Federal Highway Administration
Every Day Counts
Innovation Initiative

Safety Edge$_{SM}$ Demonstration Project Turner, Maine

Field Report
June 15, 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 Androscoggin County on State Route (SR) 117 in Turner, Maine, just east of the intersection between SR 117 and SR 4. 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 and field data measured during construction on August 11 and 12, 2010 to evaluate the use of the Advant-Edger, TransTech Shoulder Wedge Maker, and TransTech Notched Wedge Joint Maker. 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 in Turner, Maine. The Advant-Edger, TransTech Shoulder Wedge Maker, and TransTech Notched Wedge Joint Maker devices were demonstrated during this project. Details regarding the performance of the devices 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 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$_{SM}$.

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

The Safety Edge$_{SM}$ did not have a detrimental impact on the agency's paving operation during mainline paving. Some issues, however, were encountered that need to be resolved. These are noted in some of the following bullet items.

Slope of Safety Edge$_{SM}$

- The average slope of the Safety Edge$_{SM}$ using the Advant Edger Safety Edge$_{SM}$ device was found to be 54°. None of the 13 measurements were less than 45° and only one measurement was less than 50°.
- The average slope of the Safety Edge$_{SM}$ using the TransTech Shoulder Wedge Maker was found to be 45°. Eight of the 21 measurements were less than 40° and two measurements were between 45° and 50°.
- The centerline joint made using the TransTech Notched Wedge Joint Maker had an average slope of 19º.
- Although both the Advant-Edger and TransTech Shoulder Wedge Maker devices produced an edge with a slope of 30º immediately behind the screed, because of the difference in device pressure and shape, the slope of the Safety Edge$_{SM}$ made with the Advant-Edger device increased to an average of 54º and that of the Safety Edge$_{SM}$ made with the TransTech device increased to an average of 45º after rolling. It should be noted that the HMA mix for the surface wearing course was "normal" and not too tender or too stiff, and using a mix with a different level of stiffness could result in different values.

Placement

- The Safety Edge$_{SM}$ was formed using the Advant-Edger and TransTech Shoulder Wedge Maker which were properly bolted to the screed of the paver. Construction personnel suggested putting a sleeve around the Safety Edge$_{SM}$ spring to keep HMA material out of this area so it does not get into the threads and make it difficult to adjust the Safety Edge$_{SM}$ vertically. They also suggested that adding vibration to the device would probably make it better.

Compaction

- Compaction was performed using three rollers (a breakdown roller with 6 to 9 passes, an intermediate roller with 12+ passes, and a finish roller with 6 passes).

- During the paving on August 11, the contractor made 9 passes using the breakdown roller for both the section paved with the Advant-Edger and the section paved without a Safety Edge$_{SM}$ device. During the paving on August 12, the HMA was pushing, shoving, and tearing under the breakdown roller about 500 ft after paving started. It appeared to be a classic "tender zone" problem. The contractor reduced the number of the breakdown roller passes from 9 to 6 for the section paved with the TransTech Shoulder Wedge Maker.
- The HMA mix density (and percent compaction) was slightly higher and the air voids slightly lower adjacent to the edge of the mat for the Safety Edge$_{SM}$ sections in comparison to the non-Safety Edge$_{SM}$ section based on core data. Thus, the Safety Edge$_{SM}$ was believed to have a confining effect on rolling an unconfined edge condition. This observation is considered a benefit to the use of the Safety Edge$_{SM}$. However this was not corroborated with the PQI data, which showed no statistical difference between the Safety Edge$_{SM}$ sections and the non-Safety Edge$_{SM}$ section.
- Percent compaction of the HMA mat interior averaged 93% while percent compaction near the Safety Edge$_{SM}$ and the non-Safety Edge$_{SM}$ averaged around 84%, based on adjusted PQI data. The percent compaction near the centerline notched wedge joint was around 93% (after paving both lanes).

Shoulder Construction

- Type D aggregate (same as beneath the HMA layers and the foreslope) was planned to be used for the backing material. Placement of the backing material was not observed.

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

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 SR 117 (Turner Center Road), near Turner, Maine, with and without the use of the Safety Edge$_{SM}$ device. The purpose 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$_{SM}$ devices during paving.
- Safety Edge$_{SM}$ versus non-Safety Edge$_{SM}$ portions of project.
- Slope of the Safety Edge$_{SM}$.

The paving contractor (RC & Sons Paving) used the Advant-Edger (attached to the screed) on August 11 on the southbound lane and TransTech Shoulder Wedge Maker (attached to the screed) on August 12, on the northbound lane. The short section without Safety Edge$_{SM}$ was at end of day on August 11, in the southbound lane. The paving contractor also used the TransTech Notched Wedge Joint Maker attached to the screed along the centerline for the entire length of the project (it is possible that it can be adjusted and used to make a Safety Edge$_{SM)}$.

The project was located 12 miles north of Auburn, Maine. The 2.339 mile project began at station 347+00 on SR 117 (Turner Center Rd.), about 200 ft east/north of the intersection of SR 117 and SR 4 in Turner and extends east/north to station 470+50 near the Turner Center (intersection of Upper St., Center Bridge Rd., Cobb Rd., N Parish Rd. [route 117], and Turner Center Rd. [SR 117]), as shown in Figure 1. The speed limit is 25 mph for west/south half of the project (near the town of Turner) and 45 mph for east/north half of the project. MaineDOT personnel indicated that the 45 mph speed limit would be dropped to 40 mph at the conclusion of the project.

Pavement Structure and Project Conditions

The project consisted of reconstruction by milling the existing asphalt pavement, placing a variable depth (typically 18 inches) Type D aggregate for grade improvement, followed by placement of a 3 inch lift of a 19 mm HMA base course and a 2 inch lift of a 12.5 mm HMA wearing course. This two-lane two-way roadway had 11 ft travel lanes with 3 ft shoulders. Figure 2 provides a general view of the 5 inch HMA layers, and typical cross section of the pavement.

The Safety Edge$_{SM}$ was incorporated into the project after it was awarded and no work order was executed for the purpose. Thus there are no contract documents related to the Safety Edge$_{SM}$. The contractor was paid by ton of HMA at contract bid amount.

The ditches along the edge of the pavement ranged from shallow or almost level with the existing pavement to moderately deep (refer to Figure 2 and Figure 3). Shoulder backing material is Type D aggregate, which is the same material as that beneath the HMA and on the foreslopes from the HMA to the ditch line. The specifications call for placing the material in 8 inch maximum lift thickness, adding water, and compacting. The shoulder is shaped to the ditch at a slope of 3:1 (refer to Figure 3). Some locations have topsoil over the Type D aggregate; the specifications require contractor to obtain 90 percent growth of vegetation on the foreslope.

Safety Edge$_{SM}$ project near Turner, ME in Androscoggin County.
Project starts 200 ft east/north of the intersection of SR 117 and SR 4 in Turner and extends east/north to Turner Center (intersection of Upper St., Center Bridge Rd., Cobb Rd., N Parish Rd. [SR 117], and Turner Center Rd. [SR 117]).

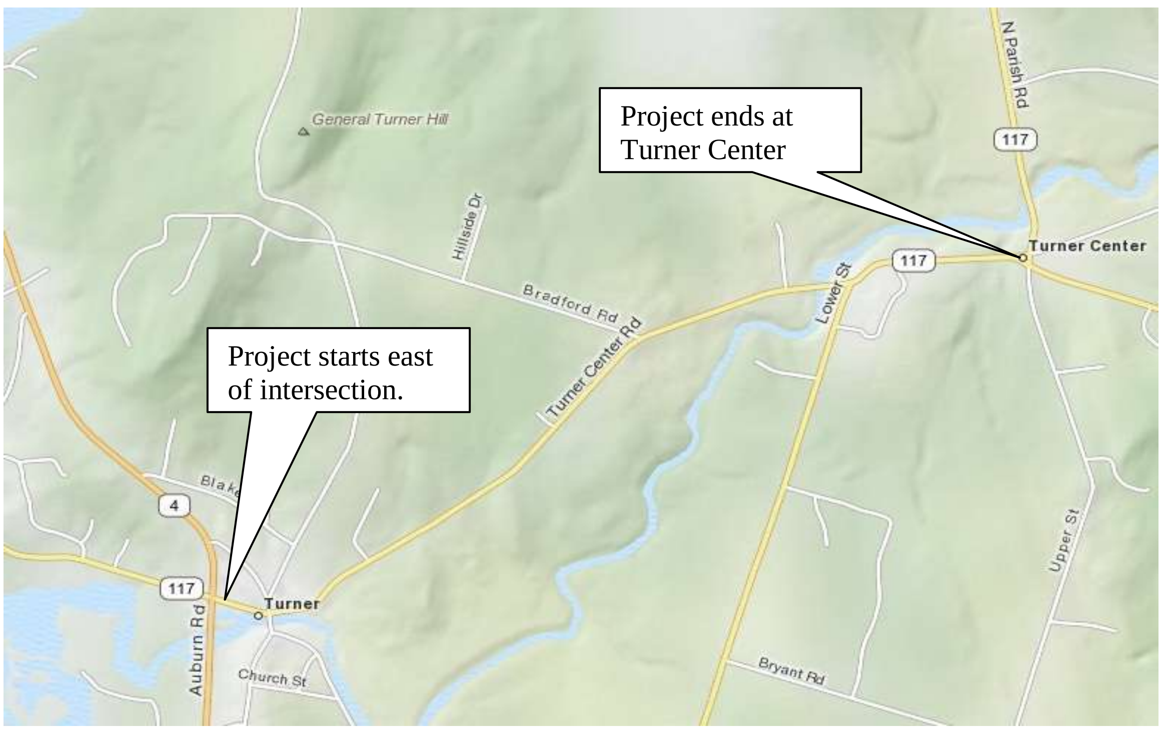


Figure 1. Location of Site

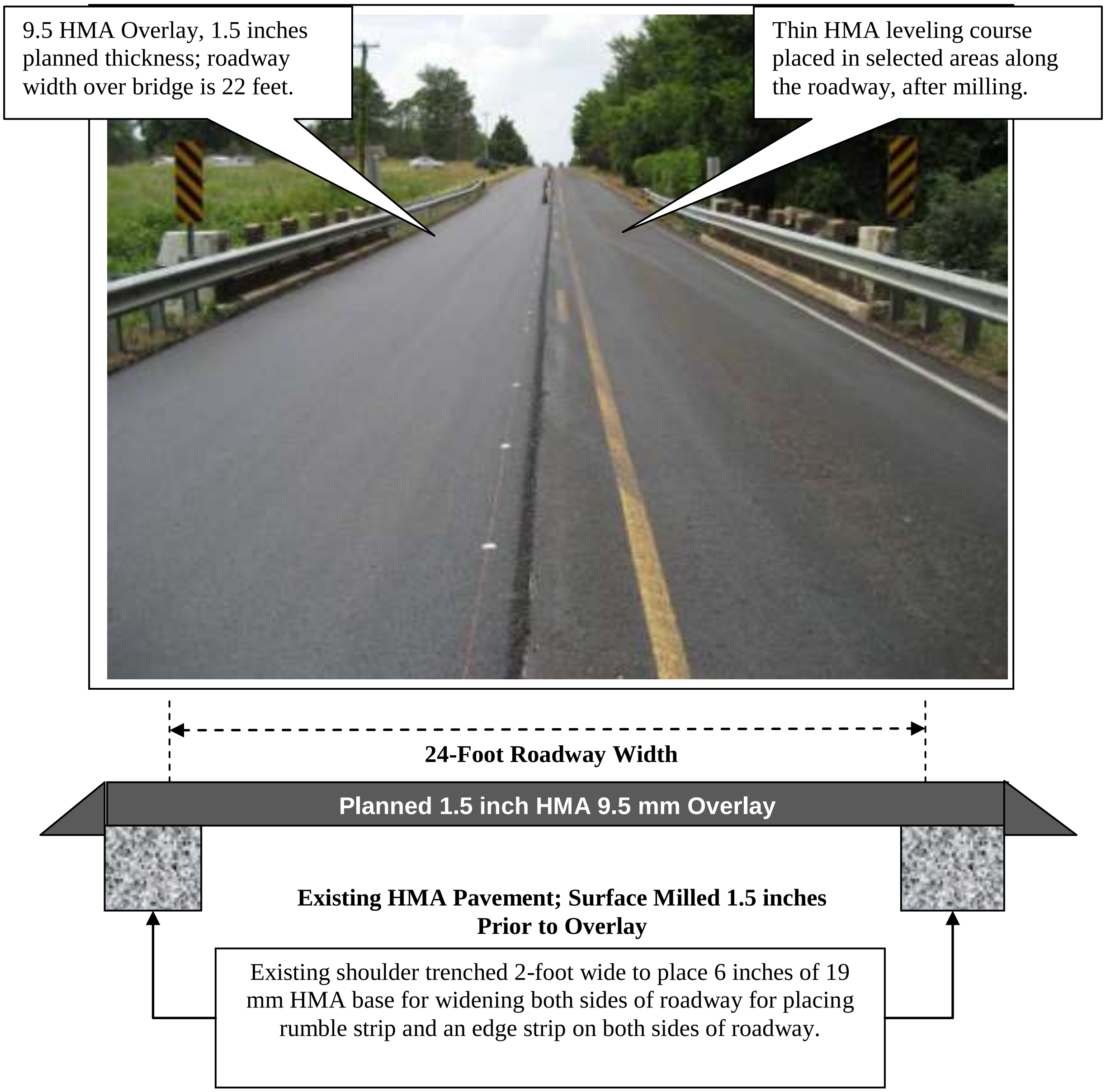


Figure 2. 9.5 mm HMA overlay already placed in one direction and the thin leveling layer placed in opposite direction after milling but prior to overlay placement.

The shoulder backing material foreslope is shaped to the ditch at a slope of 3:1 at most locations. The ditches were shallow or almost level with pavement at other locations. Shoulder backing material is Type D aggregate, which is the same material as that beneath the HMA. Some locations have topsoil over the Type D aggregate.

Figure 3. Localized area with deep ditches adjacent to the pavement.

At the time of the site visit, the contractor had completed the grade improvement and had finished placing the base course using the Advant-Edger in both the northbound and southbound directions. The contractor had started paving the wearing course with the Advant-Edger and was paving the southbound direction on August 11 (refer to Figure 3). A short “control” section without Safety Edge$_{SM}$ was paved at the end of the day on August 11 (the contractor was paving from south to north). Portions of the wearing course in the northbound direction (towards the south end of the project) had been completed prior to the site visit. On August 12, the contractor switched to the TransTech Shoulder Wedge Maker and continued paving the northbound direction. Weather conditions during paving were sunny to partly cloudy with occasional rain with highs around 85 ºF and lows around 60 ºF.

Field Evaluation Tests

Three sections were identified during the paving operation; two Safety Edge$_{SM}$ sections and one section without the Safety Edge$_{SM}$ device. Field tests were conducted within each test section using a TransTech Model PQI 301 density gauge, while slope measurements were taken using a straight-edge and six inch ruler along the two Safety Edge$_{SM}$ sections. Twelve cores were also taken in the test sections established during the paving operations. The twelve cores were obtained at six different locations within the Safety Edge$_{SM}$ and non-Safety Edge$_{SM}$ sections. The cores were taken for calibration of the PQI density gauge readings and to observe the mix near the center of the mat and adjacent to the mat's edge.

The two Safety Edge$_{SM}$ and one non-Safety Edge$_{SM}$ (control) test sections were established, all on the wearing course. The following summarizes the three sections included in this field study.

1. Section #1 (Refer to Figure 4), Safety Edge$_{SM}$ placed using Advant-Edger, southbound lane, tangent section, 700 ft section starting at Sta 367+53 going north (opposite to the direction of traffic). The section starting point is 16 ft north of posted speed limit sign, 32 ft north of a telephone pole, and 62 ft north of a driveway. 200 ft north of the section start is the center of a driveway to "Long Meadow Estates." The section ends at Sta 374+53 just before a posted sign indicating "Reduced Speed Zone Ahead." At around the 300 ft and 500 ft marks of the section are mailboxes with posts. The mailbox at the 500 ft mark is marked as "105."
2. Section #2 (Refer to Figure 5), no Safety Edge$_{SM}$ (control section), southbound lane, tangent section north of section #1, 500 ft section starting at Sta 385+38 going north (opposite to the direction of traffic). The section starting point is 40 ft south of a driveway with a culvert. Around 135 ft north of the section starting point is another driveway and a mailbox with a wooden post. The mailbox is marked as "166." Another mailbox marked as "177" is around 410 ft north of the starting point. The section ends 500 ft north of the starting point at Sta 390+38, 20 ft south of another driveway with a culvert.
3. Section #3 (Refer to Figure 6), Safety Edge$_{SM}$ placed using TransTech Shoulder Wedge Maker, northbound lane, tangent section , 500 ft section starting at Sta 401+15 going north (in the direction of traffic). The section starting point is 18 ft south of a telephone pole and exactly opposite the center of a driveway to "Maple Ridge Road" in the southbound direction. About 170 ft north of the starting point is a driveway with a culvert and at 242 ft and 482 ft north of the starting point are telephone poles. 200 ft north of the section start is the center of a driveway to "Long Meadow Estates." The section ends at Sta 406+15, 93 ft before a sign indicating "Farm Crossing."

Overview of section 1 constructed using Safety Edge$_{SM}$ for both the 3 inch HMA base course and the 2 inch HMA wearing course.

Figure 4. General overview showing the wearing course with Safety Edge$_{SM}$. Image taken facing the southbound direction around station 374+53, the end of section 1.

Overview of section 2 constructed without using Safety Edge$_{SM}$ for the 2 inch HMA wearing course.

Figure 5. General overview showing the wearing course without Safety Edge$_{SM}$. Image taken facing the northbound direction around station 385+38, the beginning of section 2.

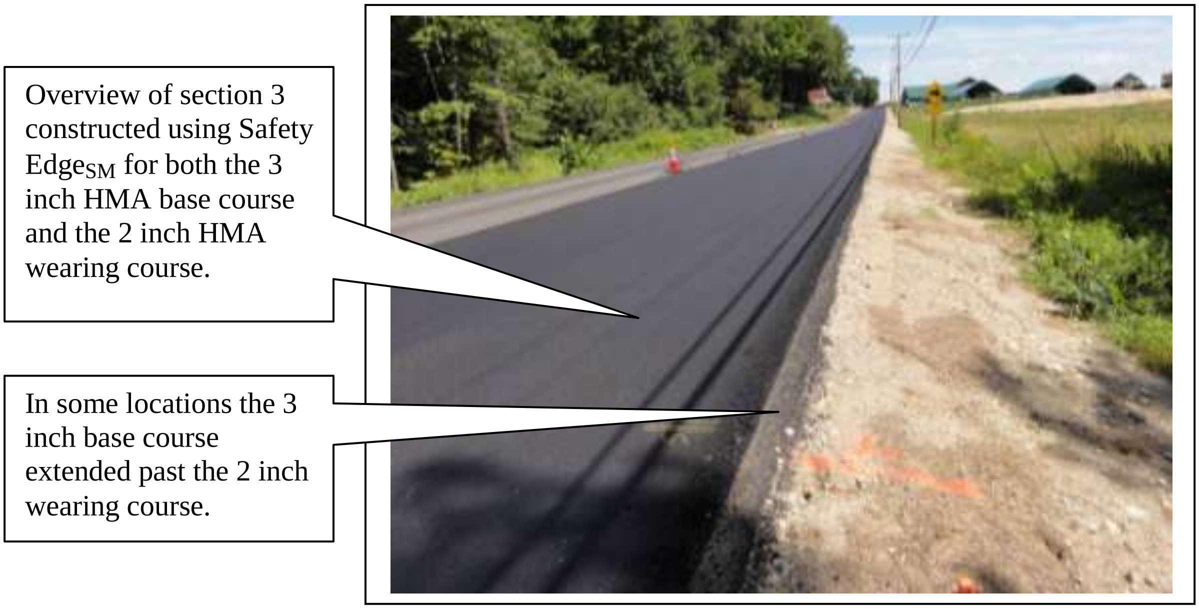


Figure 6. General overview showing the wearing course with Safety Edge$_{SM}$. Image taken facing the northbound direction around station 406+15, the end of section 3 (image shows the end of the section and the pavement north of the section).

Slope Measurements

Slope measurements were taken using a straight-edge to measure the width and thickness of the taper of the Safety Edge$_{SM}$ (refer to Figure 7). The average slope of the Safety Edge$_{SM}$ paved using the Advant-Edger was 54° and that using the TransTech device was 45°. All slope measurements are listed in Table A-1 in Appendix A. Figure 8 shows a comparison between the slope of the Safety Edge$_{SM}$ and mat thickness at the edge for the two test sections and for the centerline notched joint edge. As shown, there appears to be no correspondence between mat thickness and the slope of the Safety Edge$_{SM}$.

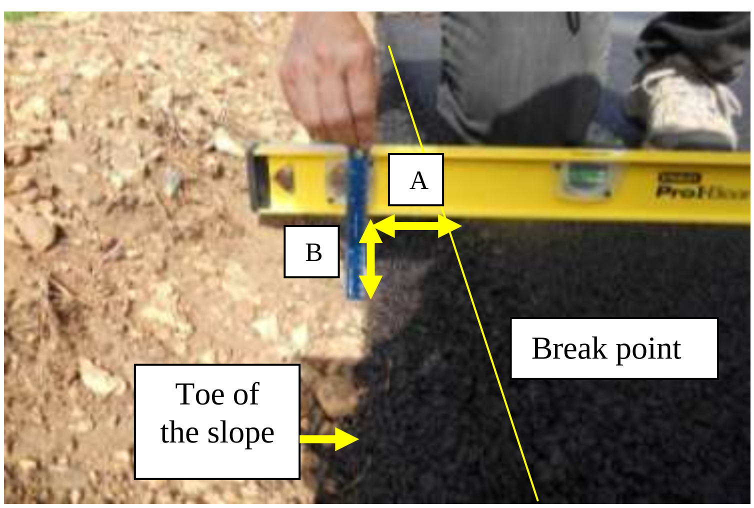


Figure 7. Measurement of Safety Edge$_{SM}$ Angle.

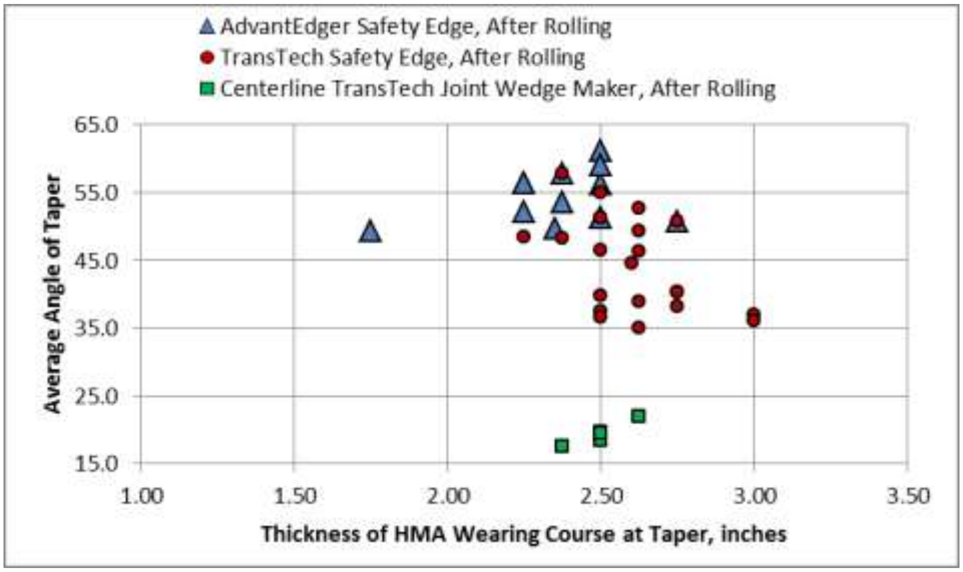


Figure 8. Comparison of the Safety Edge$_{SM}$ slope and thickness of the HMA adjacent to edge of HMA wearing course.

Other slope measurements were made at random along the Safety Edge$_{SM}$ in other areas of the project, and the results were the same as for the specific Safety Edge$_{SM}$ sections established for future performance reviews. The slope of the Safety Edge$_{SM}$ was steeper than what was planned, particularly for the Advant-Edger. The slope measurements were variable, because it was difficult to locate the end of the Safety Edge$_{SM}$ in areas where some of the HMA mixture was under the screed end plate.

The TransTech Notched Wedge Joint Maker used for the centerline appears to be capable of paving with shallow slopes; however, these were at the pavement centerline with good uniform support from the underlying pavement layer(s) and not at the edge of the pavement, where the support from the lower layers during compaction is expected to be less.

The change in the slopes of the Safety Edge$_{SM}$ and thickness at the Safety Edge$_{SM}$ was also evaluated as a function of the passes of the individual rollers for the section pavement using the TransTech Shoulder Wedge Maker (Refer to Figure 9).

Immediately behind the screed, and prior to the rolling of the HMA mat, the average slope was 30°. After the first pass of the breakdown roller, the average slope increased to 33°. There was a corresponding increase in average thickness (by about 0.5 inches) at the edge since the first pass of the breakdown roller was approximately 3 inches from the edge, resulting in some HMA wearing course material being shoved up near the edges. Following the second pass of the breakdown roller the average slope increased to 35°. The HMA thickness near the Safety Edge$_{SM}$ was now reduced to an average value of 2.6 inches (from 3.5 inches) due to the fact that the second pass of the breakdown roller was 1 to 2 inches over the edge.

After two passes of the intermediate rubber tire roller (which did not go over the edge in either of the two passes but was approximately 3 inches from the edge), the average slope of the Safety Edge$_{SM}$ increase to 41°. There was a slight increase in thickness of the HMA mat near the Safety Edge$_{SM}$ from 2.6 inches to 2.9 inches. Following the first pass of the finish roller (over the edge) the HMA mat thickness was reduced to an average value of 2.6 inches. The average slope of the Safety Edge$_{SM}$ was 42°.

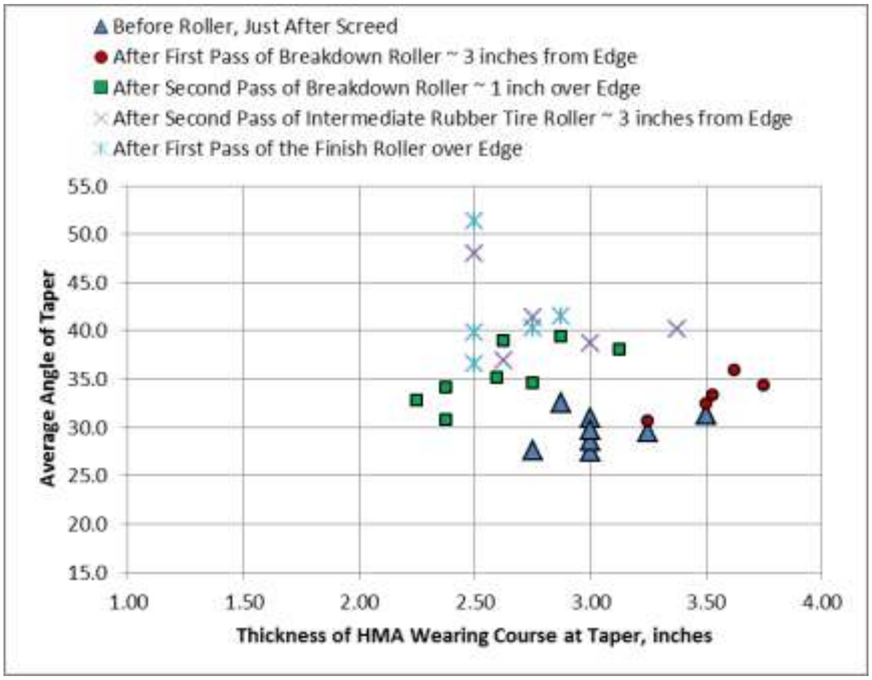


Figure 9. Effect of rolling on the angle of taper and the thickness of HMA wearing course at the taper.

<u>Cores</u>

A total of twelve cores were drilled along the project for the Safety Edge$_{SM}$ study. For each of the three sections (two Safety Edge$_{SM}$ and one control) four cores were taken at two stations. One core was taken close to the edge and the second core was taken 3 feet from the edge. Prior to coring, percent compactions were measured using the TransTech PQI 301 at the core locations. These cores were taken to measure the bulk specific gravity and percent compactions of the compacted HMA mix for developing a correction factor for the PQI gauge readings taken adjacent to the edge and within the center of the mat.

Two cores were also taken at the centerline to obtain the percent compactions near the centerline taper constructed using the TransTech Notched Wedge Joint Maker. In addition, for calibration of field PQI measurements to core percent compactions, three cores were drilled by the contractor.

Table A-2 in Appendix A includes a summary of these test results and bulk specific gravities (saturated surface dry) converted to percent compactions. Figure 10 compares the core percent compactions taken along the edge and near the center of the steel drum roller for the Safety Edge$_{SM}$ and non-Safety Edge$_{SM}$ sections. As expected the compactions (and densities) near the center of roller are significantly higher than along the edge of the mat (unconfined edge). More importantly, the core percent compactions (and densities) taken along the pavement's edge are consistently higher for the Safety Edge$_{SM}$ section than for the non-Safety Edge$_{SM}$. These results suggest that the Safety Edge$_{SM}$ is providing better confinement for rolling an unconfined edge of the mat.

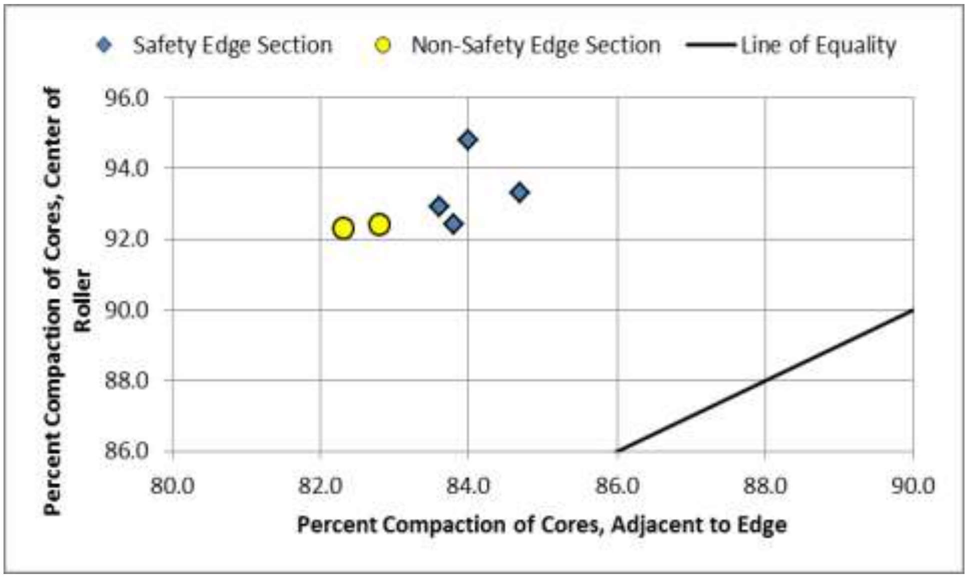


Figure 10. Comparison of core percent compactions (densities) adjacent to the edge of pavement and the near center of the roller.

PQI Percent Compaction (Density) Results

Percent compaction measurements were made with a TransTech PQI 301 gauge. Two readings were recorded at each station or location. One reading was made at a point adjacent to the Safety Edge$_{SM}$ and one was made at a distance of 3 feet from the Safety Edge$_{SM}$ (near the center of the steel drum roller). The PQI gauge readings are listed in Table A-3 in Appendix A.

PQI readings were taken at the locations of each core. Figure 11 shows a comparison of the PQI percent compaction measurements and percent compactions measured on the cores. As shown, there is close correspondence between the PQI and core percent compactions for locations away from the Safety Edge$_{SM}$. However, for locations close to the Safety Edge$_{SM}$, the lab percent compactions (and densities) were substantially lower than that measured using the PQI. This could be due to the fact that the PQI was calibrated for the higher mat densities and not for the lower densities at the edges. Adjustment factors were determined for the PQI percent compaction readings taken at the Safety Edge$_{SM}$ and near the center of the steel drum roller being used to compact the HMA mat. The adjustment factors are included in

Table A-2 in Appendix A and are used to adjust the PQI readings. The following summarizes the factors determined for this project.

Location	Adjustment Factor
Near Center of Steel Drum	0.997
Adjacent to Safety Edge$_{SM}$	0.914

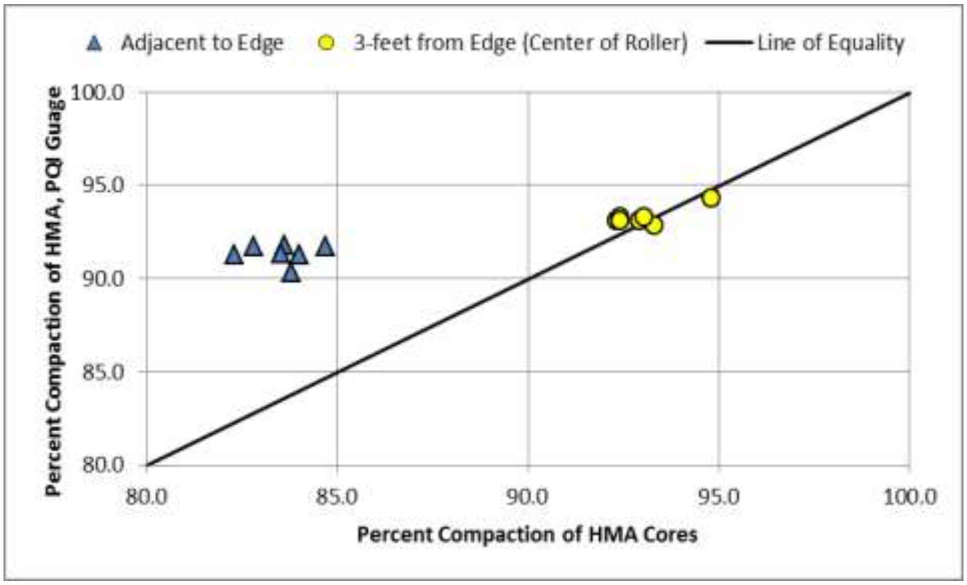


Figure 11. Comparison of the PQI percent compaction readings and percent compactions measured on cores recovered from the HMA wearing course.

The adjusted or corrected percent compactions using the correction factors are also listed in Table A-3 in Appendix A. These factors were used to adjust the PQI gauge readings to be consistent with the densities that would be measured in the laboratory.

Figure 12 shows a comparison of the adjusted PQI gauge readings taken adjacent to the Safety Edge$_{SM}$ and in the center of the vibratory steel wheel roller. As shown in the figure, the percent compaction near the edge (unconfined edge) for both the Safety Edge$_{SM}$ sections and the control section is substantially lower than the percent compaction at the center of the roller (confined edge).

The other important observation from this data is that there is no statistical difference between the percent compactions of Safety Edge$_{SM}$ sections and the control section near the edge. This may likely be due to the fact that the PQI was not calibrated to measure percent compactions at the edges. The raw PQI data (without the adjustment using core data) also reveals no statistical difference between the three sets of percent compactions.

Finally there is a small overall trend of higher percent compactions near the edges for areas with higher percent compactions near the center of the roller. This may be a result of local correlations in HMA properties, HMA thicknesses, compaction energies, and support conditions.

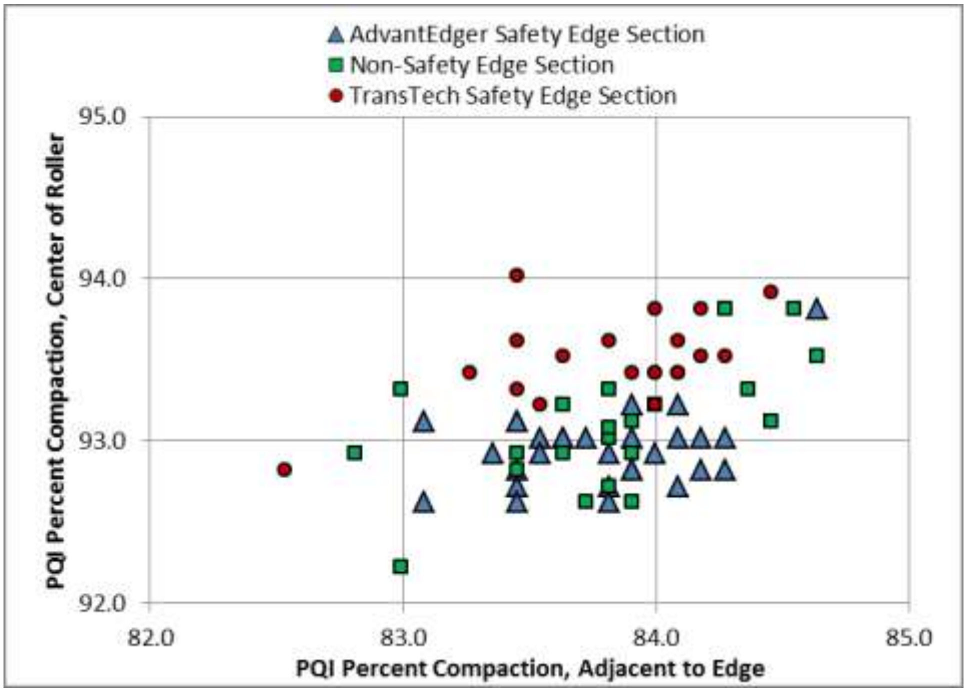


Figure 12. Comparison of the adjusted PQI percent compaction readings between the areas adjacent to the edge and center of the steel drum roller.

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

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

Safety Edge$_{SM}$ for Both HMA Lifts

The Advant-Edger was used to pave the first 3 inch HMA 19 mm base course on the compacted variable thickness (nominal thickness of 18 inches for grade improvement) Type D aggregate subbase. Figure 13 shows the HMA placed on top of the Type D aggregate subbase. Both the Advant-Edger and the TransTech Safety Edge$_{SM}$ devices were used to pave the second 2 inch HMA 12.5 mm wearing course. Each side of the road had to be widened by about 8 inches to accommodate the Safety Edge$_{SM}$ without reducing pavement width. Figure 14 shows the edge of both lifts.

While paving the 3 inch HMA base course a line in the middle of the angled edge was made by the Advant-Edger. The material to the right of this line is loose. It would seem that the 3 inch mat thickness was too much for the Safety Edge$_{SM}$ device. A slight adjustment to the angle was made by spot welding a shim to the back of the Advant-Edger.

Figure 13. Paving the lower 3 inch HMA 19 mm base course with the Advant-Edger on the compacted Type D aggregate subbase.

Both the 3 inch HMA 19 mm base course and the 2 inch HMA 12.5 mm wearing course were paved using a Safety Edge$_{SM}$. However, the Safety Edge$_{SM}$ for the lower lift at many locations did not appear to have a distinct slope.

Figure 14. Both HMA lifts were paved using a Safety Edge$_{SM}$ device.

Transition from Safety Edge$_{SM}$ to non-Safety Edge$_{SM}$

The edge of the wearing course placed without a Safety Edge$_{SM}$ had loose HMA material whereas the shape of the Safety Edge$_{SM}$ was smoother and uniform prior to rolling. After rolling the non-Safety Edge$_{SM}$ still had loose HMA material and the shape Safety Edge$_{SM}$ was still uniform but increased in slope. Figure 15 shows the appearance of the Safety Edge$_{SM}$ and non-Safety Edge$_{SM}$ sections. A close view of the loose-uncompacted HMA at the edge of the non-Safety Edge$_{SM}$ section is shown in Figure 16. One of the benefits of the Safety Edge$_{SM}$ is a relatively smooth edge of pavement.

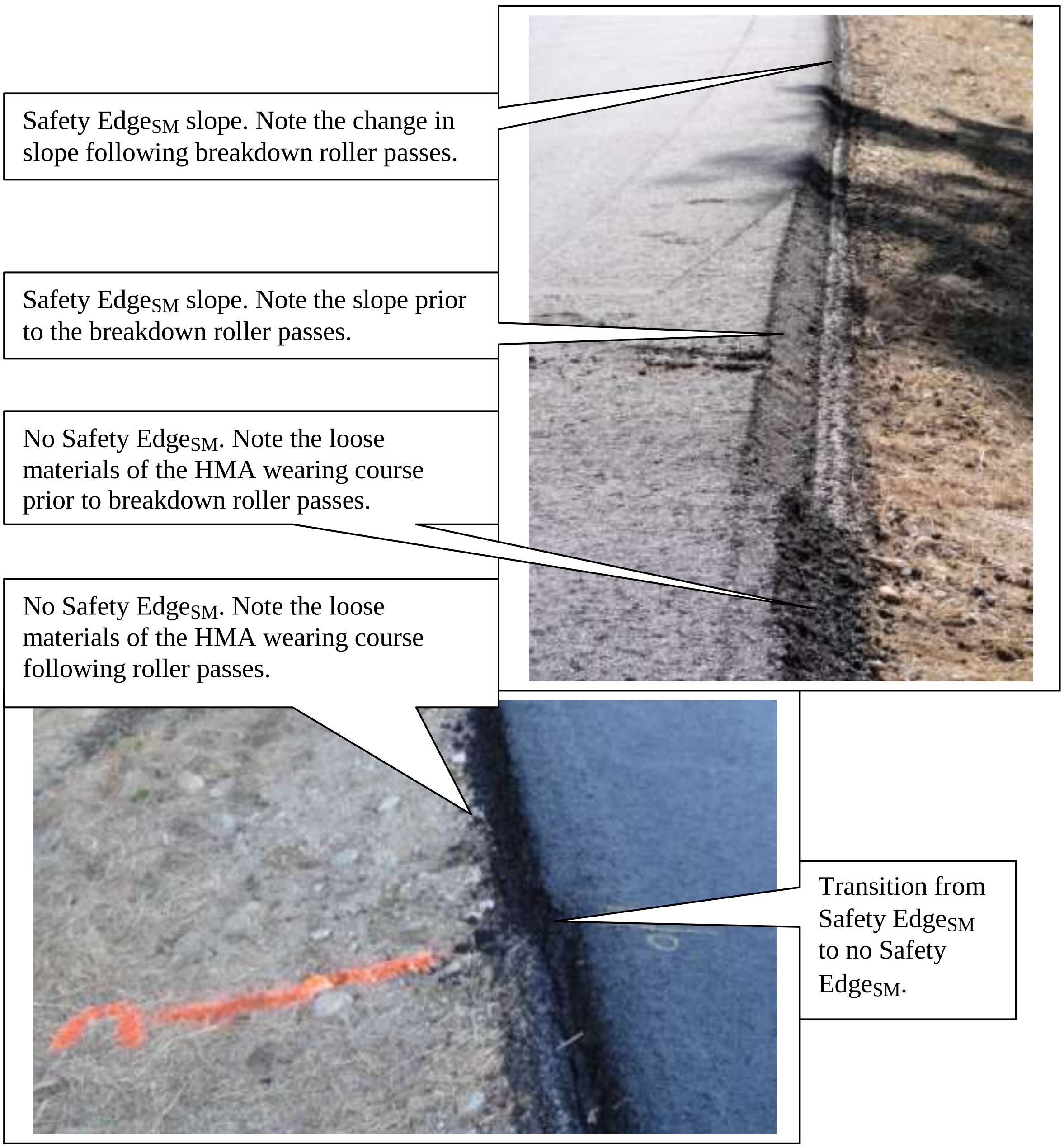
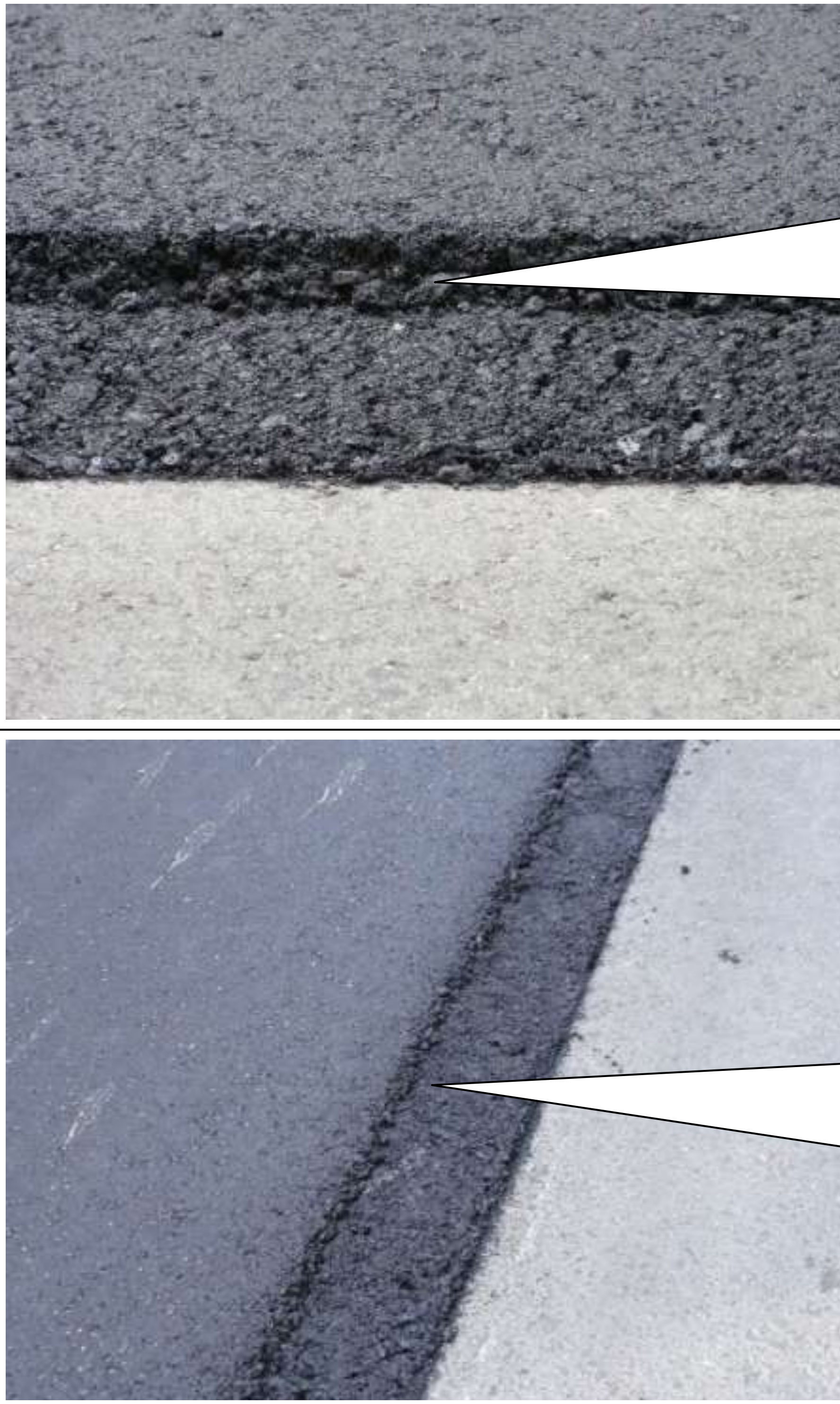


Figure 15. Appearance of the wearing course of the Safety Edge$_{SM}$ and non-Safety Edge$_{SM}$ sections.

Figure 16. Non-Safety Edge$_{SM}$ control section showing the lack of density at edges even after roller passes.

Centerline Joint Using the TransTech Notched Wedge Joint Maker

This project also included use of the TransTech Notched Wedge Joint Maker for the centerline joint (which is expected could be adapted to form a Safety Edge$_{SM}$). Figure 17 shows the vertical edge of the centerline joint is slightly reduced after rolling leaving behind an easily mountable edge for vehicles.



Close-up view of the centerline edge created by the TransTech Notched Wedge Joint Maker immediately behind the screed. Note that the edge has both a vertical portion and a sloped

Following passes of the breakdown roller, the vertical portion of the centerline edge collapses to some extent into the sloped portion leaving behind a recoverable edge.

Figure 17. Centerline joint paved using the TransTech Notched Wedge Joint Maker before and after breakdown roller passes.

The centerline joint for both the 3 inch HMA 19 mm base course and the 2 inch HMA 12.5 mm wearing course was paved using the TransTech Notched Wedge Joint Maker. MaineDOT does not have a specific HMA longitudinal density specification. The conventional density testing procedures require cores at least 9 inches from the centerline joint. As part of the quality control plan, the contractor also cut cores on the notched wedge joint, after both lanes were paved, to determine the density achieved. In their quality control plan, the contractor RC and Sons Paving states:

> "At areas where the wedge has been damaged and found to be unacceptable: these areas will be isolated, saw cut and the wedge removed, no additional pavement will be added. If during the paving process, the wedge does not perform as expected and there is an abnormal amount of breakage because of yielding gravel base or any other cause, if no other remedy is available, the use of the notched wedge joint will be suspended."

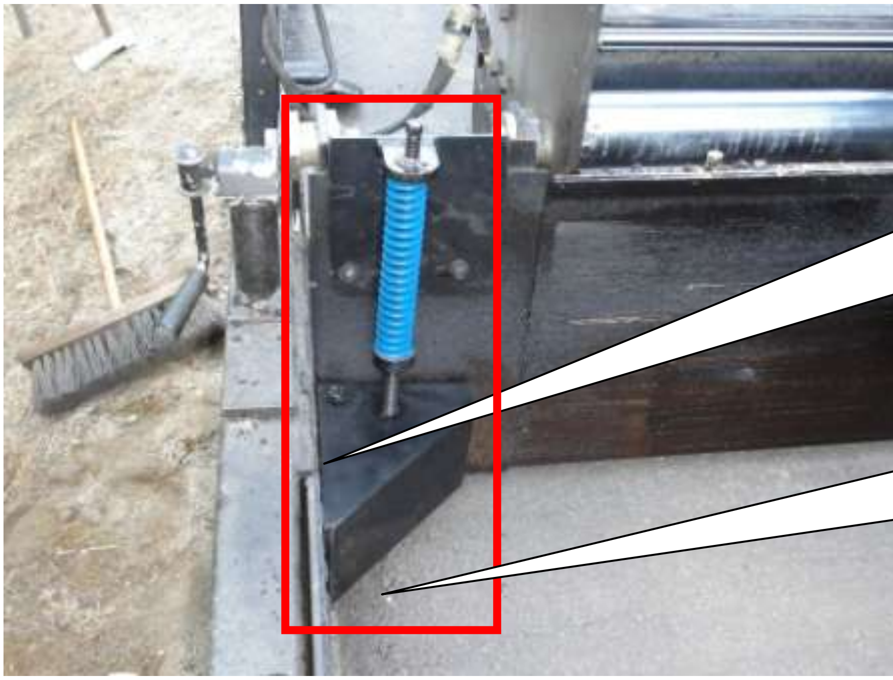
For a very short section of the project, MaineDOT and the contractor experimented with the TransTech Notched Wedge Joint Maker by raising it a bit to examine if a Safety Edge$_{SM}$-like shape could be constructed. The final edge looked like it could be recoverable for an errant vehicle tire.

Placement/Paving Operations

Overall observation of HMA placed on August 11 and August 12 was the surface appeared consistent without segregation. Mix considered "normal" not highly stable and not highly tender. Figure 18 shows the paver in operation. Figure 19 shows both the TransTech Shoulder Wedge Maker and the TransTech Notched Wedge Joint Maker attached to the screed.

End of paver material feed auger was about 2.5 feet from end gate on the Safety Edge$_{SM}$ side. Paver equipment manufacturers recommend that the auger be no more than 18 inches from end gate.

Figure 18. Paving operations showing the Safety Edge$_{SM}$ paved using the Advant-Edger and the centerline joint paved using the TransTech Notched Wedge Joint Maker.



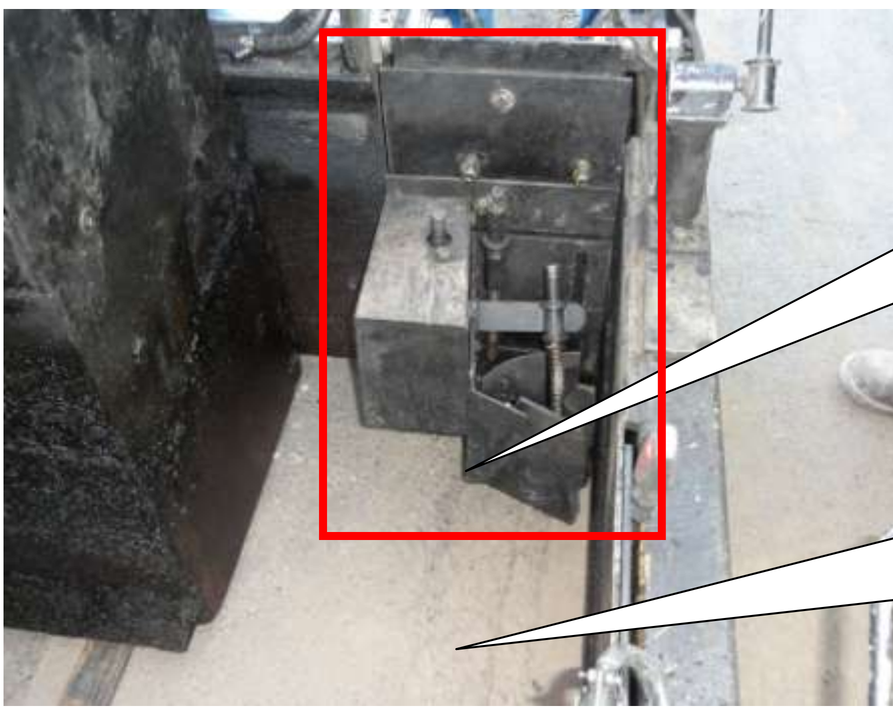


Figure 19. TransTech Shoulder Wedge Maker and TransTech Notched Wedge Joint Maker attached to the screed.

The following summarizes some of the observations and comments made by construction personnel on the use of the Safety Edge$_{SM}$ devices:

- MDOT Project Manager
  - Safety Edge$_{SM}$ application – project has shoulder backing material to be placed against pavement, so not sure Safety Edge$_{SM}$ is needed for this project.
  - TransTech Notched Wedge Joint Maker – the TransTech Notched Wedge Joint Maker used along the project centerline created a good shape for traffic to run on and good density – thought it could be adjusted to be used to make a Safety Edge$_{SM}$.
  - Production: Safety Edge$_{SM}$ had no negative impact on production.
- Project Foreman
  - Safety Edge$_{SM}$ device – suggests putting a sleeve around the Safety Edge$_{SM}$ spring to keep HMA material out of this area so it does not get into the threads and make difficult to adjust the Safety Edge$_{SM}$ vertically.
  - Safety Edge$_{SM}$ – likes the shape of the Safety Edge$_{SM}$ under the screed as compared to without the Safety Edge$_{SM}$.
  - Device comparisons – the Advant-Edger does not create the desired Safety Edge$_{SM}$ slope as well as the TransTech device, but believes using the Safety Edge$_{SM}$ is better than not using the Safety Edge$_{SM}$ for pavement performance.
  - Production – Safety Edge$_{SM}$ had no negative impact on production.
- Screed operator
  - Safety Edge$_{SM}$ device – adding vibration to the device would likely make it better.
  - Device comparisons – TransTech device provides better compaction than Advant-Edger

<u>Compaction Operations</u>

Visual observations of the mat under the roller suggested that the roll down appeared "normal" and generally speaking there were no signs of any tearing or shoving (except for one 50-100 ft portion of the project as described in this section).

Three rollers were used to compact the 2 inch HMA 12.5 mm wearing course. The breakdown roller was a Caterpillar CB-534D, the intermediate roller was a Caterpillar PS-360C, and the finish roller was a Hamm HD-90.

The Caterpillar steel wheel breakdown roller shown in Figure 20 was a 10-ton roller with 66 inch drum width. It was operated in the high frequency, low amplitude vibratory mode, with only 1 drum vibrating due to the roller "creeping" across the mat. The breakdown roller was operated close behind the paver.

- Caterpillar steel wheel roller; high frequency, low amplitude (only 1 drum vibrating); breakdown roller:
  - First pass (forward) with vibrations and 2 to 6 inches off centerline edge joint.

- Second pass (reverse) with vibrations and extended over the centerline edge joint by about 2 to 6 inches.
- Third pass (forward) with vibrations and extended over the centerline edge joint by about 2 to 6 inches.
- Fourth pass (reverse) with vibrations in the middle of the lane.
- Fifth pass (forward) with vibrations in the middle of the lane.
- Sixth pass (reverse) with vibrations in the middle of the lane.
- Seventh pass (forward) with vibrations and 2 to 6 inches off edge joint.
- Eight pass (reverse) with vibrations and extended over the edge joint by about 2 to 6 inches.
- Ninth pass (forward) with vibrations and extended over the edge joint by about 2 to 6 inches.

The above rolling pattern was performed on both the Advant-Edger section (section 1) and the control section (section 2) on August 11. General observation of edge (both the Advant-Edger section and non-Safety Edge$_{SM}$ section) during rolling was that the top of the mat edge was pushing out by approximately 1 inch.

During the paving on August 12, the HMA was pushing, shoving, and tearing under the breakdown roller about 500 ft after paving started. It appeared to be a classic "tender zone" problem. Mat temperature was about 185º. Mix in the paver hopper was about 290º and immediately behind the screed was 255-260º. Contractor modified rolling pattern after this and changed breakdown roller to 6 passes to cover the road and not 9 passes.

- Caterpillar steel wheel roller; high frequency, low amplitude (only 1 drum vibrating); primary or breakdown roller:
    - First pass (forward) with vibrations and 2 to 6 inches off centerline edge joint.
    - Second pass (reverse) with vibrations and extended over the centerline edge joint by about 2 to 6 inches.
    - Third pass (forward) with vibrations in the middle of the lane.
    - Fourth pass (reverse) with vibrations in the middle of the lane.
    - Fifth pass (forward) with vibrations and 2 to 6 inches off edge joint.
    - Sixth pass (reverse) with vibrations and extended over the edge joint by about 2 to 6 inches.

The above breakdown rolling pattern was performed on the TransTech section (section 3) August 12.

Figure 20. Steel wheel roller used in the breakdown position to compact the 12.5 mm HMA mix.

The Caterpillar intermediate rubber tire pneumatic roller shown in Figure 21 was operated right behind the breakdown roller along most of the areas. The roller had 4 tires (15 inch footprint with 9.5 inch gap between tires) in front and 3 tires (15 inch footprint with 9.5 inch gap between tires) in back to cover the gaps between the front tires. The roller was operated without water ballast; the operator indicated that the tire pressure was about 85 psi (pressure set to give good compaction and still allow the finish roller to remove the intermediate roller tire marks).

- Caterpillar intermediate rubber tire pneumatic roller:
  - First pass is on the centerline hanging over about 2 inches.
  - 6 passes to traverse across the pavement such that with each pass the roller moves over about 12 inches.
  - Another 6 passes to traverse back across the pavement.
  - Roller does not get any closer to outside edge than 6 inches (so pneumatic roller does not roll the outside edge where the Safety Edge$_{SM}$ is located).

Figure 21. Rubber tire pneumatic roller used in the intermediate position.

The Hamm finish roller shown in Figure 22 was operated in the static mode. The finish roller operator waited to roll the mat until the temperature was less than 130º at the edges of the mat. The following summarizes the number of passes and coverage used by the finish roller:

- Hamm steel wheel roller; static mode; finish roller:
  - First pass (forward) without vibrations and extended over the centerline edge joint by about 2 to 6 inches.
  - Second pass (reverse) without vibrations and extended over the centerline edge joint by about 2 to 6 inches.
  - Third pass (forward) without vibrations in the middle of the lane.
  - Fourth pass (reverse) without vibrations in the middle of the lane.
  - Fifth pass (forward) without vibrations and extended over the edge joint by about 2 to 6 inches.
  - Sixth pass (reverse) without vibrations and extended over the edge joint by about 2 to 6 inches.

Figure 22. Steel wheel roller used in the finish position.

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:

- This project on SR 117 in Turner, Maine, includes construction of Safety Edge$_{SM}$ during HMA paving using two types of Safety Edge$_{SM}$ devices – the Advant-Edger and the TransTech Shoulder Wedge Maker. In addition, the project also includes paving using a TransTech Notched Wedge Joint Maker for the centerline. Both the 3 inch HMA 19 mm base course and the 2 inch HMA 12.5 mm wearing courses were paved using a Safety Edge$_{SM}$ device and the centerline notched wedge joint maker, except for a short "control" section where the 2 inch HMA 12.5 mm wearing course was paved without the use of a Safety Edge$_{SM}$.
- Each side of the road had to be widened by approximately 8 inches to accommodate the Safety Edge$_{SM}$ without reducing pavement width. The Safety Edge$_{SM}$ had no negative impact on production.
- Both the foreman and screed operator believed that the TransTech Shoulder Wedge Maker created a better slope and provided better compaction than the Advant-Edger. This was also confirmed by the field measurements of the Safety Edge$_{SM}$ slope following rolling.
- Although both the Advant-Edger and TransTech Shoulder Wedge Maker devices produced an edge with a slope of 30º immediately behind the screed, because of the difference in device pressure and shape, the slope of the Safety Edge$_{SM}$ made with the Advant-Edger increased to an average of 54º and that of the Safety Edge$_{SM}$ made with the TransTech device increased to an average of 45º after rolling. It should be noted that the HMA mix for the surface wearing course was "normal" and not too tender or too stiff, and using a mix with a different level of stiffness could result in different values.
- The slope of the centerline edge made with the TransTech Notched Wedge Joint Maker had an average value of 19º. Field personnel believed that the TransTech Notched Wedge Joint Maker could be adjusted to form a 30º Safety Edge$_{SM}$ slope.
- The core percent compaction of the HMA mixture adjacent to the Safety Edge$_{SM}$ was found to be slightly higher than along the unconfined edge in the areas placed without the Safety Edge$_{SM}$ – a positive benefit from the Safety Edge$_{SM}$ device. However, there was no statistical difference in the PQI percent compaction measurements between the HMA mixture adjacent to the Safety Edge$_{SM}$ and the unconfined edge in the control areas placed without the Safety Edge$_{SM}$.

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 summary and listing of all field measurements recorded during the paving operations. These data are also included in the detailed evaluation forms for the Safety Edge$_{SM}$ demonstration projects.

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

Effect of edge device

Section Identifier	Core/Section ID	Station	AdvantEdger Safety Edge		
			Width of Taper	Thickness	Slope
Area #1; AdvantEdger Safety Edge Section	1A and 1B	100			
		225	1.38	2.50	61.2
		250	2.00	2.50	51.3
		275	1.50	2.25	56.3
		300	2.25	2.75	50.7
		325	1.68	2.50	56.2
		350	2.00	2.35	49.6
		375	1.75	2.38	53.6
		400	2.00	2.50	51.3
		425	1.50	1.75	49.4
		450	1.75	2.25	52.1
		475	1.50	2.38	57.7
		500	1.50	2.50	59.0
		525	1.50	2.25	56.3
	2A and 2B	600			
Mean Value			1.72	2.37	54.22
Standard Deviation			0.271	0.234	3.817
Coefficient of Variation			15.8	9.9	7.0

Section Identifier	Core/Section ID	Station	Notched Wedge Maker		
			Width of Taper	Thickness	Slope
Centerline Notched Wedge Maker			6.50	2.63	22.0
			7.00	2.50	19.7
			7.50	2.50	18.4
			7.50	2.38	17.6
Mean Value			7.13	2.50	19.41
Standard Deviation			0.479	0.102	1.919
Coefficient of Variation			6.7	4.1	9.9

Table A-1. Safety Edge$_{SM}$ slope measurements (continued).

Section Identifier	Core/Section ID	Station	TransTech Safety Edge		
			Width of Taper	Thickness	Slope
Area #3; TransTech Safety Edge Section		0	4.00	3.00	36.9
		25	4.13	3.00	36.0
		50	3.25	2.75	40.2
		75	3.75	2.63	35.0
	5A and 5B	100	2.00	2.50	51.3
		125	2.50	2.63	46.4
		150	2.38	2.50	46.5
		175	2.00	2.50	51.3
		200	1.75	2.50	55.0
		225	3.25	2.50	37.6
		250	3.50	2.75	38.2
		275	2.25	2.63	49.4
		300	2.00	2.63	52.7
		325	1.50	2.38	57.7
		350	2.25	2.75	50.7
		375	3.25	2.63	38.9
	6A and 6B	400	3.25	2.75	40.2
		425	2.13	2.38	48.2
		450	3.38	2.50	36.5
		475	2.00	2.25	48.4
		500	3.00	2.50	39.8
Mean Value			2.738	2.601	44.62
Standard Deviation			0.787	0.188	7.092
Coefficient of Variation			28.72	7.23	15.90

Effect of rolling

Section Identifier	Core/Section ID	Station	Width of Taper	Thickness	Slope
TransTech Device - Before Roller, Just After Screed			5.25	2.75	27.6
			5.00	3.00	31.0
			5.75	3.00	27.6
			5.75	3.25	29.5
		372	5.75	3.50	31.3
		384	5.75	3.50	31.3
		412	5.50	3.00	28.6
		421	4.50	2.88	32.6
		435	5.25	3.00	29.7
Mean Value			5.39	3.10	29.91
Standard Deviation			0.435	0.264	1.761
Coefficient of Variation			8.1	8.5	5.9

Table A-1. Safety Edge$_{SM}$ slope measurements(continued).

Section Identifier	Core/Section ID	Station	Width of Taper	Thickness	Slope
After First Pass of Breakdown Roller ~ 3 inches from Edge			5.50	3.50	32.5
		372	5.00	3.63	35.9
		384	5.50	3.75	34.3
		412	5.50	3.25	30.6
		421			
		435			
Mean Value			5.375	3.531	33.32
Standard Deviation			0.250	0.213	2.312
Coefficient of Variation			4.65	6.05	6.94

Section Identifier	Core/Section ID	Station	Width of Taper	Thickness	Slope
After Second Pass of Breakdown Roller ~ 1 inch over the Edge			3.50	2.88	39.4
			4.00	2.75	34.5
			4.00	2.38	30.7
			3.50	2.25	32.7
		372	4.00	3.13	38.0
		384	4.00	2.75	34.5
		412	3.50	2.38	34.2
		421	3.50	2.25	32.7
		435	3.25	2.63	38.9
Mean Value			3.69	2.60	35.07
Standard Deviation			0.300	0.305	3.035
Coefficient of Variation			8.1	11.7	8.7

Section Identifier	Core/Section ID	Station	Width of Taper	Thickness	Slope
After Second Pass of the Rubber Tire Intermediate Roller ~ 3 inches from Edge		372	4.00	3.38	40.2
		384	3.75	3.00	38.7
		412	3.50	2.63	36.9
		421	3.13	2.75	41.3
		435	2.25	2.50	48.0
Mean Value			3.33	2.85	41.01
Standard Deviation			0.682	0.347	4.259
Coefficient of Variation			20.5	12.2	10.4

Table A-1. Safety Edge$_{SM}$ slope measurements (continued).

Section Identifier	Core/Section ID	Station	Width of Taper	Thickness	Slope
After First Pass of the Finish Roller Over Edge		372	3.25	2.88	41.5
		384	3.25	2.75	40.2
		412	3.38	2.50	36.5
		421	3.00	2.50	39.8
		435	2.00	2.50	51.3
Mean Value			2.98	2.63	41.88
Standard Deviation			0.562	0.177	5.596
Coefficient of Variation			18.9	6.7	13.4

Table A-2. PQI percent compaction adjustment ratios; core percent compactions.

Area/Location	Core #	Lane Direction	Station	Type of Section	% Compaction of Cores		PQI 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
Section 1 - AdvantEdger Safety Edge Section	1A 1B	SB	368+53	AdvantEdger	84.7	93.3	91.7	92.9	0.924	1.004
	2A 2B	SB	373+53	AdvantEdger	83.6	92.9	91.8	93.1	0.911	0.998
Section 2 - Control Section (No Safety Edge)	3A 3B	SB	386+38	Non-Safety Edge	82.3	92.3	91.3	93.1	0.901	0.991
	4A 4B	SB	389+38	Non-Safety Edge	82.8	92.4	91.7	93.3	0.903	0.990
Section 3 - TransTech Safety Edge Section	5A 5B	NB	402+12	TransTech	84.0	94.8	91.3	94.3	0.920	1.005
	6A 6B	NB	405+12	TransTech	83.8	92.4	90.3	93.1	0.928	0.992
Mean					83.53	93.02	91.35	93.30	0.914	0.997
Standard Deviation					0.862	0.954	0.558	0.506	0.0111	0.0066
Coefficient of Variation					1.03	1.03	0.61	0.54	1.21	0.66
Centerline Notched Wedge EdgeMaker	Cont.			Notched Wedge	93.0		94.5			
	DOT			Notched Wedge	93.3		94.4			
Contractor Data Used for Calibration of PQI	Cont.					94.0		93.8		
	Cont.					95.0		94.3		
	Cont.					95.0		94.6		

Table A-3. Percent compaction readings made with a TransTech PQI 301 gauge.

			Adjustment Ratios for PQI Gauge:		A=	0.914
					B=	0.997
Location/Area	Core Location		PQI Percent Compactions		Adjusted PQI Values	
			A – Adjacent to Edge	B – 3 feet from Edge	A – Adjacent to Edge	B – 3 feet from Edge
Area #1; AdvantEdger Safety Edge Section		0	92.0	93.0	84.1	92.7
		25	91.3	93.4	83.4	93.1
		50	91.7	93.0	83.8	92.7
		75	91.5	93.3	83.6	93.0
	1A and 1B	100	91.7	92.9	83.8	92.6
		125	92.2	93.3	84.3	93.0
		150	92.6	94.1	84.6	93.8
		175	92.0	93.5	84.1	93.2
		200	92.0	93.3	84.1	93.0
		225	90.9	93.4	83.1	93.1
		250	91.4	93.3	83.5	93.0
		275	92.2	93.1	84.3	92.8
		300	91.3	93.1	83.4	92.8
		325	91.5	93.3	83.6	93.0
		350	91.3	93.4	83.4	93.1
		375	90.9	92.9	83.1	92.6
		400	91.6	93.3	83.7	93.0
		425	91.7	93.2	83.8	92.9
		450	91.8	93.5	83.9	93.2
		475	91.8	93.1	83.9	92.8
		500	91.3	93.0	83.4	92.7
		525	91.2	93.2	83.4	92.9
		550	91.3	92.9	83.4	92.6
		575	91.4	93.2	83.5	92.9
	2A and 2B	600	91.8	93.1	83.9	92.8
		625	91.8	93.3	83.9	93.0
		650	91.9	93.2	84.0	92.9
		675	92.1	93.3	84.2	93.0
		700	92.1	93.1	84.2	92.8
Average Value			91.67	93.23	83.78	92.95
Standard Deviation			0.403	0.239	0.368	0.238
Coefficient of Variation			0.44	0.26	0.44	0.26

Table A-3. Percent compaction readings made with a TransTech PQI 301 gauge (continued).

Area #3; TransTech Safety Edge Section		0	91.7	93.9	83.8	93.6
		25	92.0	93.7	84.1	93.4
		50	91.1	93.7	83.3	93.4
		75	92.1	94.1	84.2	93.8
	5A and 5B	100	91.3	94.3	83.4	94.0
		125	89.7	93.6	82.0	93.3
		150	91.3	93.9	83.4	93.6
		175	91.9	93.5	84.0	93.2
		200	92.2	93.8	84.3	93.5
		225	92.1	93.8	84.2	93.5
		250	92.0	93.7	84.1	93.4
		275	91.3	93.6	83.4	93.3
		300	91.9	93.7	84.0	93.4
		325	91.4	93.5	83.5	93.2
		350	91.8	93.7	83.9	93.4
		375	91.9	93.7	84.0	93.4
	6A and 6B	400	90.3	93.1	82.5	92.8
		425	91.9	94.1	84.0	93.8
		450	92.0	93.9	84.1	93.6
		475	92.4	94.2	84.5	93.9
		500	91.5	93.8	83.6	93.5
Average Value			91.61	93.78	83.73	93.49
Standard Deviation			0.643	0.266	0.587	0.265
Coefficient of Variation			0.70	0.28	0.70	0.28
Area #2; Control No Safety Edge Section		0	91.7	93.0	83.8	92.7
		25	91.3	93.2	83.4	92.9
		50	92.3	93.6	84.4	93.3
		75	91.5	93.2	83.6	92.9
	3A and 3B	100	91.3	93.1	83.4	92.8
		125	91.8	92.9	83.9	92.6
		150	91.8	93.4	83.9	93.1
		175	92.4	93.4	84.5	93.1
		200	92.5	94.1	84.5	93.8
		225	91.9	93.5	84.0	93.2
		250	91.7	93.6	83.8	93.3
		275	92.6	93.8	84.6	93.5
		300	92.2	94.1	84.3	93.8
		325	91.8	93.2	83.9	92.9
		350	91.6	92.9	83.7	92.6
		375	91.9	93.5	84.0	93.2
	4A and 4B	400	91.7	93.3	83.8	93.0
		425	91.5	93.5	83.6	93.2
		450	90.8	92.5	83.0	92.2
		475	90.6	93.2	82.8	92.9
		500	90.8	93.6	83.0	93.3
Average Value			91.70	93.36	83.81	93.08
Standard Deviation			0.543	0.387	0.496	0.385
Coefficient of Variation			0.59	0.41	0.59	0.41