety Edge also be specified for narrow paved shoulders of 4 foot width or narrower.

Outreach

Suggestions should continue to be made to Iowa county engineers to take advantage of opportunities to promote the Safety Edge concept as part of the scheduled program at workshops and conferences.

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