Federal Highway Administration
Every Day Counts
Innovation Initiative

Safety Edge$_{SM}$ Demonstration Project Little Divine Road in Johnston County, North Carolina

Draft Field Report
July 1, 2011

U.S.Department of Transportation
Federal Highway Administration

FOREWORD

The purpose of this field report is to provide a summary of observations made during the hot mix asphalt (HMA) Safety Edge$_{SM}$ project on Little Divine Road (State Route 1938). 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.

This report is a summary of the observations made on April 7, 2011 and measurements taken during construction to evaluate the use of the device developed by Carlson Paving Products, Inc. Observations and data were collected to evaluate the slope and density of the Safety Edge$_{SM}$, recommend design adjustments, and identify benefits and complications with the use of the edge 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 the Safety Edge$_{SM}$ on a two lane highway hot mix asphalt (HMA) overlay project on Little Divine Road in Johnston County, North Carolina. The Carlson end gate device 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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Safety Edge$_{SM}$, Slope, HMA, Carlson Paving Products, Inc.	No restriction.

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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$_{SM}$

- Overall, the Carlson device proved to be simple to operate and the contractor was able to produce a uniform and stable edge. The finished appearance of the Safety Edge$_{SM}$ was nearly as smooth and sealed as the rest of the mat.

Slope of the Safety Edge$_{SM}$

- The average slope of the edge was 29°.
- The slope decreased by 1° whereas typically the angle tends to increase slightly. The minor change in slope indicates good slope stability.

Edge preparation

- The contractor broomed the pavement and used a small tractor to clip the shoulders as is the contractor's typical practice for conventional overlays on this type of road. However, soil/vegetation build up was higher than the edge of the road at a few isolated locations and more clipping was needed. It is important to clip the edge of the pavement and shoulder farther than conventional overlay projects to make room for the Safety Edge$_{SM}$.

Construction/Compaction

- The contractor had not used any Safety Edge$_{SM}$ device prior to this project. The contractor noted that most of his pavers are equipped with 10-foot screeds which require the use of a cut off under the screed to reduce the paving width for narrow roads and he is unsure how to incorporate the edge device with the paver when using a cut off.
- Statistical analysis suggest the density of the Safety Edge$_{SM}$ test section is no different than the control test section either adjacent to the edge or 3 feet from the edge.

HMA Mixture

- The HMA mix behaved normally during paving operations, tearing or shoving was not observed.
- Lateral movement of the mat was minor under the passes of the rollers.

Future Considerations or Material Enhancements to Improve Performance

- It is important to clip the shoulders far enough back so soil/vegetation does not become mixed with the edge of the asphalt during paving. Clipping should be extended farther into the existing shoulder than with conventional overlays to allow extra width for the Safety Edge$_{SM}$.

This project presents the opportunity to evaluate long-term performance in terms of maintenance efforts and life cycle cost of the Safety Edge$_{SM}$.

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 overlay along Little Divine Road with and without the inclusion of the Safety Edge$_{SM}$. The objective of this field study was to evaluate the quality of the in-place HMA material and Safety Edge$_{SM}$ by investigating the following:

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

This project was located in Johnston County north of Smithfield on about 2 miles of Little Divine Road between State Route 96 and Buffalo Road. The contractor purchased the Safety Edge$_{SM}$ end gate type device after observing it at the recent ConExpo. This end gate did not have a heating element.

The general project location is shown in Figure 1. The maximum posted speed limit was 55 mph. The contractor was S.T. Wooten Corporation.

Figure 1. Project location.

Pavement Structure and Project Conditions

The existing roadway was two lanes of HMA with a chip seal wearing surface. The typical lane width was 10 feet with 6- to 12-inch-wide unpaved shoulders consisting of fine-grained soil and vegetation. The distresses along the road were varying degrees of block cracking.

The scope of the contract was to maintain the original lane width therefore the edge of the new overlay was placed directly over the existing pavement edge. New construction called for a 1.5-inch HMA RS 9.5B mix designed with 15 percent recycled asphalt pavement (RAP) and 5 percent recycled shingles.

This project included several long tangent sections, suitable for demonstrating the Safety $Edge_{SM}$ in both lane directions. The Safety $Edge_{SM}$ was not included in the contract but the contractor requested to build the Safety $Edge_{SM}$.

Field Evaluation Tests

One Safety $Edge_{SM}$ test section and one non-Safety $Edge_{SM}$ control section was established in the westbound lane. The following summarizes the pavement sections:

- Test Section #1. This section had the Safety $Edge_{SM}$ formed with the Carlson device and was 1,000-feet long beginning at the drive to the private residence address 1320 Little Divine Rd.
- Test Section #2. This section was paved with a conventional edge and was 200-feet long located about midway along the project limits and serves as the control section for comparing the test sections to conventional paving practice.

<u>Slope Measurements</u>

Slope measurements were recorded at 25-feet intervals using a straight-edge and ruler to measure the horizontal and vertical dimensions of the edge (see Figure 2). The Carlson device was set at a 25°angle and produced an average slope of 29° after compaction.

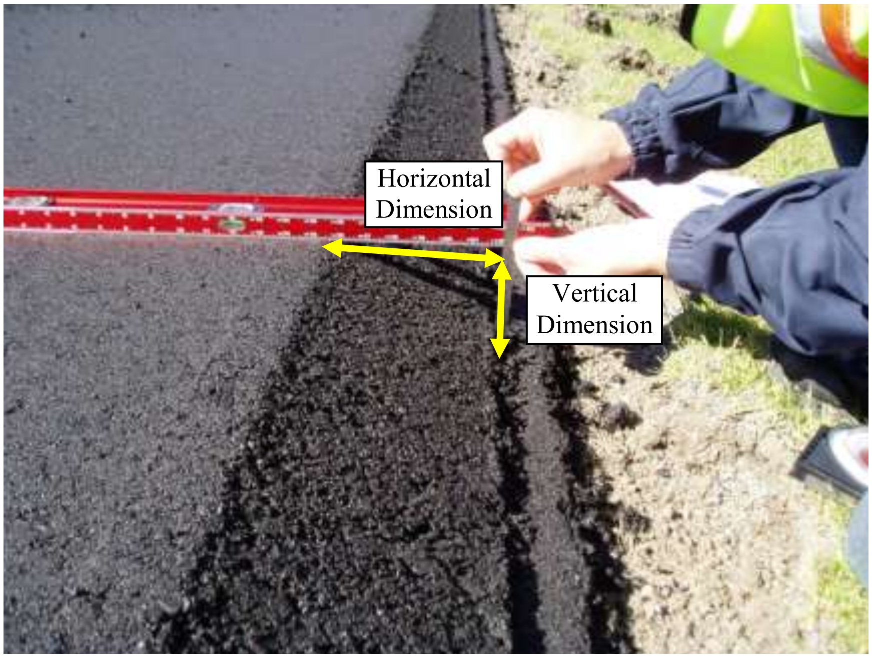

Figure 2. Slope measurement technique.

Table A-1 in Appendix A contains slope measurements recorded at each individual measurement location. Accurate edge thickness measurements were not possible due the slope of the Safety Edge$_{SM}$ extending over the edge of the existing pavement, thereby exaggerating and confounding the edge thickness measurements.

Cores

Several pairs of cores were cut from each test section. Each pair of cores had a core taken 3 feet from the edge of the mat (where the maximum number of roller passes were made) and a corresponding core taken adjacent to the edge (where fewer roller passes were made). Figure 3 shows the layout of a typical core set. Table A-2 in Appendix A lists the stations from where these cores were taken and the respective core thicknesses measured. Laboratory density was determined from the bulk specific gravity at saturated surface dry test condition, the results of which are presented in Table A-3 in Appendix A. Figure 4 compares the laboratory core density measurements for the test sections. The core densities from the Safety Edge$_{SM}$ section show more variability than the control section.

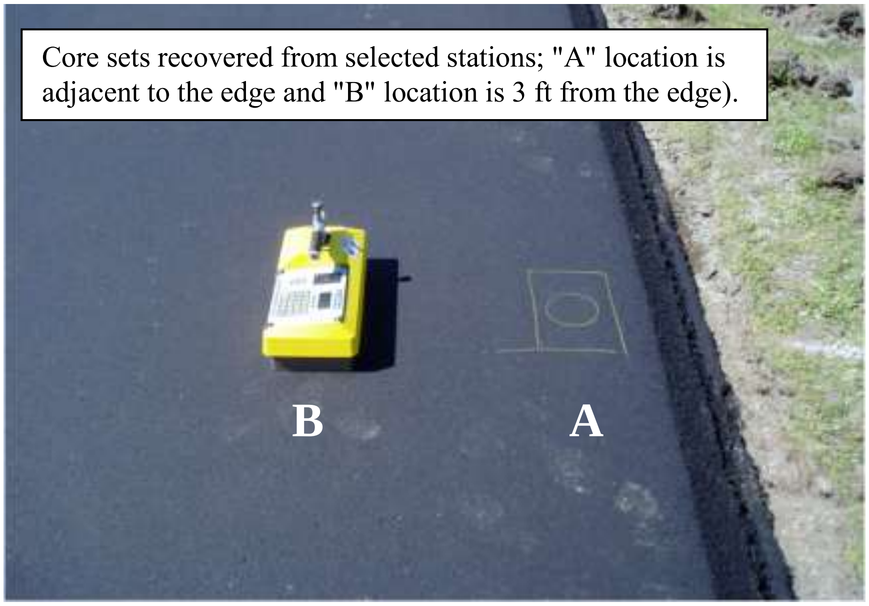

Figure 3. Photo shows the layout of cores and nuclear density tests (nuclear density tests were taken and then the overlay was cored).

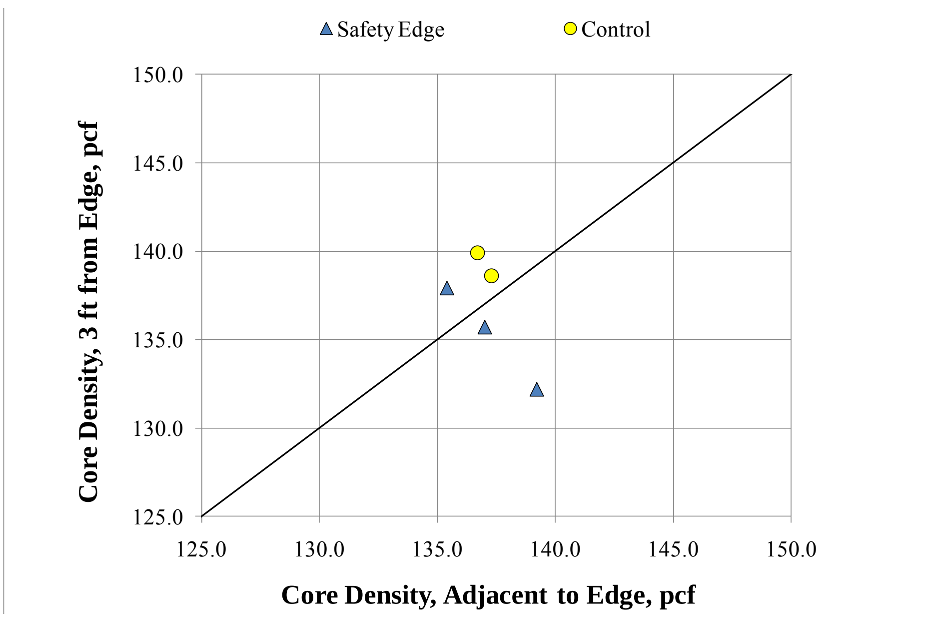

Figure 4. Comparison of core densities adjacent to the edge and 3 feet from the edge.

Nuclear Density Test Calibration Using Core Density

Before coring took place, nuclear density tests were conducted at each location on the pavement where the cores were to be cut for the purpose of calibrating the density readings of the nuclear gauge to the laboratory-determined densities from the cores. Table A-3 and Table A-4 in Appendix A present the results of the nuclear density testing and the laboratory-determined core density results. Figure 5 compares the nuclear density readings to the densities measured from the cores.

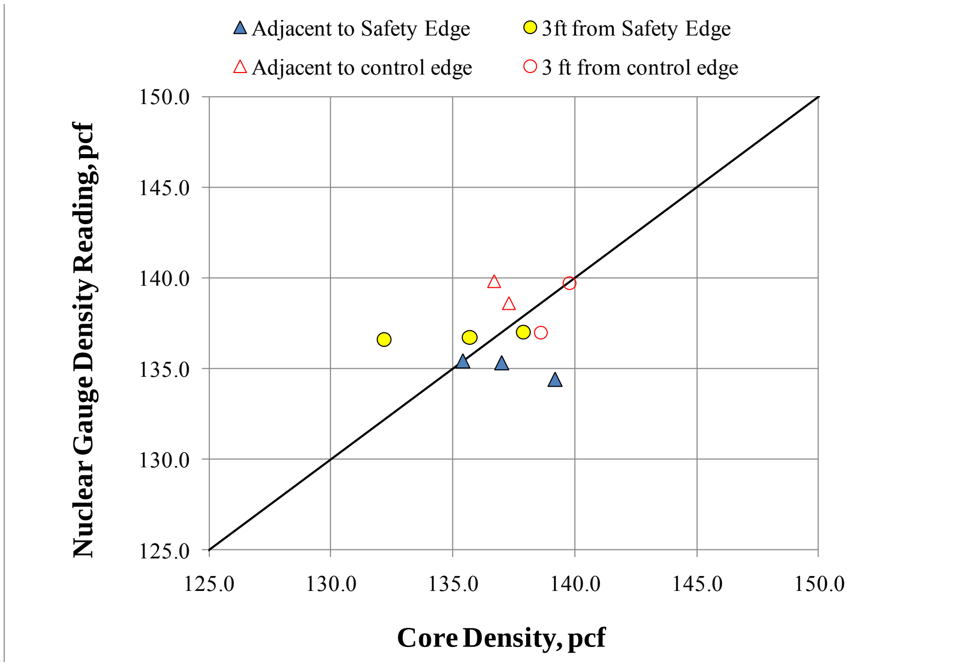

Figure 5. Comparison of the nuclear densities and core densities.

Adjustment factors used to calibrate the nuclear gauge density values were determined from correlating the nuclear density readings and the densities from the laboratory results. The two test sections had unique adjustment factors and are summarized as follows:

	Adjustment Factor	
Location	**Safety Edge$_{SM}$**	**Control**
Adjacent to the edge	1.016	0.984
3 feet from the edge	0.989	1.007

Nuclear Density Test Results

Nuclear density tests were conducted to evaluate the test sections. During testing, the nuclear density gauge was set in backscatter mode for 60-second test durations. Tests were conducted at 50-feet intervals adjacent to the edge and 3 feet from the edge. The adjusted densities using the adjustment factors are included in Tables A-5 and A-6 in Appendix A.

Statistical analyses of the data using the t-test and Welch t-test (for unequal variances) at a significance level of 95 percent were used to test the hypothesis that the density of the Safety Edge$_{SM}$ test section does not differ from that of the control test section, both adjacent to the edge and 3 feet from the edge, and similarly, the hypothesis that the densities do not differ between the test sections.

Table 1 and Table 2 present the t-test results of the density values adjacent to the edge and 3 feet from the edge within the individual Safety Edge$_{SM}$ and control test sections. Table 3 and

Table 4 present the results of comparing the density values between the Safety Edge$_{SM}$ and control sections adjacent to the edge and 3 feet from the edge by using the Welch t-test.

In all four comparisons the difference in the averages is contained within a 95 percent confidence interval that encompasses zero. This indicates that these data do not show any statistically significant differences in the averages between the test sections nor within the test sections. In other words, the results suggest the density of the Safety Edge$_{SM}$ test section is no different than the control test section either near the edge or away from the edge.

Table 1. T-test of the test data adjacent to the edge and 3 feet from the edge in the Safety Edge$_{SM}$ test section.

	Adjacent to the Edge	**3 feet from the Edge**
Mean	135.6 lbf/ft^3	135.4 lbf/ft^3
Std Dev	2.45	2.48
Test Results		
P-value		0.74
t-value		0.33
Difference in the means		0.25
95 percent confidence interval of the		-1.28 to 1.79

Table 2. T-test of the test data adjacent to the edge and 3 feet from the edge in the control test section.

	Adjacent to the Edge	**3 feet from the Edge**
Mean	135.9 lbf/ft^3	139.7 lbf/ft^3
Std Dev	5.67	3.87
Test Results		
P-value		0.25
t-value		1.25
Difference in the means		-3.83
95 percent confidence interval of the		-11.09 to 3.43

Table 3. Welch t-test of the test data adjacent to the edge in the Safety Edge$_{SM}$ and control test section.

	Safety Edge$_{SM}$	**Control**
Mean	135.6 lbf/ft^3	135.9 lbf/ft^3
Std Dev	2.44	5.67
Test Results		
P-value		0.94
t-value		0.09
Difference in the means		-0.22
95 percent confidence interval of the		-7.41 to 6.97

Table 4. Welch t-test of the test data 3 feet from the edge in the Safety Edge$_{SM}$ and control test section.

	Safety Edge$_{SM}$	**Control**
Mean	135.4 lbf/ft^3	139.7 lbf/ft^3
Std Dev	2.48	3.87
Test Results		
P-value		0.08
t-value		2.37
Difference in the means		-4.30
95 percent confidence interval of the		-9.34 to 0.73

Figure 6 compares the density values taken adjacent to the edge and 3 feet from the edge. Generally, the Safety Edge$_{SM}$ section shows no distinct trend in the relationship between data adjacent to the edge and 3 feet from the edge whereas, the values for the control section tend to be higher 3 feet from the edge.

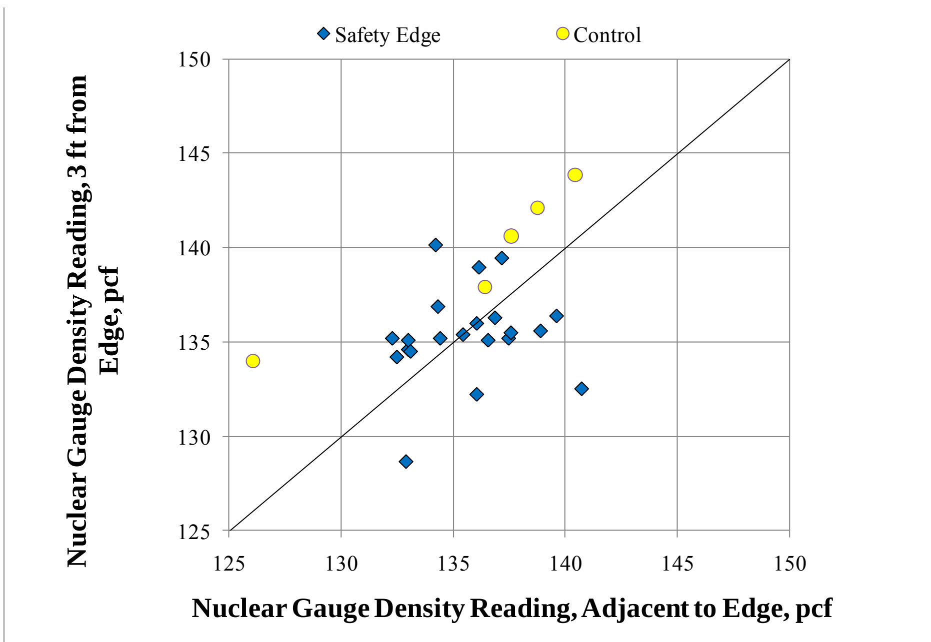

Figure 6. Comparison of the nuclear densities adjacent to the edge and 3 feet from the edge.

Figure 7 compares the percent air voids (as calculated from the density test results and the maximum theoretical mix density). The percent air voids shows no clear trend for the Safety Edge$_{SM}$ section whereas, the values for the control section were higher adjacent to the edge.

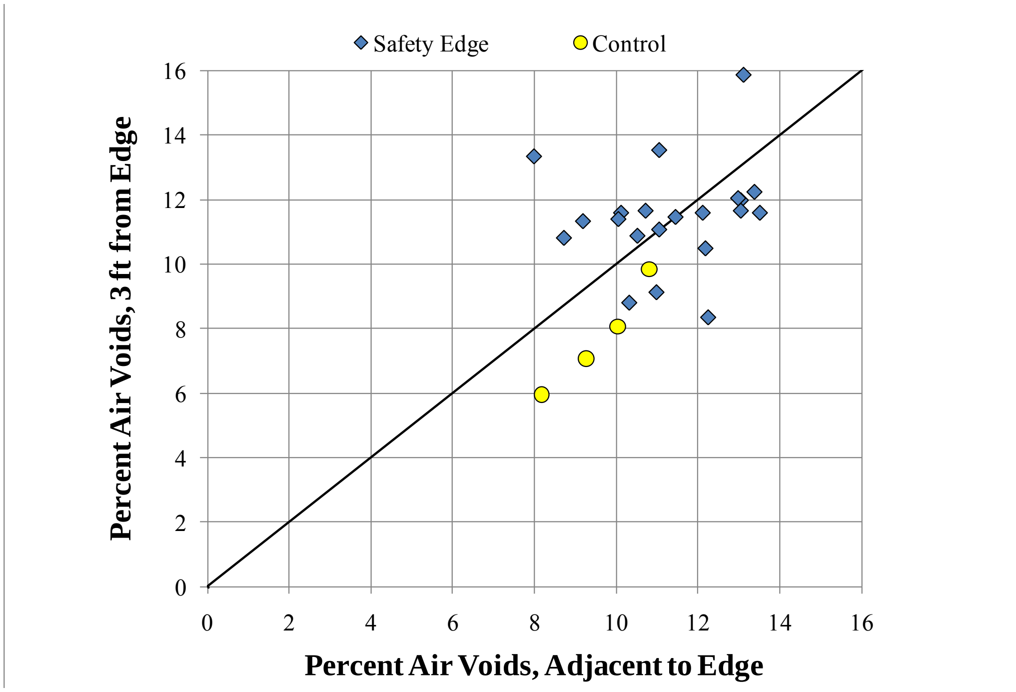

Figure 7. Comparison of the air voids adjacent to the edge and 3 feet from the edge.

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

This section provides an overview of the observations made during the paving and rolling operations.

Preparatory Work

Isolated HMA patching and continuous brooming was conducted prior to paving. In limited locations the contractor used a small tractor equipped with a blade to clip soil/vegetation from the edge of the road, exposing the existing edge of pavement. Figure 8 shows some of the vegetation removed by the preparatory work. There were a few isolated areas where the soil/vegetation was slightly higher than the existing pavement and should have been clipped back farther to make room for the Safety Edge$_{SM}$. It is important to clip the shoulders far enough back so the soil/vegetation does not become mix with the asphalt during paving.

Figure 8. Vegetation removed by clipping the edge of the existing pavement.

Placement/Paving Operations

The Carlson device proved to be simple to operate and the contractor was able to produce a uniform and stable edge. The HMA showed no signs of tearing or shoving. During the first pass of the breakdown roller minor lateral movement of the mix was observed and the mix movement under the subsequent roller passes was minimal. Some lateral movement of the HMA at the edge should be anticipated by the contractor and adjustments by the screed operator should be made accordingly.

The HMA mat was placed 1.75 inches thick as it left the screed and compacted to 1.5 inches. The contractor used a rubber tire Caterpillar 730 paver. The weather in the morning was calm, sunny, 50°F and rising.

The Carlson device created a 0.25-inch vertical lip at the breakpoint of the edge as shown in Figure 9. The lip was compacted flat by the rolling operation. The texture of the finished slope face of the Safety Edge$_{SM}$ edge as shown in Figure 10 was nearly as smooth and sealed as the rest of the mat.

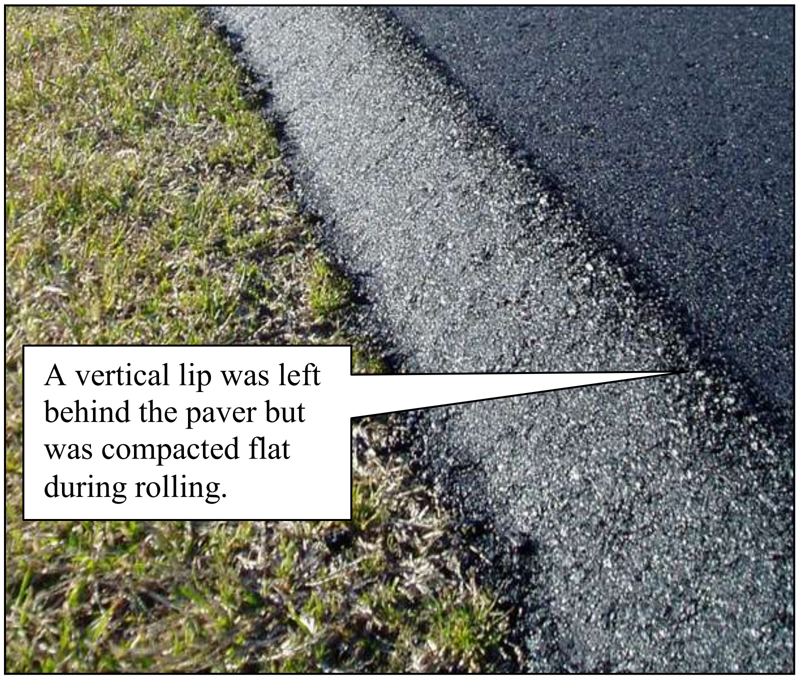

Figure 9. Vertical lip produced by the Carlson paver.

Figure 10. Texture of the Safety Edge$_{SM}$ slope face was nearly as smooth and sealed as the rest of the mat.

The Carlson device was set at a horizontal angle to the mat as shown in Figure 11 to add confining pressure to the edge as the paver moved forward. Figure 12 shows the Safety Edge$_{SM}$ directly behind the Carlson device.

Figure 11. Angled approach of the Carlson device.

Figure 12. Safety Edge$_{SM}$ directly behind the Carlson device.

The following measurements were taken at a single location to document the minor amount of slope change during compaction operations. In this case the angle of the slope decreased by 1° whereas typically the angle tends to increase slightly. Measurements were taken directly behind the paver (discounting the affect of the vertical lip on the measurement process) and after two passes of the breakdown roller overhanging the edge. Note that the breakdown roller made more passes but was located away from the edge as described in the next section.

Roller Pass	Slope
slope measured directly behind the paver	25°
1st pass, 2 inches overhanging the edge with vibration	24°
2nd pass, 3 inches overhanging the edge with vibration	24°

The contractor had no experience with any Safety Edge$_{SM}$ device prior to this project. After a couple hours of production with the Carson device the contractor expressed the following concern:

> The majority of contractor's paver fleet has 10-foot screed width. On roads with narrower than 20 feet the Safety Edge$_{SM}$ may be an issue. The contractor can pave the entire width of pavement with one pull if traffic control is allowed to shut down the road and screed extensions are used (this scenario is not expected to apply to many roads). When paving roads less than 20 feet the contractor uses a cut off under the screed to reduce the paving width. Contractor was unsure how to incorporate a Safety Edge$_{SM}$ device with the paver when using a cut off.

Compaction Operations

A dual drum Volvo DD138 HFA steel wheel roller was used as the breakdown roller with the vibration set on 3 (on a 1 to 8 scale). There was no pneumatic intermediate roller. The finish roller was a dual drum Volvo DD118 HF steel wheel roller. Different sequencing of the rolling patterns were observed in the Safety Edge$_{SM}$ section and the control section but the resulting number of coverages at the outside edge were the same.

The rolling pattern in the Safety Edge$_{SM}$ section was:

Breakdown roller:
1st pass was on the longitudinal centerline joint in vibratory mode
2nd pass was on the longitudinal centerline joint in vibratory mode.
3rd pass was 2 inches overhanging the outside edge in vibratory mode.
4th pass was 3 inches overhanging the outside edge in vibratory mode.
5th pass was on the longitudinal centerline joint in vibratory mode.

Finish roller:
1st pass was on the longitudinal centerline joint in vibratory mode.
2nd pass was on the longitudinal centerline joint in static mode.
3rd pass was directly over the outside edge in vibratory mode.

Thus the Safety Edge$_{SM}$ section outside edge received 2 vibratory coverages from the breakdown roller and 1 vibratory coverage from the finish roller. The roller sequence covered the longitudinal joint first then the outside edge.

The rolling pattern in the *control section* was:

Breakdown roller:
1st pass was 1 inch overhanging the outside edge in vibratory mode.
2nd pass was 1 inch overhanging the outside edge in vibratory mode.
3rd pass was on the longitudinal centerline joint in vibratory mode.

Finish roller:
1st pass was on the longitudinal centerline joint in vibratory mode.
2nd pass was on the longitudinal centerline joint in vibratory mode.
3rd pass was 3 inches away from the outside edge in vibratory.
4th pass was directly over the outside edge in static mode.
5th pass was on the longitudinal centerline joint in static mode.

So the outside edge of the control section received 2 vibratory coverages from the breakdown roller sooner in the pattern than the Safety Edge$_{SM}$ section. The pattern of the finish roller on the outside edge was essentially the same for both sections.

Shoulder Backing

Topsoil was to be placed as the shoulder backing material. Placement of the backing material was not observed.

Findings and Conclusions

As previously stated, the objective of this field study is to evaluate the quality of the in-place HMA material and Safety Edge$_{SM}$ by investigating three features:

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

The following findings and conclusions can be made based on the observations made during the paving/compaction operations:

- Some lateral movement of the HMA at the edge should be anticipated. Adjustments by the screed operator should be made accordingly to ensure the proper slope of the finished Safety Edge$_{SM}$.
- The slope of the Safety Edge$_{SM}$ decreased by 1° during rolling operations whereas typically the angle tends to increase slightly. The minor change in slope indicates good slope stability.

The Safety Edge$_{SM}$ should be inspected after the shoulder material has been placed to the final pavement elevation. Monitoring of this site would be beneficial in evaluating the long-term performance of the Safety Edge$_{SM.}$

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. Note that the stationing shown in the tables refer to the length of each section and not the project stationing.

Table A-1. Slope Measurements.

Section	Station	Type of Device	Edge Measurement		
			Width of Taper, in	Thickness of Taper, in	Slope, deg
1	00+00	Carlson	3.25	1.25	21
1	00+25	Carlson	3.625	1.5	22
1	00+50	Carlson	3.375	1.5	24
1	00+75	Carlson	3.375	1.5	24
1	01+00	Carlson	2.75	1.5	29
1	01+25	Carlson	3.375	1.75	27
1	01+50	Carlson	2.75	1.5	29
1	01+75	Carlson	2.5	1.375	29
1	02+00	Carlson	3.25	1.375	23
1	02+25	Carlson	2.75	1.5	29
1	02+50	Carlson	2.375	2	40
1	02+75	Carlson	2.5	1.625	33
1	03+00	Carlson	2.625	1.75	34
1	03+25	Carlson	2.5	1.75	35
1	03+50	Carlson	2.5	1.75	35
1	03+75	Carlson	2.7	1.375	27
1	04+00	Carlson	2.25	1.438	33
1	04+25	Carlson	3.5	1.4375	22
1	04+50	Carlson	3.5	1.4375	22
1	04+75	Carlson	3.5	1.75	27
1	05+00	Carlson	4	1.875	25
1	05+25	Carlson	3.75	1.75	25
1	05+50	Carlson	3.75	1.875	27
1	05+75	Carlson	3.5	2	30
1	06+00	Carlson	3.25	1.75	28
1	06+25	Carlson	2.75	1.375	27
1	06+50	Carlson	2.75	1.625	31
1	06+75	Carlson	3.5	1.625	25
1	07+00	Carlson	3	1.75	30
1	07+25	Carlson	2.5	1.625	33
1	07+50	Carlson	2.5	1.375	29
1	07+75	Carlson	2.5	1.375	29
1	08+00	Carlson	2.625	1.375	28
1	08+25	Carlson	3.125	1.75	29
1	08+50	Carlson	3.25	1.625	27
1	08+75	Carlson	2.5	1.375	29
1	09+00	Carlson	2.25	1.5	34
1	09+25	Carlson	2.25	1.375	31
1	09+50	Carlson	2.25	1.5	34
1	09+75	Carlson	2.125	1.25	30
1	10+00	Carlson	2.25	1.25	29
Mean Value			2.9	1.6	29
Standard Deviation			0.5	0.2	4.1
Coefficient of Variation, %			17.8	12.8	14.4

Table A-2. Core Thickness Measurements.

Section	Lane Direction	Station	Type of Section	Core Thickness, in: A – Adjacent to Edge	Core Thickness, in: B – 3 feet from Edge
1	WB	2+00	Safety Edge	1.50	1.75
1	WB	5+00	Safety Edge	1.75	1.75
1	WB	8+00	Safety Edge	1.88	2.13
2	WB	1+00	Control	1.50	1.50
2	WB	2+00	Control	1.50	1.38
			Mean, in.	1.63	1.70
			Standard Deviation, in.	0.18	0.29
			Coefficient of Variation, %	10.88	16.93

Table A-3. Nuclear Density Adjustment Ratios; Core Density/Nuclear Density for the Safety Edge$_{SM}$ Section.

Section	Lane Direction	Station	Type of Device	Density of Cores		Nuclear Density Values		Adjustment Ratio	
				A – Adjacent to Edge	B – 3-ft from Edge	A – Adjacent to Edge	B – 3-ft from Edge	A – Adjacent to Edge	B – 3-ft from Edge
1	WB	2+00	Safety Edge	137.0	135.7	135.3	136.7	1.013	0.993
1	WB	5+00	Safety Edge	139.2	132.2	134.4	136.6	1.036	0.968
1	WB	8+00	Safety Edge	135.4	137.9	135.4	137.0	1.000	1.007
			Mean Value, pcf	137.2	135.3	135.0	136.8	1.016	0.989
			Standard Deviation, pcf	1.9	2.9	0.6	0.2	0.018	0.020
			Coefficient of Variation, %	1.4	2.1	0.4	0.2	1.783	1.987

Table A-4. Nuclear Density Adjustment Ratios; Core Density/Nuclear Density for the Control Section.

Section	Lane Direction	Station	Type of Device	Density of Cores		Nuclear Density Values		Adjustment Ratio	
				A – Adjacent to Edge	B – 3-ft from Edge	A – Adjacent to Edge	B – 3-ft from Edge	A – Adjacent to Edge	B – 3-ft from Edge
2	WB	1+00	Control	137.3	138.6	138.6	137.0	0.991	1.012
2	WB	2+00	Control	136.7	139.9	139.8	139.7	0.978	1.001
			Mean Value, pcf	137.0	139.3	139.2	138.4	0.984	1.007
			Standard Deviation, pcf	0.4	0.9	0.8	1.9	0.009	0.007
			Coefficient of Variation, %	0.3	0.7	0.6	1.4	0.919	0.720

Table A-5. Nuclear Gauge Readings for the Safety Edge$_{SM}$ Section.

Maximum Specific Gravity of Mix (Gmm):		2.451	Max. Density, pcf:	152.9
Adjustment Ratios for Nuclear Gauge:	A=	1.016		
	B=	0.989		

Section	Lane Direction	Station	Type of Section	Nuclear Densities, pcf		Adjusted Nuclear Densities, pcf		Core Thickness Adjacent to Edge, in.	Air Voids, %	
				A – Adjacent to Edge	B – 3-ft from Edge	A – Adjacent to Edge	B – 3-ft from Edge		A – Adjacent to Edge	B – 3 ft from Edge
1	WB	00+00	Safety Edge	130.9	136.1	133.01	134.60		13.0	12.0
1	WB	00+50	Safety Edge	133.3	136.9	135.45	135.40		11.4	11.5
1	WB	01+00	Safety Edge	130.4	135.7	132.50	134.21		13.4	12.2
1	WB	01+50	Safety Edge	132.3	136.7	134.43	135.20		12.1	11.6
1	WB	02+00	Safety Edge	135.3	136.7	137.48	135.20	1.75	10.1	11.6
1	WB	02+50	Safety Edge	132.1	141.7	134.23	140.14		12.2	8.4
1	WB	03+00	Safety Edge	134.0	140.5	136.16	138.96		11.0	9.1
1	WB	03+50	Safety Edge	130.9	136.6	133.01	135.10		13.0	11.7
1	WB	04+00	Safety Edge	130.8	130.1	132.90	128.67		13.1	15.9
1	WB	04+50	Safety Edge	130.2	136.7	132.30	135.20		13.5	11.6
1	WB	05+00	Safety Edge	134.4	136.6	136.56	135.10	1.75	10.7	11.7
1	WB	05+50	Safety Edge	133.9	137.5	136.05	135.99		11.0	11.1
1	WB	06+00	Safety Edge	134.7	137.8	136.87	136.29		10.5	10.9
1	WB	06+50	Safety Edge	138.5	134.0	140.73	132.53		8.0	13.3
1	WB	07+00	Safety Edge	135.0	141.0	137.17	139.45		10.3	8.8
1	WB	07+50	Safety Edge	136.7	137.1	138.90	135.59		9.2	11.3
1	WB	08+00	Safety Edge	135.4	137.0	137.58	135.49	2.125	10.0	11.4
1	WB	08+50	Safety Edge	133.9	133.7	136.05	132.23		11.0	13.5
1	WB	09+00	Safety Edge	132.2	138.4	134.33	136.88		12.2	10.5
1	WB	09+50	Safety Edge	137.4	137.9	139.61	136.39		8.7	10.8
1	WB	10+00	Safety Edge	131.0	136.0	133.11	134.51		13.0	12.1
Average Value, pcf				133.5	136.9	135.6	135.4	1.9	11.3	11.5
Standard Deviation, pcf				2.4	2.5	2.4	2.5	0.2	1.6	1.6
Coefficient of Variation, %				1.8	1.8	1.8	1.8	11.5	14.1	14.1

Table A-6. Nuclear Gauge Readings for the Control Section.

Maximum Specific Gravity of Mix (Gmm):		2.451	Max. Density,	152.9
Adjustment Ratios for Nuclear Gauge:	A=	0.984		
	B=	1.007		

Section	Lane Direction	Station	Type of Section	Nuclear Densities, pcf		Adjusted Nuclear Densities, pcf		Core Thickness Adjacent to Edge, in.	Air Voids, %	
				A – Adjacent to Edge	B – 3-ft from Edge	A – Adjacent to Edge	B – 3-ft from Edge		A – Adjacent to Edge	B – 3 ft from Edge
2	WB	0+00	Control	142.7	142.9	140.45	143.84		8.2	6.0
2	WB	0+50	Control	141.0	141.2	138.78	142.13		9.3	7.1
2	WB	1+00	Control	138.6	137.0	136.41	137.90	1.5	10.8	9.8
2	WB	1+50	Control	128.1	133.1	126.08	133.97		17.6	12.4
2	WB	2+00	Control	139.8	139.7	137.59	140.62	1.375	10.0	8.1
Average Value, pcf				138.0	138.8	135.9	139.7	1.4	11.2	8.7
Standard Deviation, pcf				5.8	3.8	5.7	3.9	0.0	3.7	2.5
Coefficient of Variation, %				4.2	2.8	4.2	2.8	0.0	33.2	29.2