Federal Highway Administration
Every Day Counts
Innovation Initiative

Safety Edge$_{SM}$ Demonstration Project Menominee County, Wisconsin

Field Report
May 4, 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 located in Menominee County Wisconsin. 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 made on September 15, 2010 and field data measured during construction to evaluate the use of three edge devices, 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$_{SM}$ devices.

1. Report No.	2. Government Accession No	3. Recipient's Catalog No

3. Title and Subtitle

Safety Edge$_{SM}$ Project, Seaford, Delaware

5. Report Date
May 4. 2011

6. Performing Organization Code

7. Authors
Paul Littleton and Jagannath Mallela

8. Performing Organization Report No.

9. Performing Organization Name and Address
Applied Research Associates, Inc.
100 Trade Centre Drive, Suite 200
Champaign, IL 61820

10. Work Unit No.

11. Contract or Grant No.

12. Sponsoring Agency Name and Address
Office of Infrastructure
Federal Highway Administration
1200 New Jersey Avenue, SE
Washington, DC 20590

13. Type of Report and Period Covered
Field Report
September 2010–May 2011

14. Sponsoring Agency Code

15. Supplementary Notes
Contracting Officer's Technical Representative: Byron Lord and Mary Huie
Contracting Officer's Technical Manager: Andy Mergenmeier

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 in Menominee County, Wisconsin. Safety Edge$_{SM}$ paving devices from two manufacturers were demonstrated during this project. Details regarding the performance of each 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.

17. Key Words
Safety Edge$_{SM}$, Slope, HMA, TransTech Shoulder Wedge Maker

18. Distribution Statement
No restriction.

19. Security Classif.(of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	25	

Form DOT F 1700.7 (8-72)

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)

Table of Contents

SUMMARY OF OBSERVATIONS

This section of the field report provides a summary and listing of important observations made during the paving operations, interview 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$_{SM}$ and non- Safety Edge$_{SM}$ portions of this project.

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

- The TransTech Shoulder Wedge Maker and two Carlson devices (Prototype #2 and Prototype #3) were demonstrated on this project. The Carlson prototype #1 was not part of this project. Only the TransTech and Carlson prototype #2 devices were observed during paving. The Carlson prototype #3 was implemented on this project after the site visit. All three devices had varying degrees of success. The TransTech device was bolted to the screed while the Carlson devices were part of the end gate. The Carlson devices were mounted to the lower edge of the end gate and utilized the length of the end gate to apply compaction to the slope face of the Safety Edge$_{SM}$. This approach provided adequate elevation control of the Safety Edge$_{SM}$ and had the benefit of sealing the slope face and producing a smooth appearance which may extend the life of the edge by slowing water infiltration at the edge. None of the devices had a negative impact on the paving operations nevertheless, the following bulleted items call attention to remaining issues.

Slope of the Safety Edge$_{SM}$

- The average slope of the Safety Edge$_{SM}$ was 35°, 33°, and 36° for the TransTech, Carlson Prototype #2 and Prototype #3 respectively. The shape of the slopes were relatively consistent in the observed test sections but in all cases the slopes were higher than the targeted 30°.

Placement

- The Carlson's end gate devices proved to be the least intrusive on the paving crew in that the screed operator's typical end adjustments automatically controlled the edge.
- The TransTech device, on the other hand, required periodic vertical adjustment made from the screed operator by hand in addition to the operators typical adjustments.

Compaction

- The HMA mix density was slightly higher and the air voids slightly lower adjacent to the edge of the mat for the non- Safety Edge$_{SM}$ section in comparison to the Safety Edge$_{SM}$ sections. This result is contrary to other projects where the Safety Edge$_{SM}$ sections had slightly higher in-place density or similar density when compared to the non- Safety Edge$_{SM}$ section. The reasons for this result are not known as the roller patterns employed on this project were the same on the Safety Edge$_{SM}$ and non- Safety Edge$_{SM}$ sections.

Shoulder Construction

- The aggregate shoulder width on this project varied from 1 to 4 ft and plans called for an additional 1.5 inches of new granular material to be placed on the shoulder to level the grade flush with the pavement surface. New granular shoulder material was not placed during the site visit so direct observations could not be made.
- No problems were observed or expected regarding the shoulder and the Safety Edge$_{SM}$ as the new HMA overlay, including the Safety Edge$_{SM}$, was placed over the existing HMA pavement.

HMA Mixture and Safety Edge$_{SM}$

- Segregation was not observed on this project, either at the longitudinal joint or at the edge.
- In the areas inspected, the Safety Edge$_{SM}$ covered the edge of the existing pavement preventing a true measurement of the mat thickness at the Safety Edge$_{SM}$.

This project presents the opportunity to evaluate the long term performance in terms of maintenance efforts and life cycle costs of the Safety Edge$_{SM}$ placed by different types of devices.

FIELD 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 route STH 55 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 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 project was located in Menominee County on STH 55 from the intersection with STH 47 near Keshena and extending north 18.5 mi (project stationing 100+50 to 1080+70). The location of the project is shown in Figure 1. The maximum posted speed limit was 55 mph. The contractor was Northeast Asphalt (NEA).

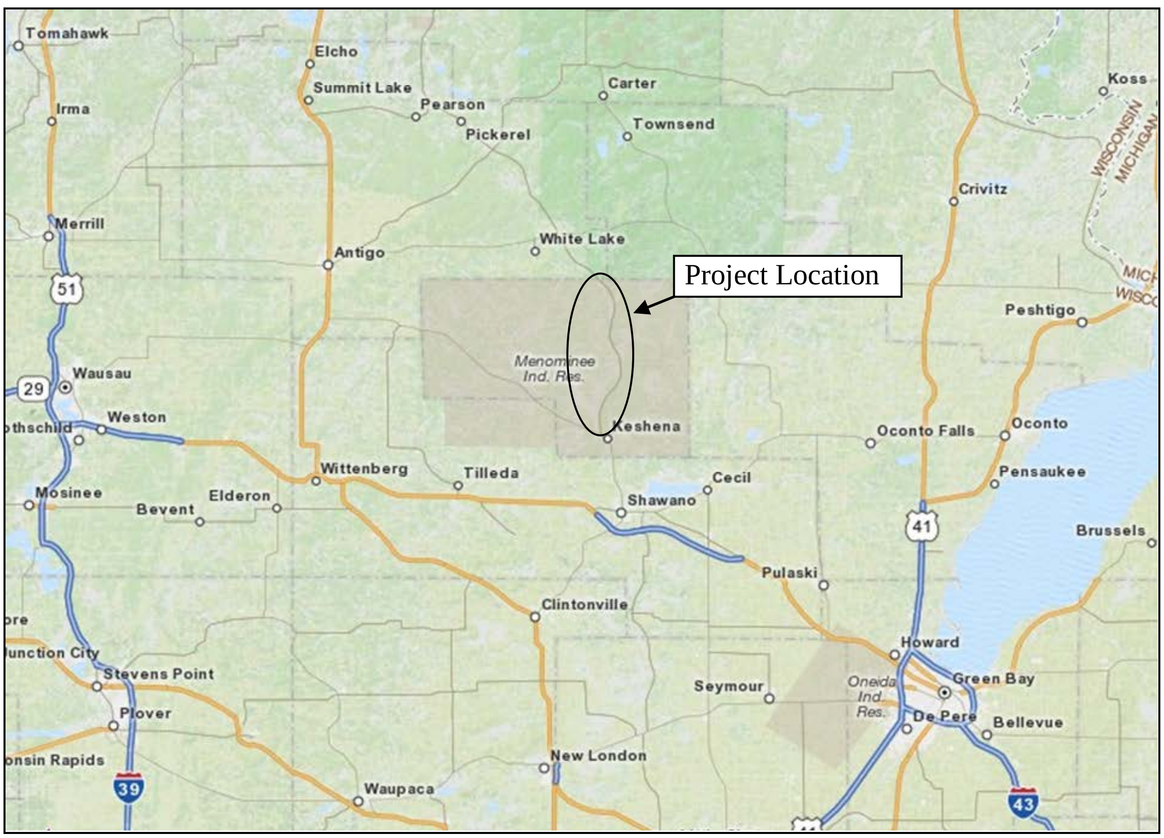

Figure 1. Project location.

Pavement Structure and Project Conditions

The existing pavement was two lanes of 4-inch HMA over a crushed aggregate base. The lane width was 11 ft for the existing roadway and was planned to be 11-ft wide after construction except in a few isolated areas the pavement was planned to be widened to 12-ft lanes. The aggregate shoulder varied from 1 to 4-ft wide for both the existing and new pavement. New construction consisted of milling the existing pavement 0.5 inches deep and placing a 2-inch HMA overlay. The asphalt mix design was a 12.5 mm Superpave Nd 40 design and included RAP and recycled asphalt shingles. WisDOT has experience with using recycled asphalt shingles. Plans for the shoulder specified a 0.75-inch nominal size dense graded aggregate placed 1.5 inches thick, the contractor planned to use clean pit run crushed gravel. A schematic of pavement cross sections is shown in Figure 2.

This overlay project included several long tangent sections and well shaped shoulders, suitable for demonstrating the Safety Edge$_{SM}$ which was built on both the northbound and southbound lanes for the length of the project. The slope was designed to be 30°. Details or drawings for the construction of the Safety Edge$_{SM}$ were not included in the plans. The Safety Edge$_{SM}$ specification was included in the contract via addendum.

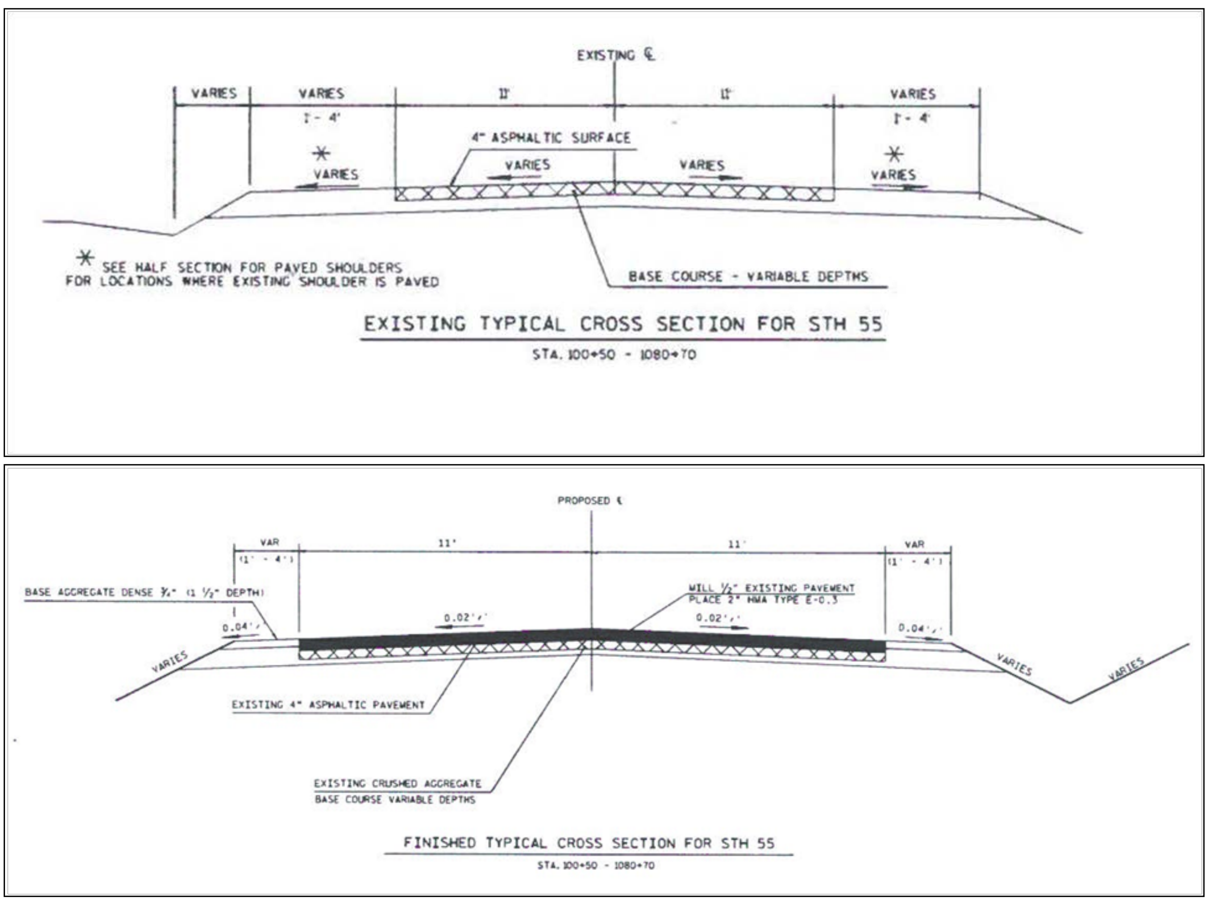

Figure 2. Pavement cross sections.

The northbound lane and about a quarter of the southbound lane had been paved with the TransTech device prior to the site visit. Rain delays during the site visit limited field observations to only a few hours during which time the contractor utilized the TransTech and the Carlson Prototype #2 devices. The Carlson Prototype #3 device was used several days later.

Field Evaluation

Three Safety Edge$_{SM}$ test sections and one non- Safety Edge$_{SM}$ control section were established in the southbound lane approximately 11.5 mi north of Spirit Rock. Spirit Rock is a well known cultural landmark on STH 55. The following summarizes the pavement sections:

- Test Section #1. This section was paved with the TransTech device and was 1,000-ft long from Sta 823+12 to Sta 813+12.
- Test Section #2. This section was paved with the Carlson Prototype #2 device and was 600-ft long from Sta 809+00 to Sta 803+00 at 50 ft south of the highway turn out.
- Test Section #3. This section was paved with the Carlson Prototype #3 device and was 1,000-ft long from Sta 381+00 to 371+00.
- Control section. This section was paved with standard screed and end gate and had no Safety Edge$_{SM}$. The section was 1,000-ft long from Sta 800+00 to Sta 790+00.

Slope Measurements

Slope measurements were recorded on test section #1, #2, and #3 at 25-ft intervals using a straight-edge and ruler to measure the horizontal and vertical dimensions of the Safety Edge$_{SM}$ as shown in Figure 3. Slope measurements are listed in Table 1 (all tables are located at the end of this report). The following summaries the average slope measurements.

Pavement Section	Slope
Test Section #1	35°
Test Section #2	33°
Test Section #3	36°

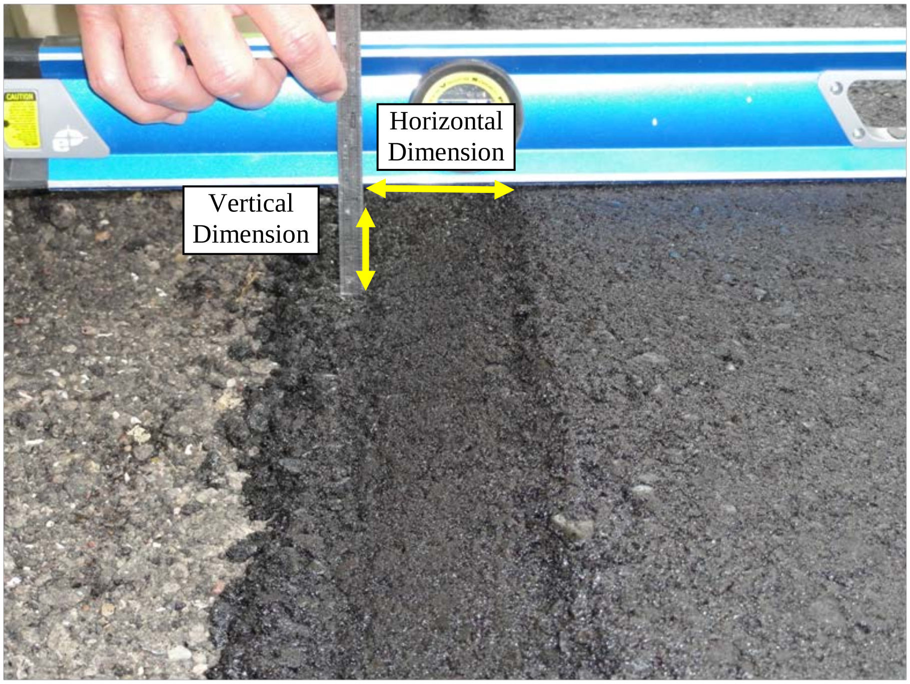

Figure 3. Slope measurement technique.

Accurate Safety Edge$_{SM}$ thickness measurements were not possible due the new overlay extending over the edge of the existing pavement and exaggerating the edge thickness.

Cores

Three pairs of cores were cut from each test section. The laboratory-determined densities from these cores serve to calibrate the nuclear density measurements. Laboratory density was determined from the bulk specific gravity at saturated surface dry test condition. Each pair of cores were taken from the center of the mat where the maximum number of roller passes occurred and adjacent to the edge where fewer roller passes were made. Tables 2 and 3 include a summary of these test results; core thickness and bulk specific gravities (saturated surface dry) converted to bulk densities.

Figure 4 shows a comparison of the core densities taken along the edge and near the center of the lane for the Safety Edge$_{SM}$ and control sections. As expected, the densities near the center of lane are significantly higher than along the edge of the mat.

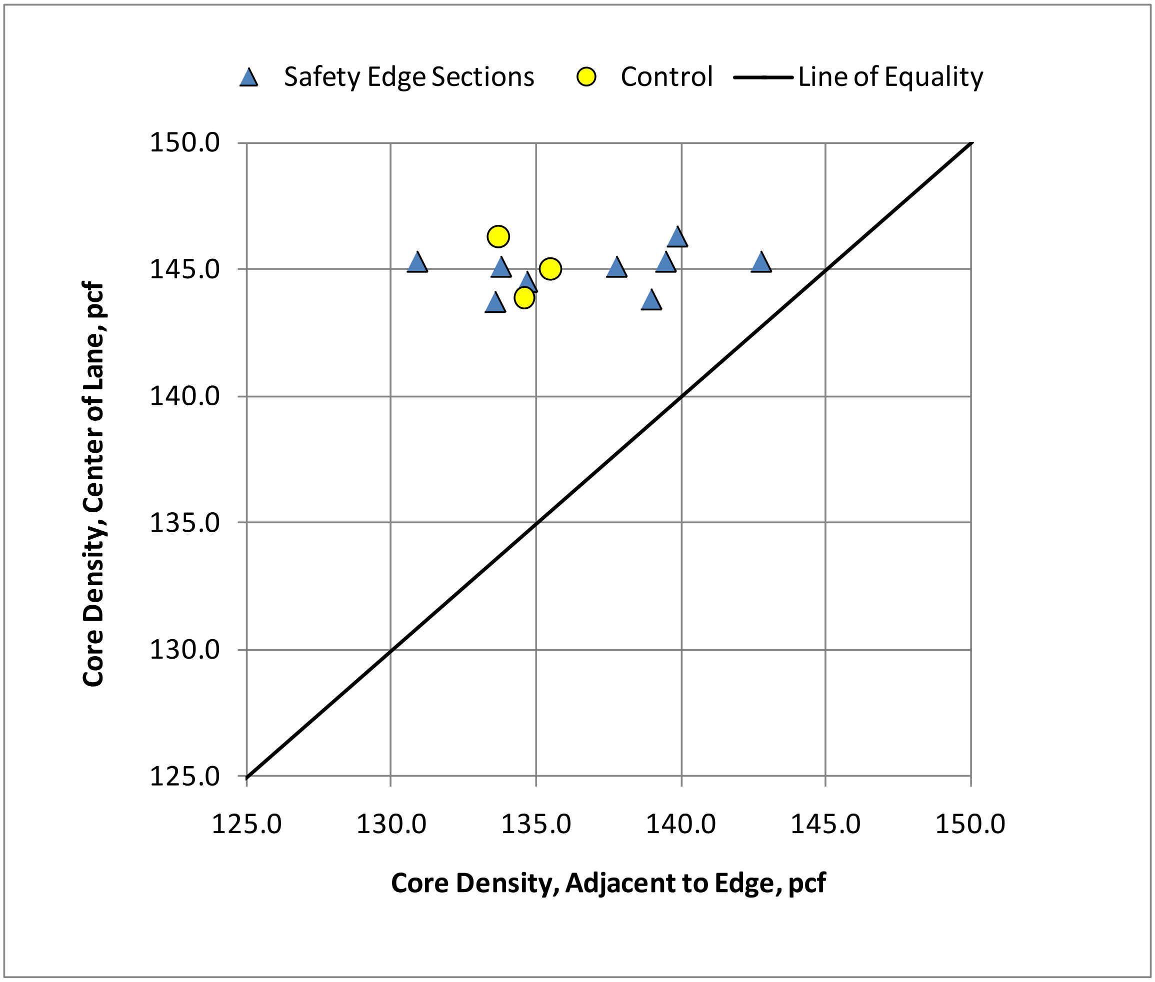

Figure 4. Comparison of core densities adjacent to the edge and at the center of the lane.

<u>Nuclear Density Results</u>

Density tests were conducted using a nuclear density gauge in backscatter mode for 60 second test durations. The tests were conducted adjacent to the edge and at the center of the lane at 50-ft intervals and at the location of each core. Figure 5 shows a comparison of the nuclear densities and densities measured on the cores. As shown, there is close correlation between the nuclear and core densities.

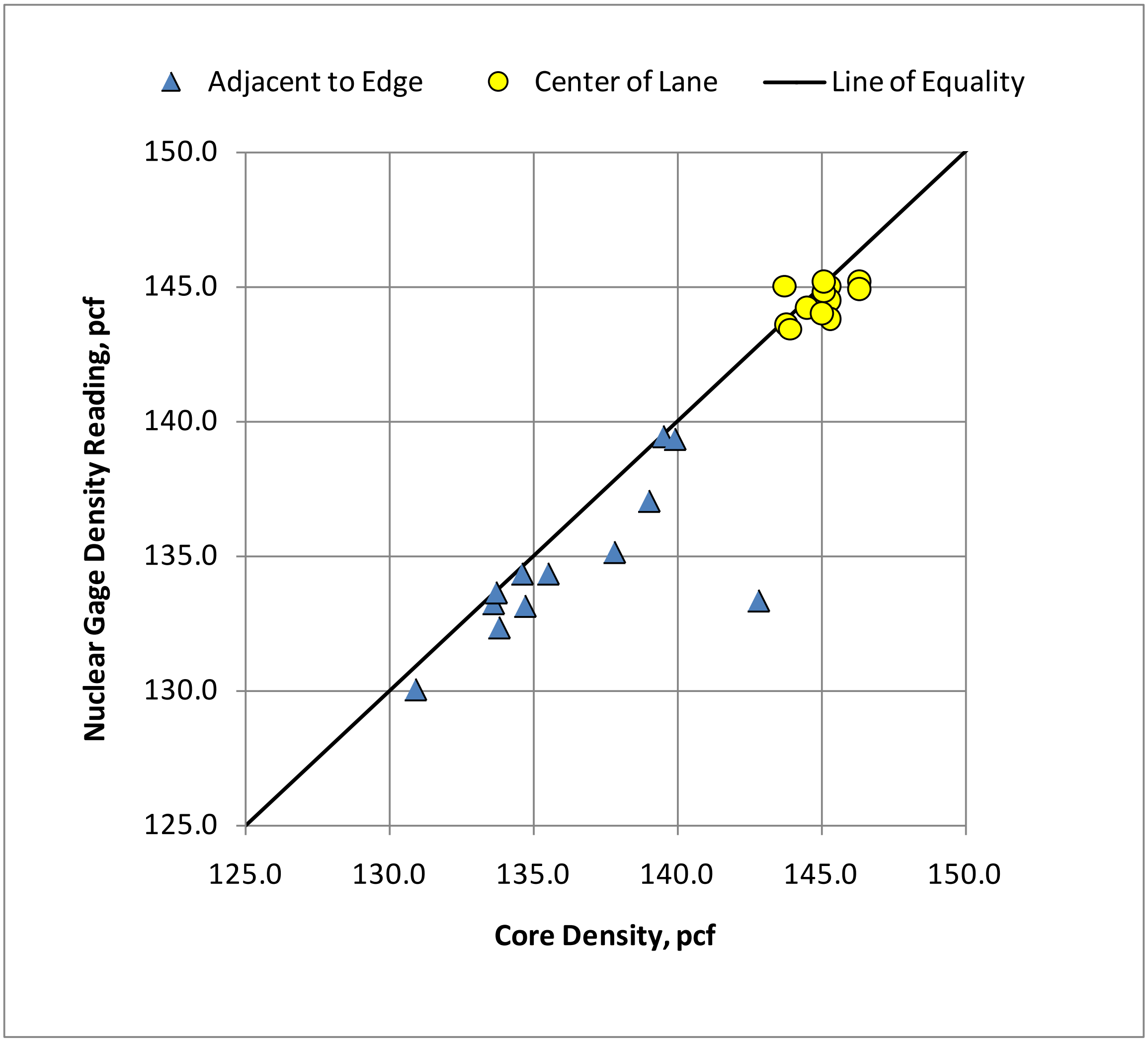

Figure 5. Comparison of the nuclear densities and core densities.

Adjustment factors were determined from correlating the nuclear density readings and the core laboratory density results shown in Table 3. The factors were used to adjust the nuclear density gauge readings to be consistent with the densities that were measured in the laboratory. The following summarizes the adjustment factors determined for this project.

Location	Adjustment Factor
Adjacent to the edge	1.013
Center of lane	1.003

As shown, the value near the center of the lane is closer to unity than the value near the edge. The adjusted or corrected densities using the correction factors are also listed in Table 4.

As expected, the results of the nuclear density tests of each test section show the densities adjacent to the edge were lower than the densities at the center of the lane. The control section had a slightly higher average density value (137.1 pcf) adjacent to the edge compared to the average density of all the Safety Edge$_{SM}$ sections (134.9 pcf) even though the rolling pattern was assumed to have been the same for all the sections. Test sections #1 and #2 were observed as receiving identical rolling patterns and based on discussions with the contractor, the rolling pattern would have been the same for test sections #3 and #4. The paving of the latter two test sections occurred after the site visit and was not directly observed.

Figure 6 shows a comparison of the nuclear densities taken adjacent to the edge and at the center of the lane. Figure 7 compares the air voids (as calculated from the density test results and the maximum theoretical mix density). The two figures show the densities were lower and the air voids were higher adjacent to the edge than away from the edge.

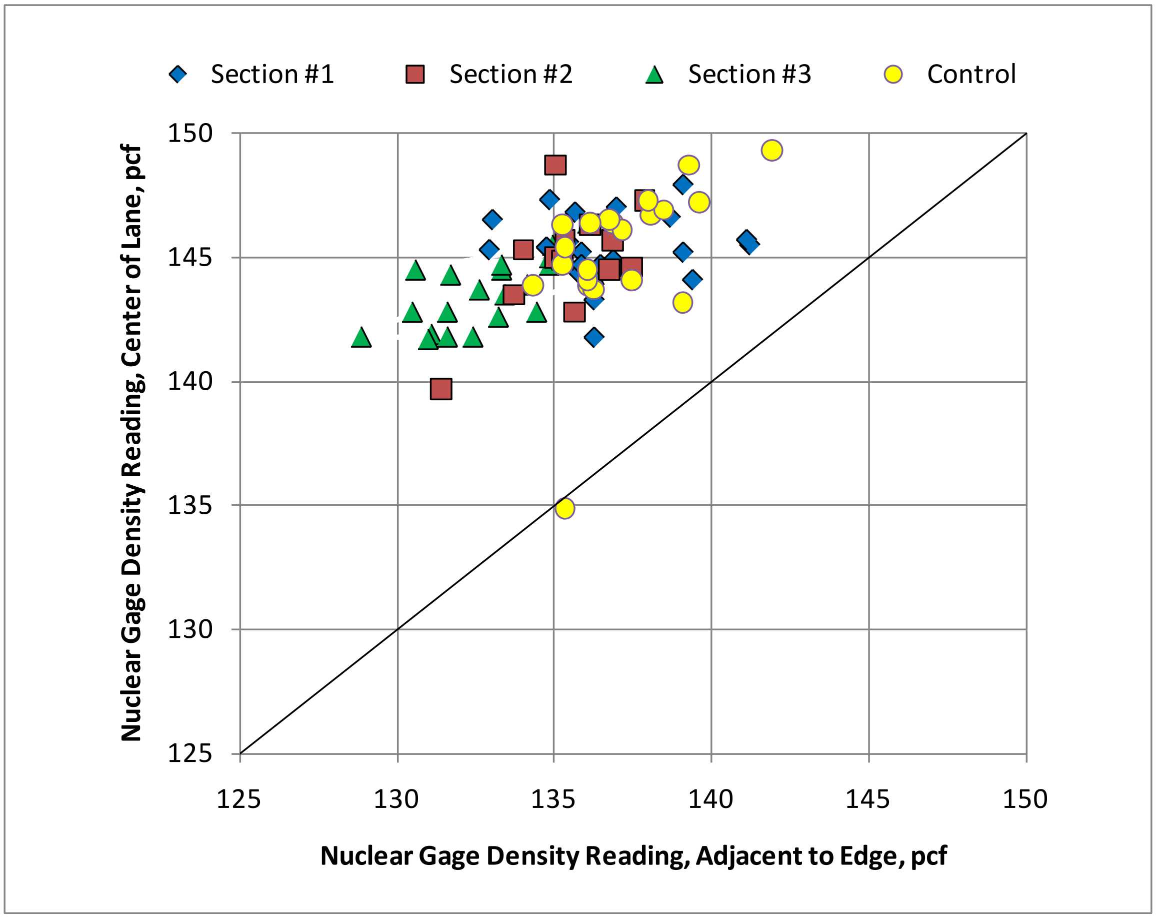

Figure 6. Comparison of the nuclear densities adjacent to the edge and at center of the lane.

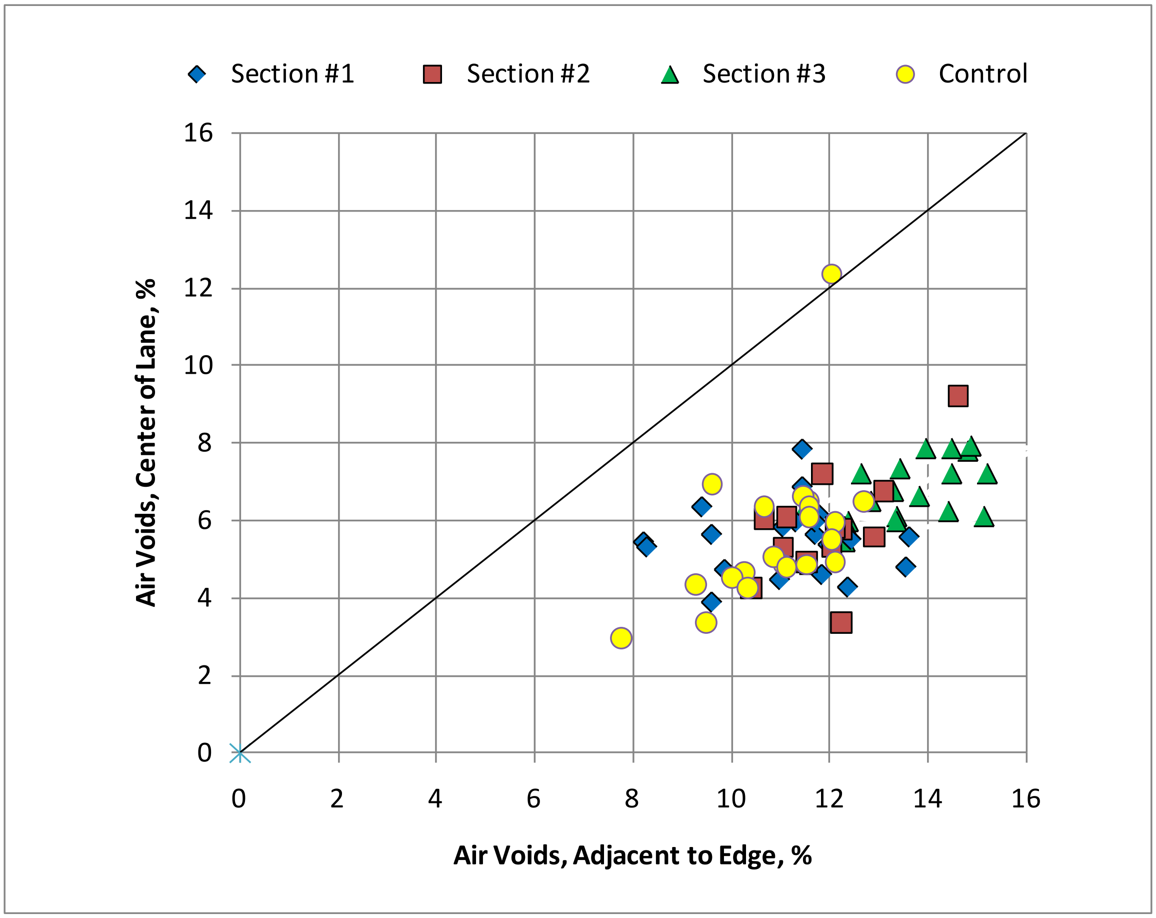

Figure 7. Comparison of the air voids adjacent to the edge and at the center of the lane.

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

This section discusses the observations made during the paving and rolling operations that could have a significant impact on the performance of the Safety Edge$_{SM}$ over time. As stated in the Introduction to the Field Report section, 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 Safety Edge$_{SM}$ devices during paving.
2. Safety Edge$_{SM}$ versus non-Safety Edge$_{SM}$ portions of project.
3. Slope of the Safety Edge$_{SM}$.

<u>Placement/Paving Operations</u>

During this site visit, field observations were limited to the paving of test sections #1 and #2 in which the contractor utilized the TransTech Shoulder Wedge Maker and the Carlson prototype #2. Neither device appeared to cause disturbances in the mat or with the shoulder material. Mix segregation in the finished overlay was not noticed in the test sections.

The contractor used a rubber tire Blaw-Knox PF-3200 paver and a Roadtec SB-2500C material transfer vehicle to overlay the existing milled HMA pavement. Test section #1 was paved first with the TransTech device mounted on the screed extension next to the end gate. Next, test section #2 was paved with the Carlson prototype #2 device which was quickly installed during a short break in paving. This device and Carlson's prototype #3 was a modified end gate with the angle of the Safety Edge$_{SM}$ built into the end gate ski. The end gate ski was flat in the front and transitioned to 30° at the back of the ski. While paving with the Carlson prototype #2, the TransTech device remained mounted to the paver and was simply raised up and out of the way (Figure 8).

Figure 8. Paving with the Carlson prototype #2 device with the TransTech device is still attached but raised and out of the way.

Visual inspection of the slope faces of the first two sections revealed a coarse appearance with more gaps between exposed aggregate in section #1 than section #2 which had a smooth or sealed appearance. The smooth slope face produced by the Carlson device is thought to be a result of extruding the HMA over the length of the end gate ski into the Safety Edge$_{SM}$ shape gradually from no slope near the front of the ski to 30° at the end of the ski.

Test section #3 was paved after the site visit and photos from WisDOT show a smooth slope face similar to section #2. An FHWA engineer on site indicated that before the Carlson Prototype #3 was sufficiently heated from the fresh HMA the slope face appeared only slightly smoother than the slope face produced by the TransTech device. It took roughly 200 ft of paving to heat up the end gate ski of the Carlson device after which the slope face became sealed and smooth. Future design modifications to the end gate design are expected to include a heating element to preheat and maintain the temperature of the device.

Regardless of which device was used, the shape of the slope faces were consistent throughout the test sections. One distinct difference among the edges was the slope face on section #2 produced by the Carlson Prototype #2 had a 0.25-inch vertical rise or lip as the slope face meets the horizontal surface of the mat. The lip may help retain the granular shoulder material. Figure 9, 10, and 11 show the three finished edges after compaction.

Figure 9. TransTech edge.

Figure 10. Carlson Prototype #2 edge.

Figure 11. Carlson Prototype #3 edge.

<u>Compaction Operations</u>

The contractor's breakdown roller was an Ingersoll-Rand dual steel drum DD-110HF operating in low amplitude and high frequency mode (the roller vibrator control setting was set for a 2-inch mat). Typically, one vibratory pass was made hanging 12 inches over the free edge of the mat and 6 vibratory passes were made over the rest of the mat. No static passes were made by the breakdown roller. The intermediate roller was a Caterpillar PS-150B pneumatic tire roller that made 6 to 8 passes, none of which were at the edge. The finish roller was a Bomag BW 11 AS dual steel wheel roller. This roller was operated in static mode and made one pass hanging 6 inches over the free edge and 5 to 7 passes over the rest of the mat. The mat was stable and not overly tender under any of the rollers. No tearing or shoving was observed.

Findings and Conclusions

As stated above, 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.

1. Correct use of 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.

- This overlay project with its long tangent sections and well shaped shoulders was well suited for demonstrating the use of the three Safety Edge$_{SM}$ devices. Each device proved to be simple to use and did not greatly impede the paving operations. The Carlson devices were quickly attached and simplified the screed operators adjustments during paving.
- The average density adjacent to the edge of the mat in the non- Safety Edge$_{SM}$ test section had a higher density than any of the Safety Edge$_{SM}$ test sections. This is contrary to other demonstration projects in which the Safety Edge$_{SM}$ device is believed to add to the compactive effort at the edge and increase density.
- The slope of the edges produced by the three devices varied from 33° to 36°. Each device produced a uniform edge with unique characteristics. The TransTech device produced a relatively coarse slope face whereas the slope produced by the Carlson devices had a smooth/sealed appearance which may promote increased durability by reducing water infiltration at the edge. The Carlson prototype #2 device produced a 0.25-inch lip on the slope face that may help to retain the shoulder dressing material.

The Safety Edge$_{SM}$ should be inspected after the material for the shoulder has been placed to the final pavement elevation. In the long term, special attention should be focused on test section #2 to determine if the lip on this Safety Edge$_{SM}$ is effective in retaining the shoulder material and if the smooth slope face on test section #2 and #3 impact the pavement performance.

APPENDIX A

DATA TABLES

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 1. Safety Edge$_{SM}$ Slope Measurements.

Section	Station	Type of Device	Edge Measurements		
			Width of Taper, in	Thickness of Taper, in	Slope, deg
1	823+12	TransTech	4.5	3.25	36
1	822+87	TransTech	4.625	3.25	35
1	822+62	TransTech	4.5	3.25	36
1	822+37	TransTech	4.75	3	32
1	822+12	TransTech	4.5	3.125	35
1	821+87	TransTech	4.875	3.125	33
1	821+62	TransTech	4.25	3.125	36
1	821+37	TransTech	4.625	3.25	35
1	821+12	TransTech	4.75	3.5	36
1	820+87	TransTech	5.25	3.375	33
1	820+62	TransTech	4	2.75	35
1	820+37	TransTech	4	2.875	36
1	820+12	TransTech	3.875	3	38
1	819+87	TransTech	3.75	2.75	36
1	819+62	TransTech	3.75	2.75	36
1	819+37	TransTech	3.75	2.875	37
1	819+12	TransTech	4	2.875	36
1	818+87	TransTech	3.75	3	39
1	818+62	TransTech	3.75	2.625	35
1	818+37	TransTech	3.5	2.75	38
1	818+12	TransTech	3.875	2.75	35
1	817+87	TransTech	4.25	3	35
1	817+62	TransTech	4.25	2.875	34
1	817+37	TransTech	4.375	3	34
1	817+12	TransTech	4.25	2.875	34
1	816+87	TransTech	4.25	3	35
1	816+62	TransTech	5	3.25	33
1	816+37	TransTech	4.5	3.125	35
1	816+12	TransTech	4.375	3.125	36
1	815+87	TransTech	4.375	3.25	37
1	815+62	TransTech	4.625	3.125	34
1	815+37	TransTech	4.625	3.125	34
1	815+12	TransTech	4	2.625	33
1	814+87	TransTech	4.25	3.625	40
1	814+62	TransTech	4.75	3.625	37
1	814+37	TransTech	5.625	3.625	33
1	814+12	TransTech	6	3.5	30
1	813+87	TransTech	5.25	3.375	33
1	813+62	TransTech	6	3.75	32
1	813+37	TransTech	6	3.75	32
1	813+12	TransTech	5.75	3.5	31
		Mean Value	4.5	3.1	35
		Standard Deviation	0.7	0.3	2.1
		Coefficient of Variation, %	14.6	9.8	6.0

Table 1. Safety Edge$_{SM}$ Slope Measurements (Continued).

Section	Station	Type of Device	Edge Measurements		
			Width of Taper, in	Thickness of Taper, in	Slope, deg
2	809+00	Carlson Prototype #2	3.125	2.125	34
2	808+75	Carlson Prototype #2	3.25	2.125	33
2	808+50	Carlson Prototype #2	2.875	1.875	33
2	808+25	Carlson Prototype #2	3.125	2.125	34
2	808+00	Carlson Prototype #2	3	2	34
2	807+75	Carlson Prototype #2	3.125	2	33
2	807+50	Carlson Prototype #2	3.25	2.125	33
2	807+25	Carlson Prototype #2	3.375	2.125	32
2	807+00	Carlson Prototype #2	3.25	2.125	33
2	806+75	Carlson Prototype #2	3.5	2.25	33
2	806+50	Carlson Prototype #2	3.25	2	32
2	806+25	Carlson Prototype #2	3.125	2	33
2	806+00	Carlson Prototype #2	3.125	1.875	31
2	805+75	Carlson Prototype #2	3	1.75	30
2	805+50	Carlson Prototype #2	3.125	2	33
2	805+25	Carlson Prototype #2	3.125	2	33
2	805+00	Carlson Prototype #2	2.875	2.125	36
2	804+75	Carlson Prototype #2	3.25	2	32
2	804+50	Carlson Prototype #2	2.625	1.875	36
2	804+25	Carlson Prototype #2	2.625	1.875	36
2	804+00	Carlson Prototype #2	3.75	1.875	27
2	803+75	Carlson Prototype #2	3.125	2.375	37
2	803+50	Carlson Prototype #2	3	2.125	35
2	803+25	Carlson Prototype #2	2.375	1.875	38
2	803+00	Carlson Prototype #2	2.625	1.75	34
		Mean Value	3.1	2.0	33
		Standard Deviation	0.3	0.2	2.4
		Coefficient of Variation, %	9.6	7.5	7.1

Table 1. Safety Edge$_{SM}$ Slope Measurements (Continued).

Section	Station	Type of Section	Edge Measurements		
			Width of Taper, in	Thickness of Taper, in	Slope, deg
3	800+00	Carlson Prototype #3	3.6	2.16	31
3	799+75	Carlson Prototype #3	3.84	2.4	32
3	799+50	Carlson Prototype #3	2.4	1.8	37
3	799+25	Carlson Prototype #3	2.4	1.92	39
3	799+00	Carlson Prototype #3	3	2.28	37
3	798+75	Carlson Prototype #3	2.4	1.92	39
3	798+50	Carlson Prototype #3	2.4	1.8	37
3	798+25	Carlson Prototype #3	2.4	2.04	40
3	798+00	Carlson Prototype #3	2.4	1.8	37
3	797+75	Carlson Prototype #3	3	2.52	40
3	797+50	Carlson Prototype #3	3	2.4	39
3	797+25	Carlson Prototype #3	2.4	1.92	39
3	797+00	Carlson Prototype #3	2.4	1.8	37
3	796+75	Carlson Prototype #3	3	1.92	33
3	796+50	Carlson Prototype #3	2.4	1.8	37
3	796+25	Carlson Prototype #3	3	2.52	40
3	796+00	Carlson Prototype #3	2.4	1.68	35
3	795+75	Carlson Prototype #3	3	2.16	36
3	795+50	Carlson Prototype #3	3	2.4	39
3	795+25	Carlson Prototype #3	3.6	2.64	36
3	795+00	Carlson Prototype #3	2.4	1.8	37
3	794+75	Carlson Prototype #3	2.4	1.68	35
3	794+50	Carlson Prototype #3	2.4	1.8	37
3	794+25	Carlson Prototype #3	2.4	1.68	35
3	794+00	Carlson Prototype #3	2.4	1.68	35
3	793+75	Carlson Prototype #3	3.6	2.4	34
3	793+50	Carlson Prototype #3	3	2.16	36
3	793+25	Carlson Prototype #3	3.6	2.64	36
3	793+00	Carlson Prototype #3	3	2.16	36
3	792+75	Carlson Prototype #3	2.4	1.68	35
3	792+50	Carlson Prototype #3	3.6	2.64	36
3	792+25	Carlson Prototype #3	3.6	2.76	37
3	792+00	Carlson Prototype #3	3	2.16	36
3	791+75	Carlson Prototype #3	3.6	2.52	35
3	791+50	Carlson Prototype #3	3	2.28	37
3	791+25	Carlson Prototype #3	2.4	1.56	33
3	791+00	Carlson Prototype #3	3	1.92	33
3	790+75	Carlson Prototype #3	3.6	2.16	31
3	790+50	Carlson Prototype #3	3.6	2.64	36
3	790+25	Carlson Prototype #3	3	1.92	33
3	790+00	Carlson Prototype #3	3	2.4	39
		Mean Value	2.9	2.1	36
		Standard Deviation	0.5	0.3	2.4
		Coefficient of Variation, %	16.9	16.2	6.6

Table 2. Core Thickness Measurements.

Section	Lane Direction	Station	Type of Section	Core Thickness, inch	
				A – Adjacent to Edge	B – 3 feet from Edge
1	Southbound	821+62	TransTech	3.11	--
1	Southbound	818+12	TransTech	3.15	3.79
1	Southbound	814+62	TransTech	2.38	--
2	Southbound	808+50	Carlson Prototype #2	2.48	2.84
2	Southbound	807+00	Carlson Prototype #2	2.46	3.35
2	Southbound	805+00	Carlson Prototype #2	3.12	3.60
3	Southbound	379+50	Carlson Prototype #3	1.83	2.91
3	Southbound	376+00	Carlson Prototype #3	2.78	1.62
3	Southbound	372+50	Carlson Prototype #3	1.99	3.80
4	Southbound	789+50	Control	1.67	2.79
4	Southbound	795+00	Control	2.81	2.83
4	Southbound	791+50	Control	4.63	5.05
			Mean, in.	2.70	3.26
			Standard Deviation, in.	0.79	0.90
			Coefficient of Variation, %	29.21	27.61

Table 3. Nuclear Density Adjustment Ratios; Core Density/Nuclear Density.

Section	Lane Direction	Station	Type of Device	Density of Cores		Nuclear Density Values		Adjustment Ratio	
				A – Adjacent to Edge	B – Center of Lane	A – Adjacent to Edge	B – Center of Lane	A – Adjacent to Edge	B – Center of Lane
1	Southbound	821+62	TransTech	139.0	143.8	137.0	143.6	1.015	1.001
1	Southbound	818+12	TransTech	139.5	145.3	139.4	145.0	1.001	1.002
1	Southbound	814+62	TransTech	139.9	146.3	139.3	145.2	1.004	1.008
2	Southbound	808+50	Carlson Prototype #2	142.8	145.3	133.3	144.5	1.071	1.006
2	Southbound	807+00	Carlson Prototype #2	133.8	145.1	132.3	144.8	1.011	1.002
2	Southbound	805+00	Carlson Prototype #2	137.8	145.1	135.1	145.2	1.020	0.999
3	Southbound	379+50	Carlson Prototype #3	134.7	144.5	133.1	144.2	1.012	1.002
3	Southbound	376+00	Carlson Prototype #3	130.9	145.3	130.0	143.8	1.007	1.010
3	Southbound	372+50	Carlson Prototype #3	133.6	143.7	133.2	145.0	1.003	0.991
4	Southbound	798+50	Control	134.6	143.9	134.3	143.4	1.002	1.003
4	Southbound	795+00	Control	135.5	145.0	134.3	144.0	1.009	1.007
4	Southbound	791+50	Control	133.7	146.3	133.6	144.9	1.001	1.010
			Mean Value, pcf	136.3	145.0	134.6	144.5	1.013	1.003
			Standard Deviation, pcf	3.4	0.9	2.8	0.6	0.019	0.005
			Coefficient of Variation, %	2.5	0.6	2.1	0.4	1.905	0.522

Table 4. Nuclear Gauge Readings.

Maximum Specific Gravity of Mix (Gmm):	2.466	Max. Density, pcf:	153.9
Adjustment Ratios for Nuclear Gauge: A=	1.013		
B=	1.003		

Section	Lane Direction	Station	Type of Device	Nuclear Densities, pcf		Adjusted Nuclear Densities, pcf		Edge Thickness from Cores, in.	Air Voids, %	
				A – Adjacent to Edge	B – Lane Center	A – Adjacent to Edge	B – Lane Center		A – Adjacent to Edge	B – Lane Center
1	SB	823+12	TransTech	134.5	142.8	136.25	143.29		11.5	6.9
1	SB	822+62	TransTech	134.5	141.3	136.25	141.79		11.5	7.9
1	SB	822+12	TransTech	137.3	144.7	139.09	145.20		9.6	5.6
1	SB	821+62	TransTech	137.6	143.6	139.39	144.10	3.11	9.4	6.4
1	SB	821+12	TransTech	136.9	146.1	138.68	146.61		9.9	4.7
1	SB	820+62	TransTech	131.3	146.0	133.01	146.51		13.6	4.8
1	SB	820+12	TransTech	133.7	145.1	135.44	145.60		12.0	5.4
1	SB	819+62	TransTech	137.3	147.4	139.09	147.91		9.6	3.9
1	SB	819+12	TransTech	134.7	144.2	136.45	144.70		11.3	6.0
1	SB	818+62	TransTech	135.1	144.4	136.86	144.90		11.1	5.8
1	SB	818+12	TransTech	139.4	145.0	141.21	145.50	3.146	8.2	5.4
1	SB	817+62	TransTech	133.0	144.9	134.73	145.40		12.4	5.5
1	SB	817+12	TransTech	134.0	143.9	135.74	144.40		11.8	6.2
1	SB	816+62	TransTech	135.2	146.5	136.96	147.01		11.0	4.5
1	SB	816+12	TransTech	133.9	146.3	135.64	146.81		11.9	4.6
1	SB	815+62	TransTech	134.1	144.7	135.84	145.20		11.7	5.6
1	SB	815+12	TransTech	131.2	144.8	132.91	145.30		13.6	5.6
1	SB	814+62	TransTech	139.3	145.2	141.11	145.70	2.375	8.3	5.3
1	SB	814+12	TransTech	133.1	146.8	134.83	147.31		12.4	4.3
1	SB	813+62	TransTech	133.0	144.9	134.73	145.40		12.4	5.5
1	SB	813+12	TransTech	134.1	144.2	135.84	144.70		11.7	6.0
Average Value, pcf				134.9	144.9	136.7	145.4	2.9	11.2	5.5
Standard Deviation, pcf				2.3	1.4	2.3	1.4	0.4	1.5	0.9
Coefficient of Variation, %				1.7	1.0	1.7	1.0	15.1	13.5	16.4

Table 4. Nuclear Gauge Readings (Continued).

Section	Lane Direction	Station	Type of Device	Nuclear Densities, pcf		Adjusted Nuclear Densities, pcf		Edge Thickness from Cores, in.	Air Voids, %	
				A – Adjacent to Edge	B – Lane Center	A – Adjacent to Edge	B – Lane Center		A – Adjacent to Edge	B – Lane Center
2	SB	809+00	Carlson Prototype #2	133.9	142.3	135.64	142.79		11.9	7.2
2	SB	808+50	Carlson Prototype #2	133.3	144.5	135.03	145.00	2.477	12.2	5.8
2	SB	808+00	Carlson Prototype #2	129.7	139.2	131.39	139.68		14.6	9.2
2	SB	807+50	Carlson Prototype #2	133.5	144.4	135.24	144.90		12.1	5.8
2	SB	807+00	Carlson Prototype #2	132.3	144.8	134.02	145.30	2.455	12.9	5.6
2	SB	806+50	Carlson Prototype #2	132.0	143.0	133.72	143.50		13.1	6.7
2	SB	806+00	Carlson Prototype #2	135.7	144.1	137.46	144.60		10.7	6.0
2	SB	805+50	Carlson Prototype #2	134.4	145.8	136.15	146.31		11.5	4.9
2	SB	805+00	Carlson Prototype #2	136.1	146.8	137.87	147.31	3.118	10.4	4.3
2	SB	804+50	Carlson Prototype #2	135.1	145.2	136.86	145.70		11.1	5.3
2	SB	804+00	Carlson Prototype #2	133.6	145.2	135.34	145.70		12.0	5.3
2	SB	803+50	Carlson Prototype #2	133.3	148.2	135.03	148.71		12.2	3.4
2	SB	803+00	Carlson Prototype #2	135.0	144.0	136.76	144.50		11.1	6.1
Average Value, pcf				133.7	144.4	135.4	144.9	2.7	12.0	5.8
Standard Deviation, pcf				1.7	2.2	1.7	2.2	0.4	1.1	1.4
Coefficient of Variation, %				1.3	1.5	1.3	1.5	14.0	9.4	24.5

Table 4. Nuclear Gauge Readings (Continued).

Section	Lane Direction	Station	Type of Device	Nuclear Densities, pcf		Adjusted Nuclear Densities, pcf		Edge Thickness from Cores, in.	Air Voids, %	
				A – Adjacent to Edge	B – Lane Center	A – Adjacent to Edge	B – Lane Center		A – Adjacent to Edge	B – Lane Center
3	SB	381+00	Carlson Prototype #3	129.9	142.3	131.59	142.79		14.48	7.20
3	SB	380+50	Carlson Prototype #3	131.6	144.0	133.31	144.50		13.37	6.10
3	SB	380+00	Carlson Prototype #3	132.4	143.4	134.12	143.90		12.84	6.49
3	SB	379+50	Carlson Prototype #3	133.1	144.2	134.83	144.70	1.825	12.38	5.96
3	SB	379+00	Carlson Prototype #3	134.3	145.9	136.05	146.41		11.59	4.86
3	SB	378+50	Carlson Prototype #3	129.4	141.4	131.08	141.89		14.81	7.79
3	SB	378+00	Carlson Prototype #3	131.5	142.1	133.21	142.59		13.43	7.33
3	SB	377+50	Carlson Prototype #3	134.5	143.8	136.25	144.30		11.46	6.23
3	SB	377+00	Carlson Prototype #3	131.6	144.2	133.31	144.70		13.37	5.96
3	SB	376+50	Carlson Prototype #3	131.7	143.0	133.41	143.50		13.30	6.75
3	SB	376+00	Carlson Prototype #3	130.0	143.8	131.69	144.30	2.783	14.42	6.23
3	SB	375+50	Carlson Prototype #3	129.3	141.2	130.98	141.69		14.88	7.92
3	SB	375+00	Carlson Prototype #3	129.9	141.3	131.59	141.79		14.48	7.86
3	SB	374+50	Carlson Prototype #3	127.2	141.3	128.85	141.79		16.26	7.86
3	SB	374+00	Carlson Prototype #3	128.8	142.3	130.48	142.79		15.21	7.20
3	SB	373+50	Carlson Prototype #3	130.9	143.2	132.60	143.70		13.83	6.62
3	SB	373+00	Carlson Prototype #3	128.9	144.0	130.58	144.50		15.14	6.10
3	SB	372+50	Carlson Prototype #3	133.2	145.0	134.93	145.50	1.986	12.31	5.44
3	SB	372+00	Carlson Prototype #3	133.1	144.5	134.83	145.00		12.38	5.77
3	SB	371+50	Carlson Prototype #3	130.7	141.3	132.40	141.79		13.96	7.86
3	SB	371+00	Carlson Prototype #3	132.7	142.3	134.43	142.79		12.64	7.20
Average Value, pcf				131.2	143.1	132.9	143.6	2.2	13.6	6.7
Standard Deviation, pcf				1.94	1.37	1.96	1.38	0.5	1.3	0.9
Coefficient of Variation, %				1.48	0.96	1.48	0.96	23.3	9.4	13.4

Table 4. Nuclear Gauge Readings (Continued).

Section	Lane Direction	Station	Type of Device	Nuclear Densities, pcf		Adjusted Nuclear Densities, pcf		Edge Thickness from Cores, in.	Air Voids, %	
				A – Adjacent to Edge	B – 3 feet from Edge	A – Adjacent to Edge	B – Center of Lane		A – Adjacent to Edge	B – 3 feet from Edge
4	SB	800+00	Control	133.6	134.4	135.34	134.87		12.05	12.36
4	SB	799+50	Control	133.5	144.2	135.24	144.70		12.11	5.96
4	SB	799+00	Control	132.6	143.4	134.32	143.90		12.71	6.49
4	SB	798+50	Control	134.3	143.4	136.05	143.90	1.67	11.59	6.49
4	SB	798+00	Control	134.5	143.2	136.25	143.70		11.46	6.62
4	SB	797+50	Control	133.5	145.8	135.24	146.31		12.11	4.92
4	SB	797+00	Control	137.8	146.7	139.59	147.21		9.28	4.33
4	SB	796+50	Control	134.3	143.6	136.05	144.10		11.59	6.36
4	SB	796+00	Control	135.1	145.9	136.86	146.41		11.06	4.86
4	SB	795+50	Control	137.3	142.7	139.09	143.19	2.809	9.61	6.94
4	SB	795+00	Control	134.3	144.0	136.05	144.50		11.59	6.10
4	SB	794+50	Control	137.5	148.2	139.29	148.71		9.48	3.36
4	SB	794+00	Control	135.4	145.6	137.16	146.10		10.86	5.05
4	SB	793+50	Control	135.7	143.6	137.46	144.10		10.67	6.36
4	SB	793+00	Control	135.0	146.0	136.76	146.51		11.13	4.79
4	SB	792+50	Control	136.3	146.2	138.07	146.71		10.27	4.66
4	SB	792+00	Control	136.7	146.4	138.48	146.91		10.01	4.53
4	SB	791+50	Control	133.6	144.9	135.34	145.40	4.63	12.05	5.51
4	SB	791+00	Control	134.4	145.9	136.15	146.41		11.52	4.86
4	SB	790+50	Control	136.2	146.8	137.97	147.31		10.34	4.27
4	SB	790+00	Control	140.1	148.8	141.92	149.32		7.77	2.97
			Average Value, pcf	135.3	144.7	137.1	145.2	3.0	10.9	5.6
			Standard Deviation, pcf	1.82	2.90	1.84	2.91	1.5	1.2	1.9
			Coefficient of Variation, %	1.34	2.00	1.34	2.00	49.2	11.0	33.7