Federal Highway Administration
Every Day Counts
Innovation Initiative

Safety Edge$_{SM}$ HMA Demonstration Project Jasper County, Iowa

Field Report
June 6, 2011

U.S.Department of Transportation
Federal Highway Administration

FOREWORD

The purpose of this field report is to provide a summary of the observations and field measurements made during the hot mix asphalt (HMA) Safety Edge$_{SM}$ project located 50 miles east of Des Moines in Jasper County on route F62 between the villages of Sully and Lynnville, Iowa. These observations and data are to be used with similar information from other Safety Edge$_{SM}$ projects to facilitate the development of standards and guidance for Safety Edge$_{SM}$ construction and long term performance.

All field and laboratory test results, HMA mixture design information and data, observations made during paving, and comments provided by construction personnel are included in the Field Evaluation Form that is provided as a separate document to this field report. This field report is a summary of the observations and field data collected during construction on August 5 and 6, 2010 to evaluate the use of the Safety Edge$_{SM}$ during paving, compare Safety Edge$_{SM}$ and non-Safety Edge$_{SM}$ portions along the project, determine the slope of the Safety Edge$_{SM}$, recommend adjustments to the Safety Edge$_{SM}$ design if found to be needed, and identify benefits and complications with the use of the Safety Edge$_{SM}$ device.

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16. Abstract

In a coordinated effort with highway authorities and industry leaders, the Every Day Counts initiative serves as a catalyst to identify and promote cost effective innovations to bring about rapid change to increase safety of our nations highway system, decrease project delivery time, and protect our environment. The Safety Edge$_{SM}$ concept is an example of one such initiative in which the edge of the road is beveled during construction for the purpose of helping drivers who migrate off the roadways to more easily return to the road without over correcting and running into the path of oncoming traffic or running off the other side of the roadway.

This field report documents the observations made on the construction of Safety Edge$_{SM}$ on a two lane highway hot mix asphalt (HMA) overlay project route F62 between the villages of Sully and Lynnville, Iowa. The TransTech Shoulder Wedge Maker was demonstrated during this project. Details regarding the performance of the device along with the shape and physical properties of the finished Safety Edge$_{SM}$ are presented for the purpose of understanding what processes and techniques were most successful in forming the Safety Edge$_{SM}$.

The findings from this overlay project and other similar ongoing projects form the basis for understanding the construction process and material performance necessary to bring this innovation into common highway practice and make our Nation's highways safer.

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SI* (MODERN METRIC) CONVERSION FACTORS				
APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
(none)	mil	25.4	micrometers	µm
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	millimeters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela per square meter	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	Newtons	N
lbf/in^2 (psi)	poundforce per square inch	6.89	kiloPascals	kPa
k/in^2 (ksi)	kips per square inch	6.89	megaPascals	MPa
		DENSITY		
lb/ft^3 (pcf)	pounds per cubic foot	16.02	kilograms per cubic meter	kg/m^3
APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
µm	micrometers	0.039	mil	(none)
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela per square meter	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	Newtons	0.225	poundforce	lbf
kPA	kiloPascals	0.145	poundforce per square inch	lbf/in^2 (psi)
MPa	megaPascals	0.145	kips per square inch	k/in^2 (ksi)

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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SUMMARY OF OBSERVATIONS

This section of the report provides a summary of important observations made during the paving operations, interviews with paving personnel, and findings from the field measurements taken during paving that are expected to have a significant impact on the performance of the Safety Edge$_{SM}$.

Overall Opinion of the Safety Edge$_{SM}$

- The paving operation was not noticeably slowed or otherwise inconvenienced by incorporating the Safety Edge$_{SM}$. However, the average slope of the completed Safety Edge$_{SM}$ was greater than the targeted 30° and the density at the edge may affect the long-term pavement performance. These issues and other issues are noted in the following bulleted items.

Slope of Safety Edge$_{SM}$

- The slope of the Safety Edge$_{SM}$ varied throughout the project. The average slope measurement was 38°.
- The sloped face of the Safety Edge$_{SM}$ had a well formed but had a coarse/open texture. Large aggregates in the slope face could be removed by hand without much difficulty, which was the same observation for the non-Safety Edge$_{SM}$ sections.
- The Safety Edge$_{SM}$ was incorporated into all three lifts in some sections of the road increasing the amount of HMA placed on this project. The lower lifts extended out slightly farther to accommodate the lifts above resulting in more HMA used to build the edge.

Edge Preparation

- Overall, the project was well suited for the Safety Edge$_{SM}$ given that the base for the shoulders was well constructed and wide enough to accommodate the Safety Edge$_{SM}$. Edge clearance was not an issue which allowed the endplate of the paving screed and the Safety Edge$_{SM}$ device to operate freely.

Construction/ Compaction

- The Safety Edge$_{SM}$ was formed using the TransTech Shoulder Wedge Maker attached to the paving screed. The device was hand operated and required some elevation adjustments by the screed operator when approaching turnouts and cross roads. The demonstration project had many long tangents so making adjustments occurred only periodically.
- In an effort to maintain the slope of the Safety Edge$_{SM}$, the breakdown roller and intermediate roller were kept from overhanging the edge and applying the maximum compactive force. It was observed that by overhanging the edge of the mat the edge would shift and increase the slope of the Safety Edge$_{SM}$. Therefore, the contractor

decided to make only one pass at the edge of the mat with the finish roller in static mode.

- The non-Safety Edge$_{SM}$ test sections of this project received a typical rolling pattern that covered the edge of the mat with passes made by the breakdown and intermediate rollers. As a consequence of the different rolling patterns, the average density adjacent to the edge of the mat was 6 percent less for the Safety Edge$_{SM}$ compared to the non-Safety Edge$_{SM}$ test sections.
- The air voids adjacent to the Safety Edge$_{SM}$ were high (average of 13.6 percent). The air void content is higher than desirable for long term pavement performance.

HMA Mixture

- The mat did not appear to be overly tender during compaction. However, horizontal displacement was observed at the edge of the mat under the breakdown roller.
- Only slight segregation was observed sporadically at the longitudinal joint and at the edge of the mat.
- The planned HMA thickness was 1.5 inches for the intermediate course from which measurements were made. The thickness of the cores from this lift varied from 1.2 to 2.4 inches along the outside edge of the project.
- The slope of the Safety Edge$_{SM}$ tended to increase with increased lift thickness.

Future Considerations or Material Enhancements to Improve Performance

- Automatic adjustment to the vertical profile of the Safety Edge$_{SM}$ device would be of benefit to the operator.
- Currently the angle of the Safety Edge$_{SM}$ device shoe is not adjustable. It would be beneficial to be able to decrease the angle of the device when using HMA mixtures for which the slope angle tends to increase when compacted.

This Safety Edge$_{SM}$ project should be monitored to determine its long-term performance and the frequency of any required maintenance operations, as well as the life cycle cost of the Safety Edge$_{SM}$ and its effectiveness over time.

EVALUATION OF HMA OVERLAY WITH SAFETY EDGE$_{SM}$

Introduction

A series of field tests were carried out to assess the placement and condition of the HMA along route F62 with and without the use of the Safety Edge$_{SM}$ device. The objective or purpose of this field study was to evaluate the quality of the in-place HMA material and Safety Edge$_{SM}$ by investigating three issues or features.

1. Correct use of the Safety Edge$_{SM}$ device during paving.
2. Safety Edge$_{SM}$ versus non-Safety Edge$_{SM}$ portions of project.
3. Slope of the Safety Edge$_{SM}$.

Project stationing began at Station 22+00 (west project limit) at the intersection of 1st Street and route F62 in Sully and extends to the Jasper/Poweshiek County line east of Lynnville (east project limit), refer to Figure 1. The maximum posted speed on this roadway was 55 mph. The contractor, Manatt's Inc., used the TransTech Shoulder Wedge Maker for this demonstration.

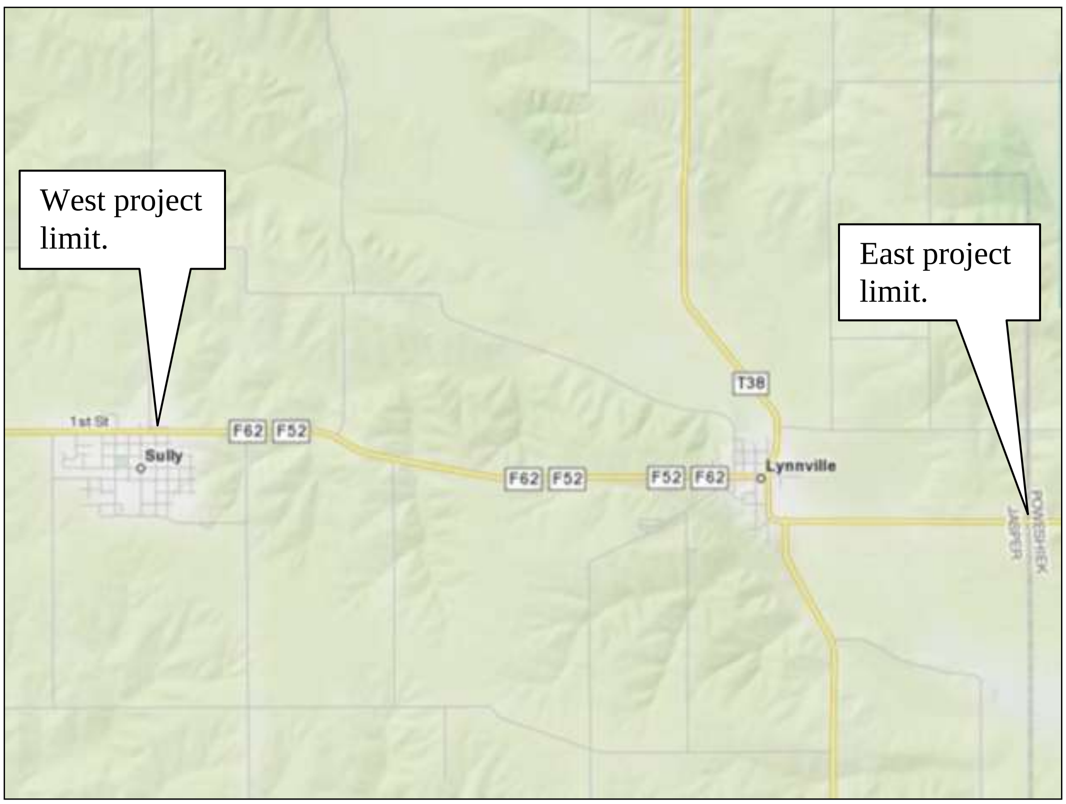

Figure 1. Site location.

Pavement Structure and Project Conditions

The project consisted of a 5-inch cold in-place recycling of the existing asphalt pavement then placement of a 2-inch HMA base course, a 1.5-inch HMA intermediate course, and a 1.5-inch HMA surface course. All three HMA layers were comprised of the same 19.0 mm mix, the only exception was the base course contained RAP. Earthwork was not required on this project as the original width of the pavement and shoulders matched the new cross section plan. Figure 2 shows the typical pavement cross section.

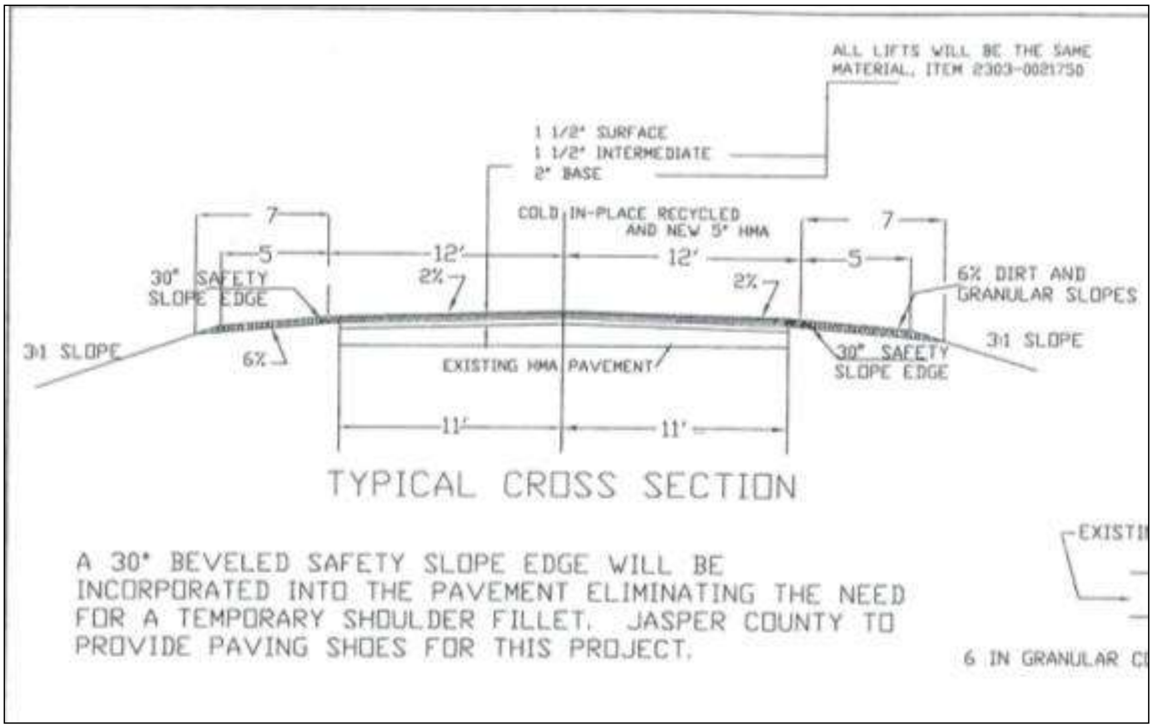

Figure 2. Typical pavement cross section.

At the time of the site visit, the contractor had placed the base and intermediate courses, both with the Safety Edge$_{SM}$, from Sully to Lynnville. The section east of Lynnville had the base, intermediate, and the westbound surface course paved without the Safety Edge$_{SM}$.

Field Evaluation Tests

Four Safety Edge$_{SM}$ and two non-Safety Edge$_{SM}$ test sections were established, all on the intermediate course. In an effort to maximize the number of test sites and reduce the amount of coring, the test sections were located where the County had previously cut QA cores at approximately 3 ft. from the edge or near the center of the lane. The cores from the County together with cores cut adjacent the Safety Edge$_{SM}$ (and some cores cut from 3 ft. from the edge) during the current testing would have served to calibrate the nuclear density tests taken in each test section. Unfortunately, the laboratory test results from the County were unavailable, nevertheless, the cores taken at the time of the field evaluation were used for calibration.

The four Safety Edge$_{SM}$ test sections were located between Sully and Lynnville. The two non-Safety EdgeSMs sections were located east of Lynnville and serve as control sections for comparison. The following summarizes the six test sections included in this field study:

1. Section #1, Safety Edge$_{SM}$, westbound lane, tangent section , centered at Sta 150+75 at a field entrance across from the "welcome to Lynnville" sign on the west side of the village.
2. Section #2, Safety Edge$_{SM}$, westbound lane, curved section, centered at Sta 116+15 across from a "No Passing Sign" between the gravel drives to residence address numbers 13848 and 13808.
3. Section #3, Safety Edge$_{SM}$, westbound lane, curved section, centered at Sta 81+27 and 150 ft. east of the center of the gravel drive to residence/farm address number 13288.
4. Section #4, Safety Edge$_{SM}$; westbound lane, curve section, centered at Sta 69+82 at the intersection with East 132nd Street.
5. Section #5, non-Safety Edge$_{SM}$, eastbound, tangent section, centered at Sta 254+92 at 525 ft. east of the centerline of gravel drive to residential address number 15686.
6. Section #6, non-Safety Edge$_{SM}$, eastbound, tangent section, centered at Sta 251+08 at 300 ft. west of the centerline of gravel drive to residential address number 15686.

At the time of the site visit mechanical difficulties with the asphalt plant delayed paving until later in the day, ultimately shortening the amount of surface course paved. However, the intermediate course from previous paving had been paved with the Safety Edge$_{SM}$ and was suitable for testing. Therefore, all tests and edge slope measurements were conducted on the intermediate course.

<u>Slope Measurements</u>

Slope measurements were taken at 25-ft. intervals (spacing was adjusted for field/driveway entrances) using a straight-edge and tape measure to determine the horizontal and vertical dimensions of the Safety Edge$_{SM}$ on the intermediate course only. The Safety Edge$_{SM}$ on the base course was ignored.

The vertical measurement was also the thickness at the edge of the mat which is not always the case. For example when HMA is allowed to slide down the slope during paving the true edge thickness is obscured. Figure 3 shows the technique in measuring the edge slope.

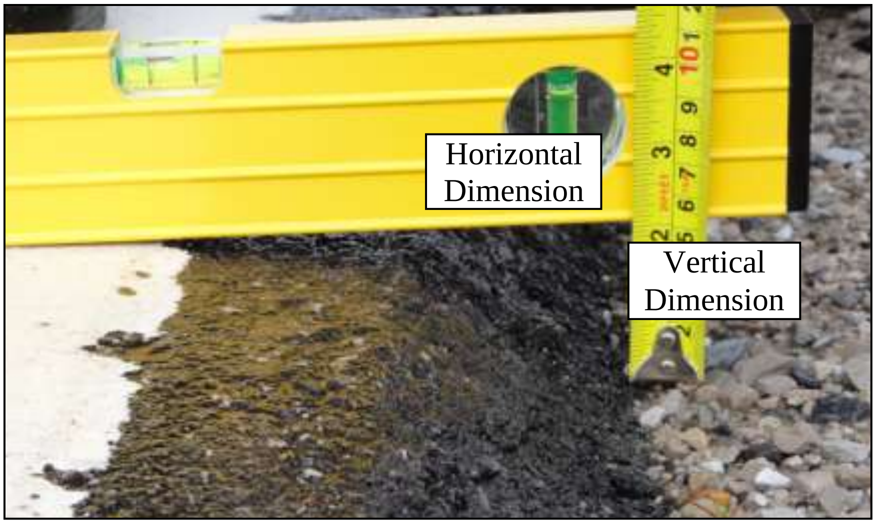

Figure 3. Slope measurement technique.

The average slope of the Safety Edge$_{SM}$ was calculated to be 38° from the width and thickness measurements. Slope measurements are listed in Table A-1 and Table A-2 in Appendix A.

Cores

Cores were cut from the mid-point of each test section. These cores were taken to measure thickness and for laboratory testing. Table 3 in the Appendix provides a summary of the core thickness results. Figure 4 shows the location of the cores taken adjacent to the pavement edge and 3 ft. away from the edge.

Figure 4. Safety Edge$_{SM}$ section with cores cut adjacent to the edge and at 3 ft. from the edge.

Figure 5 compares the thickness of the intermediate course near the Safety Edge$_{SM}$ and the slope of the Safety Edge$_{SM}$. As shown, the slope appears to increase with the thickness of the Safety Edge$_{SM}$.

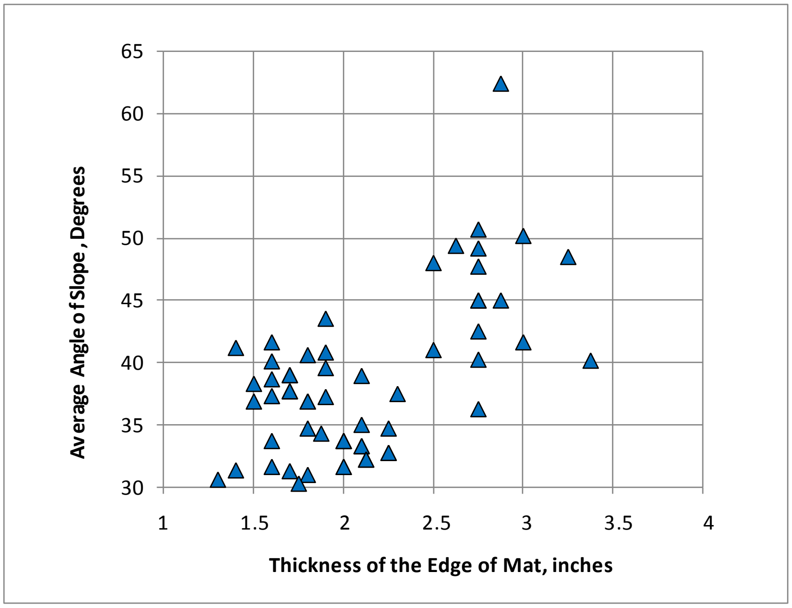

Figure 5. Comparison of slope and edge thickness.

Figure 6 shows the comparison of the core densities taken adjacent to the edge and at 3 ft. from the edge for the Safety Edge$_{SM}$ and non-Safety Edge$_{SM}$ sections. As expected the densities away from the edge where the mat received full coverage of the roller passes are significantly higher than near the edge of the pavement. This result reflects the relatively low degree of compactive effort applied to the Safety Edge$_{SM}$ in comparison to standard compaction given to the non-Safety Edge$_{SM}$ section.

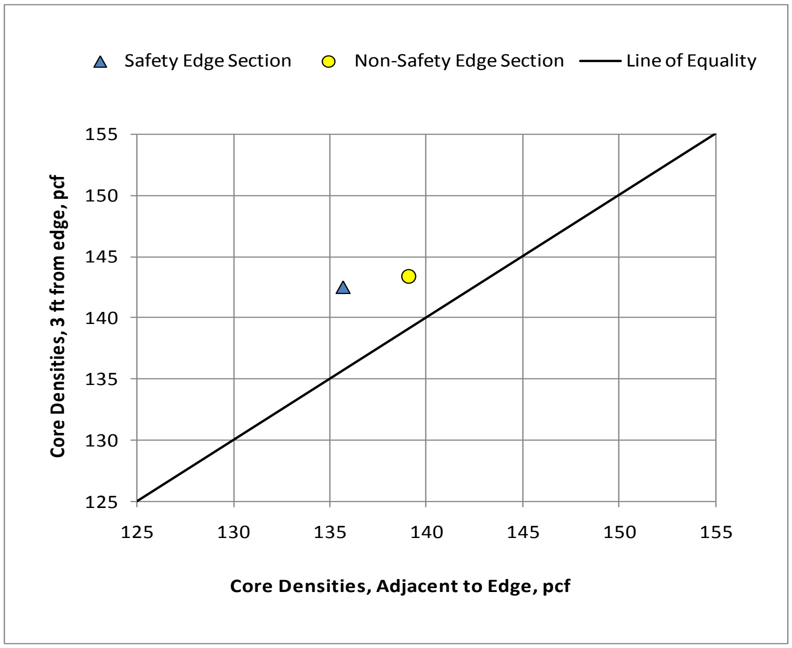

Figure 6. Comparison of core densities adjacent to the edge and 3 ft. from the edge.

Nuclear Density Results

Density tests were conducted using a Troxler 3411 nuclear density gauge in backscatter mode for 60 second test durations. Nuclear density tests were conducted adjacent to the edge and 3 ft. from the edge at 50-ft intervals for 200 ft. before and after the location of the cores. The actual test spacing was adjusted to avoid non-representative areas at field/driveway entrances.

Adjustment factors were determined by correlating the nuclear density readings to the core laboratory test results of bulk specific gravity (saturated surface dry test condition) testing. The following summarizes the adjustment factors determined for this project.

Location	Adjustment Factor
Adjacent to the edge	0.978
3 ft. from the edge	0.995

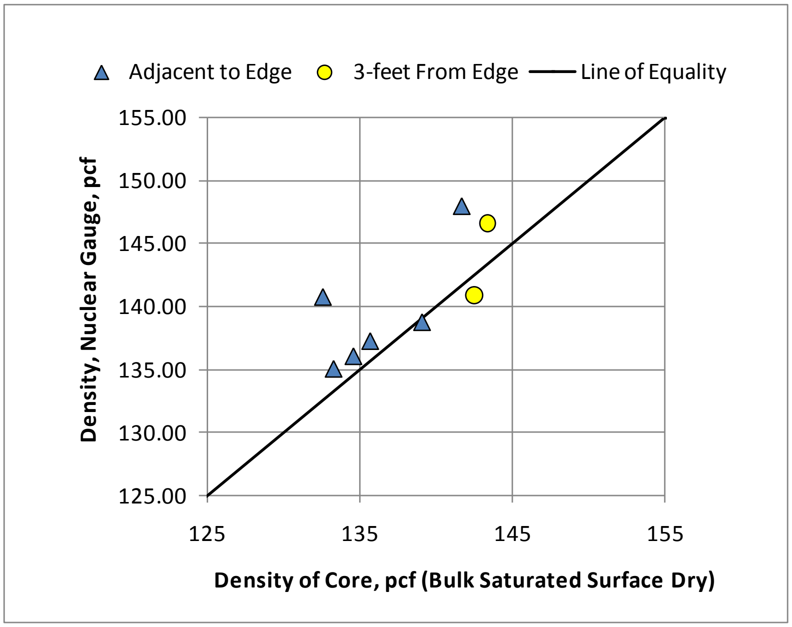

Figure 7 shows a comparison of the nuclear densities and densities measured from the cores As shown, the value at 3 ft. from the edge was close to unity and the value adjacent to the edge is not as close to unity. The adjusted densities using the adjustment factors are also listed in Table A-4 in Appendix A. The factors were used to adjust the nuclear density gauge readings to be consistent with the densities that were measured in the laboratory. The nuclear density test results are listed in Table A-5 and A-6 in Appendix A.

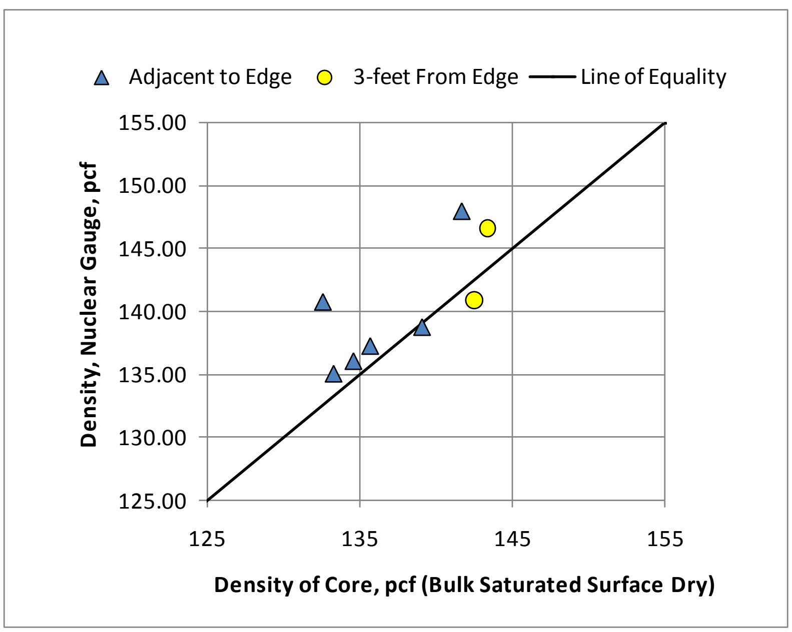

Figure 7. Comparison of the nuclear density readings and core densities**.**

Figure 8 is a comparison of the adjusted nuclear density gauge readings taken adjacent to the edge and at 3 ft. from the edge. Figure 9 is a comparison of the HMA air voids between both areas. Generally, the two figures show densities were lower and the air voids were higher adjacent to the edge than away from the edge. The same correlation holds true for comparing the Safety Edge$_{SM}$ sections to the non-Safety Edge$_{SM}$ sections, and it is recognized that the non-Safety Edge$_{SM}$ sections received greater compactive effort from the rolling procedures.

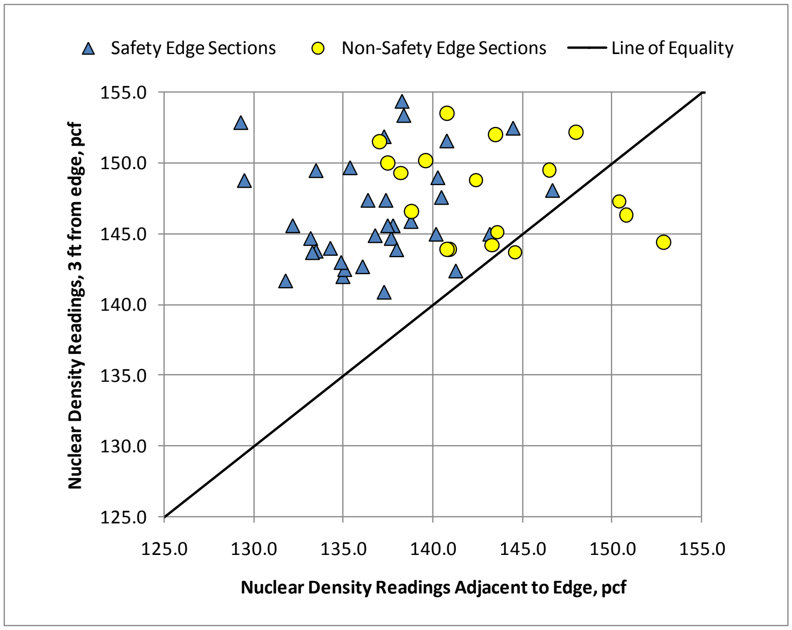

Figure 8. Comparison of densities adjacent to the edge and 3 ft. from the edge.

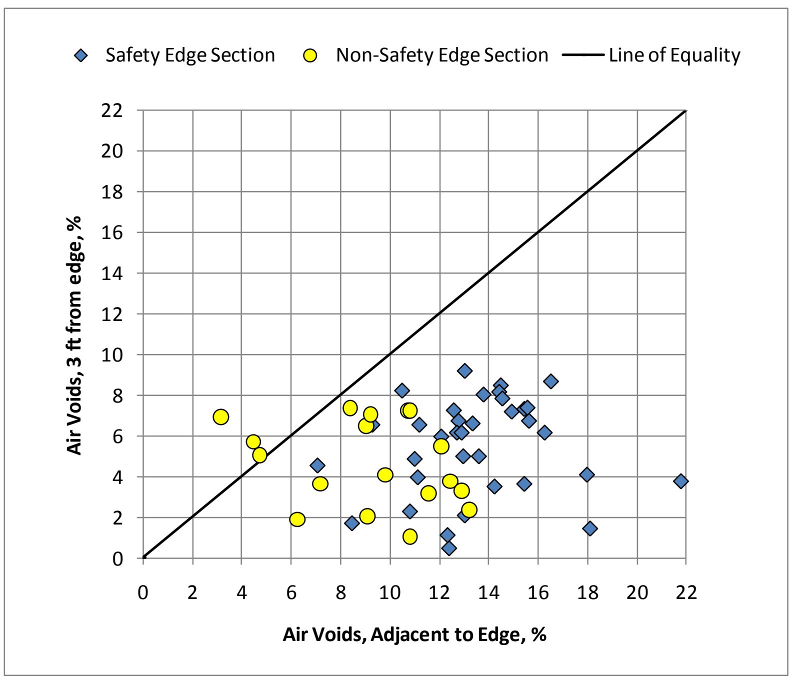

Figure 9. Comparison of air voids adjacent to the edge and 3 ft. from the edge.

Observations Made During Paving with the Safety Edge$_{SM}$

This section shares the observations made during the paving and rolling of the surface course starting in Sully and proceeding east toward Lynnville.

Preparatory Work

The base for the shoulders was well constructed and wide enough to accommodate the Safety Edge$_{SM}$. Edge work on the pavement or shoulders prior to paving was not observed. Edge clearance was not an issue which allowed the endplate of the paving screed and the Safety Edge$_{SM}$ device to operate freely.

Placement/Paving Operations

The contractor utilized a windrow material transfer vehicle (MTV) together with a Blaw-Knox rubber tire paver equipped a Caterpillar Extend-A-Mat 10-20B screed (Figure 10). Figure 11 and Figure 12 are images of the paving screed and the Safety Edge$_{SM}$ device bolted to the screed. Vertical control of the Safety Edge$_{SM}$ device was accomplished by hand cracking the device by the screed operator walking beside the paver.

Slight segregation was noticed at both the unconfined longitudinal centerline joint and at the free edge when compared to the center of the mat. The segregation was present in the Safety Edge$_{SM}$ as well as the non-Safety Edge$_{SM}$ sections of the project. Each course of HMA was offset during construction to accommodate the sloped Safety Edge$_{SM}$ on the following lift of HMA. Consequently, more HMA was placed to obtain the planned pavement width than would otherwise be placed with a traditional pavement edge. Figure 13 shows the Safety Edge$_{SM}$ and the offset placement of each pavement layer.

Figure 10. Material transfer vehicle ahead of the paver.

Figure 11. Blaw-Know paver with the Caterpillar screed.

Figure 12. TransTech Shoulder Wedge Maker bolted to the paver screed.

Figure 13. Offset HMA layers with Safety Edge$_{SM}$.

Compaction Operations

According to contractor personnel, all three courses with the Safety Edge$_{SM}$ were constructed using identical compactive effort and rolling pattern. The compaction equipment consisted of a Caterpillar CB 654D 16-ton steel drum breakdown roller followed by a Bomag pneumatic rubber tire intermediate roller and finished with a Hamm HD12DHV 16-ton steel drum finish roller. The rollers are shown in Figure 14.

The following rolling pattern was observed during the paving of the surface course on August 5. The pavement received 2 coverages from the breakdown roller in vibratory mode (low amplitude and high frequency) and the middle portion of the lane received an additional third coverage in vibratory mode. The first pass of the breakdown roller overhung the centerline joint 2 to 4 inches and the next pass overhung 1 inch. The breakdown roller stayed 6 inches from the Safety Edge$_{SM}$. The intermediate roller made up to 9 passes with each part of the mat receiving 4 coverages except that the intermediate roller stayed away from the edge of the mat. The area near the Safety Edge$_{SM}$ received no breakdown or intermediate roller coverages and only 1 coverage of the finish roller in static mode overhanging the edge by 2 inches. The finish roller made 5 passes over the rest of the mat to smooth the tire marks from the intermediate roller.

Upon special request, the breakdown roller operator hung over the Safety Edge$_{SM}$ of the mat about 2 inches on the first vibratory pass for a short section. Doing so caused the edge of the mat to displace horizontally and become steeper. This proved the slope of the Safety Edge$_{SM}$ was sensitive to the rollers position. The vibratory first pass at the longitudinal centerline joint caused the mat to move approximately 0.75 inches horizontally.

Although paving and compaction operations were not observed for the non-Safety Edge$_{SM}$ portion of this project, discussions with the contractor indicated normal rolling was conducted in which the breakdown roller made passes overhanging the edge and generally both the breakdown and intermediate rollers made passes closer to the edge. Thus, greater compactive effort was applied to the non-Safety Edge$_{SM}$ sections compared to the Safety Edge$_{SM}$ sections.

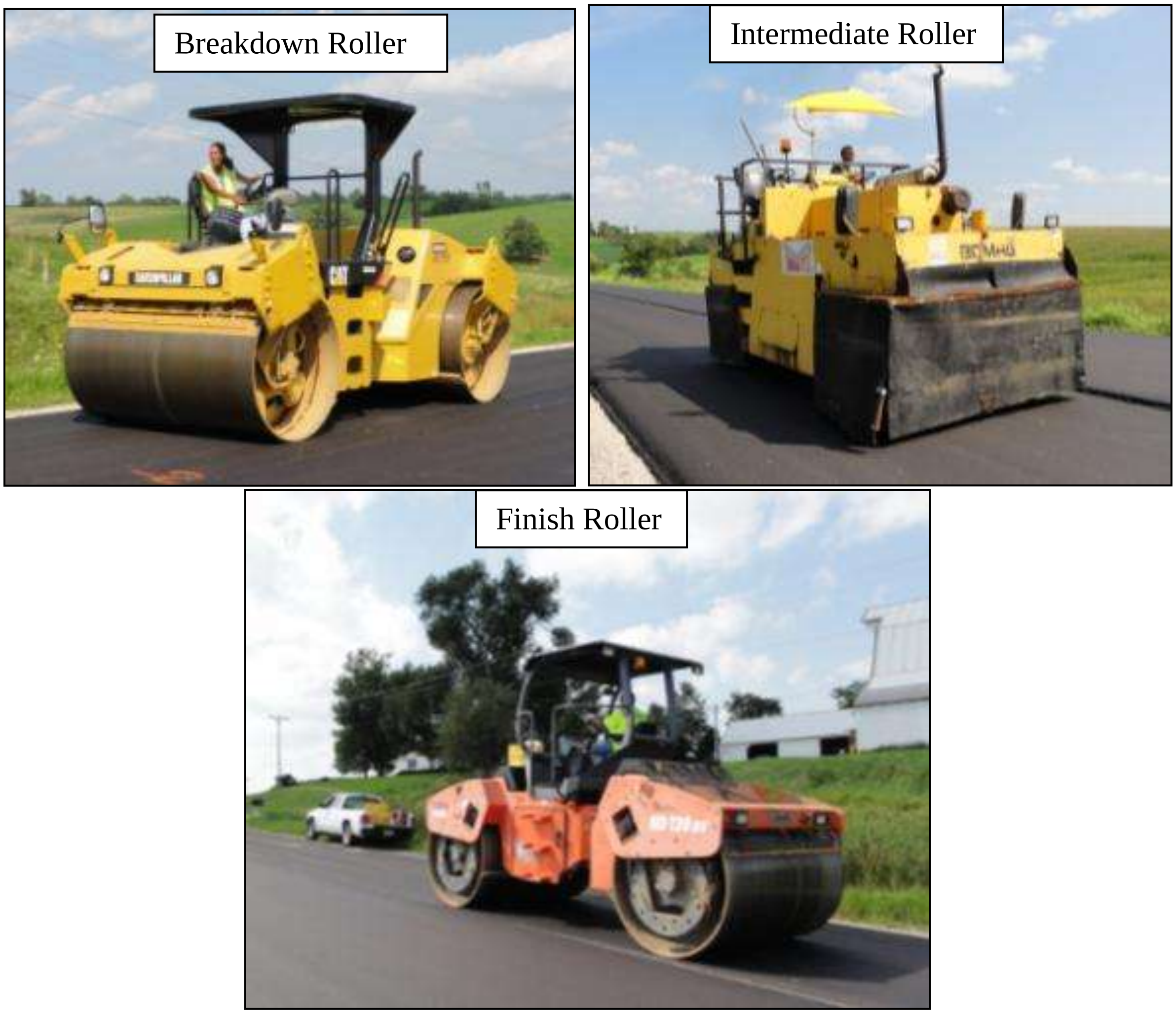

Figure 14. Compaction equipment.

Shoulder edge backing

Nearly all of the existing granular shoulder material was free of vegetation or any debris that might interfere with paving operations. At this point in construction before the surface course was paved, new granular shoulder material had not been placed in some areas exposing the Safety Edge$_{SM}$ from the base course upward. The contractor was allowed an extended time frame to pull up the shoulder material because of the use of the Safety Edge$_{SM}$. Normally the shoulder material would need to be placed in conjunction with each day's mainline paving. Figure 15 is a typical view of the project east of Sully showing the shoulder and the exposed Safety Edge$_{SM}$ of the base and intermediate courses.

Figure 15. Typical view showing the base and intermediate course with Safety Edge$_{SM}$ and granular shoulder material. Image taken east of Sully.

Findings and Conclusions

The objective of this field study was to evaluate the quality of the in-place HMA material and Safety Edge$_{SM}$ by investigating three features.

1. Correct use of the Safety Edge$_{SM}$ device during paving.
2. Safety Edge$_{SM}$ versus non-Safety Edge$_{SM}$ portions of project.
3. Slope of the Safety Edge$_{SM}$.

This section of the field report summarizes some of the findings and conclusions made during the paving/compaction operations.

- The contractor stayed away from the Safety Edge$_{SM}$ in an effort to preserve the slope of the Safety Edge$_{SM}$. The Safety Edge$_{SM}$ received only one pass of the finish roller in static mode.
- As a consequence of preserving the slope of the Safety Edge$_{SM}$, the density test results at the Safety Edge$_{SM}$ were lower and the air voids higher than the control sections where normal rolling (more compactive effort) was performed.
- The design of the Safety Edge$_{SM}$ device should be improved to achieve the desired slope and density.
- A benefit of the Safety Edge$_{SM}$ to this project is the extra time allowed for placing shoulder material.

APPENDIX A. DATA TABLES FROM FIELD MEASUREMENTS

This section of the field report provides a listing of the field measurements recorded during the paving operations. These data are also included in the detailed evaluation forms.

Table A-1. Safety Edge$_{SM}$ Slope Measurements.

Section ID	Station	Type of Section	Safety Edge$_{SM}$		
			Width of Taper, in	Thickness of Taper, in	Slope, deg
1	148+75	Safety Edge$_{SM}$	2.4	1.8	37
1	149+00	Safety Edge$_{SM}$	2.1	1.8	41
1	149+25	Safety Edge$_{SM}$	2.4	1.8	37
1	149+50	Safety Edge$_{SM}$	2.0	1.9	44
1	149+75	Safety Edge$_{SM}$	2.1	1.7	39
1	150+00	Safety Edge$_{SM}$	2.2	1.9	41
1	150+25	Safety Edge$_{SM}$	2.6	1.8	35
1	150+50	Safety Edge$_{SM}$	1.9	1.5	38
1	150+75	Safety Edge$_{SM}$	1.6	1.4	41
1	151+25	Safety Edge$_{SM}$	2.3	1.4	31
1	151+50	Safety Edge$_{SM}$	1.8	1.6	42
1	151+75	Safety Edge$_{SM}$	2.1	1.7	39
1	152+00	Safety Edge$_{SM}$	1.9	1.6	40
1	152+25	Safety Edge$_{SM}$	2.2	1.7	38
1	152+50	Safety Edge$_{SM}$	2.2	1.7	38
1	152+75	Safety Edge$_{SM}$	2.0	1.6	39
2	114+15	Safety Edge$_{SM}$	2.2	1.3	31
2	114+40	Safety Edge$_{SM}$	2.8	1.7	31
2	114+65	Safety Edge$_{SM}$	2.4	1.6	34
2	114+90	Safety Edge$_{SM}$	2.8	1.5	28
2	115+15	Safety Edge$_{SM}$	2.1	1.6	37
2	116+15	Safety Edge$_{SM}$	3.0	1.8	31
2	116+40	Safety Edge$_{SM}$	3.2	2.1	33
2	117+40	Safety Edge$_{SM}$	3.0	2.1	35
2	117+65	Safety Edge$_{SM}$	3.2	2.1	33
2	117+90	Safety Edge$_{SM}$	3.0	2.3	37
2	118+15	Safety Edge$_{SM}$	2.6	2.1	39
2	118+40	Safety Edge$_{SM}$	2.3	1.9	40
2	118+65	Safety Edge$_{SM}$	2.6	1.6	32
2	118+90	Safety Edge$_{SM}$	2.5	1.9	37
3	78+27	Safety Edge$_{SM}$	4.0	3.375	40
3	78+52	Safety Edge$_{SM}$	3.375	3.0	42
3	78+77	Safety Edge$_{SM}$	5.25	2.5	25
3	79+02	Safety Edge$_{SM}$	2.75	2.75	45
3	79+27	Safety Edge$_{SM}$	2.75	2.75	45
3	79+52	Safety Edge$_{SM}$	2.375	2.75	49
3	79+77	Safety Edge$_{SM}$	2.25	2.75	51
3	81+02	Safety Edge$_{SM}$	3.0	2.75	43
3	81+27	Safety Edge$_{SM}$	2.875	2.875	45
3	81+52	Safety Edge$_{SM}$	2.25	2.625	49
3	81+77	Safety Edge$_{SM}$	1.5	2.875	62
3	82+02	Safety Edge$_{SM}$	2.875	3.25	49
3	82+27	Safety Edge$_{SM}$	3.25	2.75	40

Section ID	Station	Type of Section	Safety Edge$_{SM}$		
			Width of Taper, in	Thickness of Taper, in	Slope, deg
3	82+52	Safety Edge$_{SM}$	2.875	2.5	41
3	82+77	Safety Edge$_{SM}$	2.25	2.5	48
3	83+02	Safety Edge$_{SM}$	2.5	3.0	50
3	83+27	Safety Edge$_{SM}$	2.5	2.75	48
4	67+82	Safety Edge$_{SM}$	3.75	2.0	28
4	68+07	Safety Edge$_{SM}$	3.75	2.75	36
4	68+32	Safety Edge$_{SM}$	3.25	2.0	32
4	68+57	Safety Edge$_{SM}$	3.5	2.25	33
4	68+82	Safety Edge$_{SM}$	3.0	2.0	34
4	69+07	Safety Edge$_{SM}$	3.5	2.0	30
4	69+32	Safety Edge$_{SM}$	3.0	2.0	34
4	69+57	Safety Edge$_{SM}$	3.0	2.0	34
4	69+82	Safety Edge$_{SM}$	2.75	1.875	34
4	71+32	Safety Edge$_{SM}$	3.375	2.125	32
4	71+57	Safety Edge$_{SM}$	3.25	2.0	32
4	71+82	Safety Edge$_{SM}$	3.0	1.75	30
4	72+07	Safety Edge$_{SM}$	2.0	1.5	37
4	72+32	Safety Edge$_{SM}$	3.25	1.875	30
4	72+57	Safety Edge$_{SM}$	3.375	1.875	29
4	72+82	Safety Edge$_{SM}$	3.25	2.25	35
4	73+07	Safety Edge$_{SM}$	3.5	2.25	33
4	73+32	Safety Edge$_{SM}$	3.375	2.125	32
		Mean Value	2.7	2.1	38
		Standard Deviation	0.6	0.5	6.8
		Coefficient of Variation,%	23.7	23.7	18.1

Table 2. Non-Safety Edge$_{SM}$ Measurements.

Section ID	Station	Type of Section	Safety Edge$_{SM}$		
			Width of Taper, in	Thickness of Taper, in	Slope, deg
5	256+92	Non-Safety Edge$_{SM}$			
5	256+67	Non-Safety Edge$_{SM}$			
5	256+42	Non-Safety Edge$_{SM}$			
5	256+17	Non-Safety Edge$_{SM}$			
5	255+92	Non-Safety Edge$_{SM}$			
5	255+67	Non-Safety Edge$_{SM}$			
5	255+42	Non-Safety Edge$_{SM}$	2.75	2.5	42
5	255+17	Non-Safety Edge$_{SM}$			
5	254+92	Non-Safety Edge$_{SM}$	2.0	2.625	53
5	254+67	Non-Safety Edge$_{SM}$			
5	254+42	Non-Safety Edge$_{SM}$	2.25	2.5	48
5	254+17	Non-Safety Edge$_{SM}$			
5	253+92	Non-Safety Edge$_{SM}$			
5	253+67	Non-Safety Edge$_{SM}$			
5	253+42	Non-Safety Edge$_{SM}$			
5	253+17	Non-Safety Edge$_{SM}$			
5	252+92	Non-Safety Edge$_{SM}$			
6	249+08	Non-Safety Edge$_{SM}$	1.25	1.75	54
6	249+33	Non-Safety Edge$_{SM}$	1.25	1.75	54
6	249+58	Non-Safety Edge$_{SM}$	1.25	1.75	54
6	249+83	Non-Safety Edge$_{SM}$	1.25	1.75	54
6	250+08	Non-Safety Edge$_{SM}$	1.25	1.625	52

Section ID	Station	Type of Section	Safety Edge$_{SM}$		
			Width of Taper, in	Thickness of Taper, in	Slope, deg
6	250+33	Non-Safety Edge$_{SM}$	1.25	1.75	54
6	250+58	Non-Safety Edge$_{SM}$	1.5	1.625	47
6	250+83	Non-Safety Edge$_{SM}$	1.5	1.875	51
6	251+08	Non-Safety Edge$_{SM}$	1.25	1.75	54
6	251+33	Non-Safety Edge$_{SM}$	1.25	1.75	54
6	251+58	Non-Safety Edge$_{SM}$	1.5	1.375	43
6	251+83	Non-Safety Edge$_{SM}$	1.5	1.75	49
6	252+08	Non-Safety Edge$_{SM}$	1.75	1.75	45
6	252+33	Non-Safety Edge$_{SM}$	1.75	1.75	45
6	252+58	Non-Safety Edge$_{SM}$			
6	252+83	Non-Safety Edge$_{SM}$	1.25	2.375	62
6	253+08	Non-Safety Edge$_{SM}$	1.25	2.375	62
		Mean Value	1.5	1.9	52
		Standard Deviation	0.4	0.4	5.7
		Coefficient of Variation, %	27.2	18.9	11.0

Table 3. Core Thickness Measurements.

Area/Location	Section #	Lane Dir.	Station	Type of Section	Core Thickness, in	
					A – Adjacent to Edge	B – 3 feet from Edge
Safety Edge $_{SM}$ test sections were between the villages of Sully and Lynnville.	1	WB	150+75	Safety Edge$_{SM}$	1.25	
	2	WB	116+15	Safety Edge$_{SM}$	1.875	
	3	WB	81+27	Safety Edge$_{SM}$	2.5	2.25
	4	WB	69+82	Safety Edge$_{SM}$	1.75	
Non-Safety Edge $_{SM}$ (control) test sections were located east of Lynnville.	5	EB	254+92	Non-Safety Edge$_{SM}$	2.0	2.06
	6	EB	251+08	Non-Safety Edge$_{SM}$	1.5	1.875
				Mean, in.	1.81	2.06
				Standard Deviation, in.	0.43	0.19
				Coefficient of Variation, %	23.79	9.09

Table 4. Nuclear Density Adjustment Factors; Core Density/Nuclear Density.

Area/Location	Section #	Lane Dir.	Station	Type of Section	Density of Cores		Nuclear Density Values		Adjustment Ratio	
					A – Adjacent to Edge	B – 3 feet from Edge	A – Adjacent to Edge	B – 3 feet from Edge	A – Adjacent to Edge	B – 3 feet from Edge
Safety Edge $_{SM}$ test sections were between the villages of Sully and Lynnville.	1	WB	150+75	Safety Edge$_{SM}$	134.6		136.10	142.70	0.989	
	2	WB	116+15	Safety Edge$_{SM}$	133.3		135.10	142.50	0.987	
	3	WB	81+27	Safety Edge$_{SM}$	135.7	142.5	137.30	140.90	0.988	1.011
	4	WB	69+82	Safety Edge$_{SM}$	132.6		140.80	151.60	0.942	
Non-Safety Edge $_{SM}$ (control) test sections were located east of Lynnville.	5	EB	254+92	Non-Safety Edge$_{SM}$	141.7		148.00	152.20	0.957	
	6	EB	251+08	Non-Safety Edge$_{SM}$	139.1	143.4	138.80	146.60	1.002	0.978
				Mean Value, pcf	136.2	143.0	139.4	146.1	0.978	0.995
				Standard Deviation, pcf	3.54	0.64	4.69	4.88	0.02	0.02
				Coefficient of Variation, %	2.60	0.45	3.37	3.34	2.34	2.36

Table 5. Safety Edge$_{SM}$ Nuclear Gage Readings.

Maximum Specific Gravity of Mix (Gmm):	2.471	Max. Density:	154.2
Adjustment Ratios for Nuclear Gauge: A=	0.978		
B=	0.995		

Core Location	Lane Direction	Station	Type of Section	Nuclear Densities A – Adjacent to Edge	Nuclear Densities B – 3 feet from Edge	Adjusted Nuclear Values A – Adjacent to Edge	Adjusted Nuclear Values B – 3 feet from Edge	HMA Thickness, in.	Air Voids, % A – Adjacent to Edge	Air Voids, % B – 3 feet from Edge
1	WB	148+75	Safety EdgeSM	132.2	145.6	129.29	144.87	1.8	16.15	6.04
1	WB	149+25	Safety EdgeSM	133.5	149.5	130.56	148.75	1.8	15.32	3.53
1	WB	149+75	Safety EdgeSM	123.5	149.3	120.78	148.55	1.7	21.67	3.66
1	WB	150+25	Safety EdgeSM	122.0	143.9	119.32	143.18	1.8	22.62	7.14
1	WB	150+75	Safety EdgeSM	136.1	142.7	133.11	141.99	1.4	13.67	7.91
1	WB	151+25	Safety EdgeSM	134.3	144.0	131.35	143.28	1.4	14.82	7.08
1	WB	151+75	Safety EdgeSM	133.2	144.7	130.27	143.98	1.7	15.51	6.62
1	WB	152+25	Safety EdgeSM	136.4	147.4	133.40	146.66	1.7	13.48	4.88
1	WB	152+75	Safety EdgeSM	135.0	142.0	132.03	141.29	1.6	14.37	8.37
2	WB	114+15	Safety EdgeSM	140.3	149.0	137.21	148.26	1.3	11.01	3.85
2	WB	114+65	Safety EdgeSM	131.8	141.7	128.90	140.99	1.6	16.40	8.56
2	WB	115+15	Safety EdgeSM	140.5	147.6	137.41	146.86	1.6	10.88	4.75
2	WB	116+15	Safety EdgeSM	135.1	142.5	132.13	141.79	1.8	14.31	8.04
2	WB	117+40	Safety EdgeSM	133.5	143.8	130.56	143.08	2.1	15.32	7.20
2	WB	117+90	Safety EdgeSM	133.3	143.7	130.37	142.98	2.3	15.45	7.27
2	WB	118+40	Safety EdgeSM	141.3	142.4	138.19	141.69	1.9	10.38	8.11
2	WB	118+90	Safety EdgeSM	140.2	145.0	137.12	144.28	1.9	11.07	6.43
3	WB	78+27	Safety EdgeSM	137.7	144.7	134.67	143.98	3.375	12.66	6.62
3	WB	78+77	Safety EdgeSM	138.0	143.9	134.96	143.18	2.5	12.47	7.14
3	WB	79+27	Safety EdgeSM	129.5	148.8	126.65	148.06	2.75	17.86	3.98
3	WB	79+77	Safety EdgeSM	134.9	143.0	131.93	142.29	2.75	14.44	7.72
3	WB	81+27	Safety EdgeSM	137.3	140.9	134.28	140.20	2.875	12.91	9.08
3	WB	81+77	Safety EdgeSM	136.8	144.9	133.79	144.18	2.875	13.23	6.50
3	WB	82+27	Safety EdgeSM	137.8	145.6	134.77	144.87	2.75	12.60	6.04
3	WB	82+77	Safety EdgeSM	138.8	145.9	135.75	145.17	2.5	11.96	5.85
3	WB	83+27	Safety EdgeSM	137.5	145.6	134.48	144.87	2.75	12.79	6.04
4	WB	67+82	Safety EdgeSM	129.3	152.9	126.46	152.14	2	17.99	1.33
4	WB	68+32	Safety EdgeSM	135.4	149.7	132.42	148.95	2	14.12	3.40
4	WB	68+82	Safety EdgeSM	143.2	145.0	140.05	144.28	2	9.17	6.43
4	WB	69+32	Safety EdgeSM	137.4	147.4	134.38	146.66	2	12.85	4.88
4	WB	69+82	Safety EdgeSM	140.8	151.6	137.70	150.84	1.875	10.69	2.17
4	WB	71+32	Safety EdgeSM	138.3	154.4	135.26	153.63	2.125	12.28	0.36
4	WB	71+82	Safety EdgeSM	144.5	152.5	141.32	151.74	1.75	8.35	1.59
4	WB	72+32	Safety EdgeSM	146.7	148.1	143.47	147.36	1.875	6.95	4.43
4	WB	72+82	Safety EdgeSM	138.4	153.4	135.36	152.63	2.25	12.22	1.01
4	WB	73+32	Safety EdgeSM	137.3	151.9	134.28	151.14	2.125	12.91	1.98
Average Value				136.2	146.5	133.2	145.8	2.1	13.6	5.4
Standard Deviation				5.04	3.67	4.93	3.65	0.49	3.19	2.37
Coefficient of Variation				3.70	2.50	3.70	2.50	23.70	23.43	43.50

Table 6. Non-Safety Edge$_{SM}$ Nuclear Gage Readings.

Core Location	Lane Direction	Station	Type of Section	Nuclear Densities		Adjusted Nuclear Values		HMA Thickness, in.	Air Voids, %	
				A – Adjacent to Edge	B – 3 feet from Edge	A – Adjacent to Edge	B – 3 feet from Edge		A – Adjacent to Edge	B – 3 feet from Edge
5	EB	256+92	Non-Safety Edge$_{SM}$	143.6	145.1	140.44	144.37		8.92	6.37
5	EB	256+42	Non-Safety Edge$_{SM}$	140.9	143.9	137.80	143.18		10.63	7.14
5	EB	255+92	Non-Safety Edge$_{SM}$	152.9	144.4	149.54	143.68		3.02	6.82
5	EB	255+42	Non-Safety Edge$_{SM}$	143.5	152.0	140.34	151.24	2.5	8.98	1.91
5	EB	254+92	Non-Safety Edge$_{SM}$	148.0	152.2	144.74	151.44	2.625	6.13	1.78
5	EB	254+42	Non-Safety Edge$_{SM}$	137.0	151.5	133.99	150.74	2.5	13.10	2.24
5	EB	253+92	Non-Safety Edge$_{SM}$	146.5	149.5	143.28	148.75		7.08	3.53
5	EB	253+42	Non-Safety Edge$_{SM}$	140.8	143.9	137.70	143.18		10.69	7.14
5	EB	252+92	Non-Safety Edge$_{SM}$	138.2	149.3	135.16	148.55		12.34	3.66
6	EB	249+08	Non-Safety Edge$_{SM}$	150.8	146.3	147.48	145.57	1.75	4.35	5.59
6	EB	249+58	Non-Safety Edge$_{SM}$	140.8	153.5	137.70	152.73	1.75	10.69	0.95
6	EB	250+08	Non-Safety Edge$_{SM}$	142.4	148.8	139.27	148.06	1.625	9.68	3.98
6	EB	250+58	Non-Safety Edge$_{SM}$	137.5	150.0	134.48	149.25	1.625	12.79	3.20
6	EB	251+08	Non-Safety Edge$_{SM}$	138.8	146.6	135.75	145.87	1.75	11.96	5.40
6	EB	251+58	Non-Safety Edge$_{SM}$	150.4	147.3	147.09	146.56	1.375	4.60	4.95
6	EB	252+08	Non-Safety Edge$_{SM}$	144.6	143.7	141.42	142.98	1.75	8.28	7.27
6	EB	252+58	Non-Safety Edge$_{SM}$	139.6	150.2	136.53	149.45		11.45	3.08
6	EB	252+08	Non-Safety Edge$_{SM}$	143.3	144.2	140.15	143.48	2.375	9.11	6.95
			Average Value	143.3	147.9	140.2	147.2	2.0	9.1	4.6
			Standard Deviation	4.76	3.28	4.66	3.26	0.44	3.02	2.12
			Coefficient of Variation	3.32	2.22	3.32	2.22	22.41	33.18	46.47