EVALUATION OF THE SAFETY EDGE SM APPLICATION IN OREGON

Final Report

SPR 714

Oregon Department of Transportation

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by

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16. Abstract

This report summarizes a recent assessment of the Safety Edge SM that was performed to determine the feasibility of using this pavement edge treatment on Oregon construction projects. The report includes a review of research that has been published about the performance of the Safety Edge SM. The report also incorporates a state of practice review of the states currently using or considering the use of this treatment. Specifications, standard drawings, or technical documents developed by other agencies are included in the report appendix.

ODOT performed one demonstration project and assessed the ease of use, time to train, and issues related to deploying the Safety Edge SM treatment in Oregon. It was found that the initial mounting of the shoe on the paving equipment was straightforward and could be done with limited training required. The site selected was free of guardrail and driveways, so the researchers could not assess functionality of the shoe at locations with obstructions.

As a result of this research effort, the research team developed draft language for a sample Oregon specification for the Safety Edge SM as well as a Technical Bulletin that addresses key issues related to benefits, cost, deployment, and similar for the Safety Edge SM. Though the Safety Edge SM will likely benefit most pavement projects, it should particularly be considered if the following conditions are present:

- A history of run-off-the-road crashes;
- Numerous sharp horizontal curves subjected to off-road tracking;
- Locations subject to roadside erosion; or
- Locations where vehicles can be expected to frequently exit and re-enter the active lane (i.e. rural mailbox clusters).

It should be acknowledged that the guidance included in the Technical Bulletin as well as the details given in the draft specification are based on the findings of the current research effort. As projects begin to incorporate use of the Safety Edge SM and ODOT staff and contractors become more familiar with the application process, it is expected that the specific guidance may be modified

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
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	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	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	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit	(F-32)/1.8	Celsius	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
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	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
m^2	meters squared	1.196	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius	1.8C+32	Fahrenheit	°F

*SI is the symbol for the International System of Measurement

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DISCLAIMER

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1.0 INTRODUCTION

Lane departure crashes in which a vehicle unintentionally departs from its lane and crashes with another vehicle, rolls over, or hits a fixed object represent from 60 to 80% of rural Oregon crashes. Often these collisions involve a vehicle that runs off the road or at least has two tires that exit the highway. It is preferred, of course, for such a vehicle to safely return to the road without incident or injury. These run-off-road crashes, though present in urban environments, are overly represented in rural areas. In 2007, total fixed object crashes in Oregon rural areas accounted for approximately 69% of the rural crashes with an additional 12% of crashes involving an overturned vehicle. While this translates into approximately 81% of rural crashes associated with these two crash types, it is even more alarming that 89% of the rural **fatal crashes** and 89% of the rural **injury crashes** in 2007 were associated with these two specific collision types. This trend has remained consistent for many years for Oregon as well as many states that have a high number of rural roads.

In 2005 the Highway Safety Engineering Committee allocated $7.5 million to 14 safety projects designed to reduce these run-off-road crashes. The 14 safety projects included installation of rumble strips, cable median barrier, durable pavement markings, precast concrete median barrier, guardrail, and a curve realignment project. These projects are now completed or nearing completion and appear to be making a difference in reducing roadway departure crashes. However, one relatively low cost solution known as the Safety Edge $_{SM}$ has yet to be widely used in Oregon. The Safety Edge $_{SM}$ is a paving technique that improves the angle between the roadway edge and graded shoulder to minimize the vertical pavement edge drop-off and improve the chance of errant vehicle recovery. Safety Edge $_{SM}$ can be applied to asphalt as well as portland cement concrete paving treatments. An added advantage of an asphalt Safety Edge $_{SM}$ is that pavement at the edge of the road is compacted using a simple device that attaches to standard paving equipment. As a result, this pavement edge grading technique also provides stability to the road by minimizing erosion and by protecting the edge of the road so that drainage has a direct path away from the road. The most frequently cited advantage of the Safety Edge $_{SM}$ is that it can minimize the likelihood of a crash occurring if the vehicle leaves the road. This affect results in a reduction in the severity of run-off-road crashes.

The Federal Highway Administration has identified the Safety Edge $_{SM}$ to be a proven safety countermeasure. Additionally, several states have adopted the Safety Edge $_{SM}$ as standard practice for certain types of roads. The purpose of this research effort, therefore, was to explore the feasibility of utilizing the Safety Edge $_{SM}$ application in the state of Oregon.

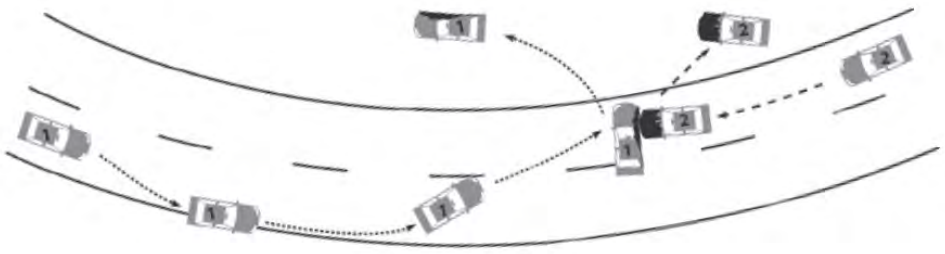
The objectives of this Safety Edge $_{SM}$ research project included:

- Evaluation of the cost, benefit, environmental considerations, and feasibility of utilizing the Safety Edge $_{SM}$ on pavement preservation projects in Oregon;
- Identification of common characteristics of locations where the Safety Edge $_{SM}$ could be deployed based on pavement design, lane width, shoulder width, roadside environment, traffic volume, crash history, and similar characteristics; and
- Development of guidance for the deployment of the Safety Edge $_{SM}$ by the Oregon Department of Transportation (ODOT) and local agencies in Oregon.

This report summarizes the findings of this research effort. It includes a literature review of current Safety Edge $_{SM}$ knowledge, an overview of how the Safety Edge $_{SM}$ is used by several states, and content including Oregon-specific items such as sample language for the Oregon standard specifications and a draft Technical Bulletin developed to aid with Safety Edge $_{SM}$ deployment in Oregon. The appendix includes example specifications or special provisions, technical memorandums, design guidance, and standard drawings for states active with the deployment of the Safety Edge $_{SM}$.

2.0 LITERATURE REVIEW

In Oregon, 66% of fatal crashes are roadway departure crashes (*FHWA 2010a*). The Safety Edge $_{SM}$ brochure provided by the Federal Highway Administration (FHWA) (*2010b*) states that the steep drop-off at the pavement edge is a major contributor to these fatal crashes. At a location with an edge drop-off, a driver who runs off the roadway and tries to steer back onto the active roadway may be prevented from returning by the sharp vertical edge of the pavement. The vehicle may overturn, enter the opposing lane and collide with the oncoming vehicle, impact fix objects, or be involved in a variety of other crash types. Figure 2.1 shows a typical crash caused by this abrupt vertical pavement edge. Crashes attributed to the steep vertical pavement edge are likely to be more severe than other similar crashes when the pavement edge is flush and traversable.



Source: FHWA 2010b

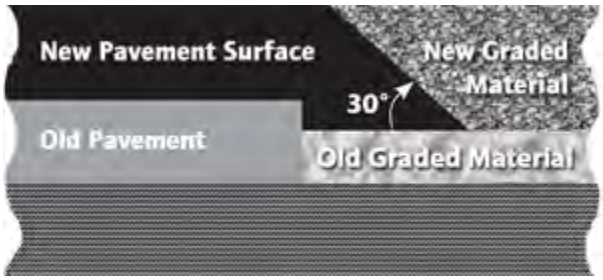
Figure 2.1: Typical Graph of Vertical Pavement Edge Related Crashes

A vertical pavement edge can be created in many ways. A drop-off can occur as the result of pavement overlay projects or may develop when the pavement edge becomes exposed due to shoulder deterioration. The *Safety Edge $_{SM}$ Pavement Edge Treatment* Brochure (*FHWA 2010b*) recommends a simple and effective solution to prevent the steep pavement edge. This strategy, known as the Safety Edge $_{SM}$, is a 30-degree wedge along the pavement edge. The Safety Edge $_{SM}$ is expected to enhance the longevity of the pavement and reduce roadway departure crashes. Many states have started systematically using the Safety Edge $_{SM}$ in their resurfacing and reconstruction projects.

To meet the goal of the Oregon Transportation Safety Action Plan (TSAP) (*ODOT 2004*), the Roadway Departure Safety Implementation Plan (*FHWA 2010a*) indicated that the state of Oregon needs to reduce the roadway departure fatalities on Oregon highways by 20%. The use of the Safety Edge $_{SM}$ for resurfacing projects may help Oregon to meet this requirement. This literature review is a first step to help ODOT determine where, when, and how to implement this low-cost pavement edge treatment.

2.1 DESCRIPTION OF THE SAFETY EDGE SM

The Safety Edge SM is a 30-degree pavement wedge along the pavement edge (*FHWA 2010b*). This wedge provides a smooth, strong, and durable transition between the pavement and the graded materials. The 30-degree angle is an optimal angle to reduce roadway departure crashes. Figure 2.2 depicts the typical cross section of the Safety Edge SM.

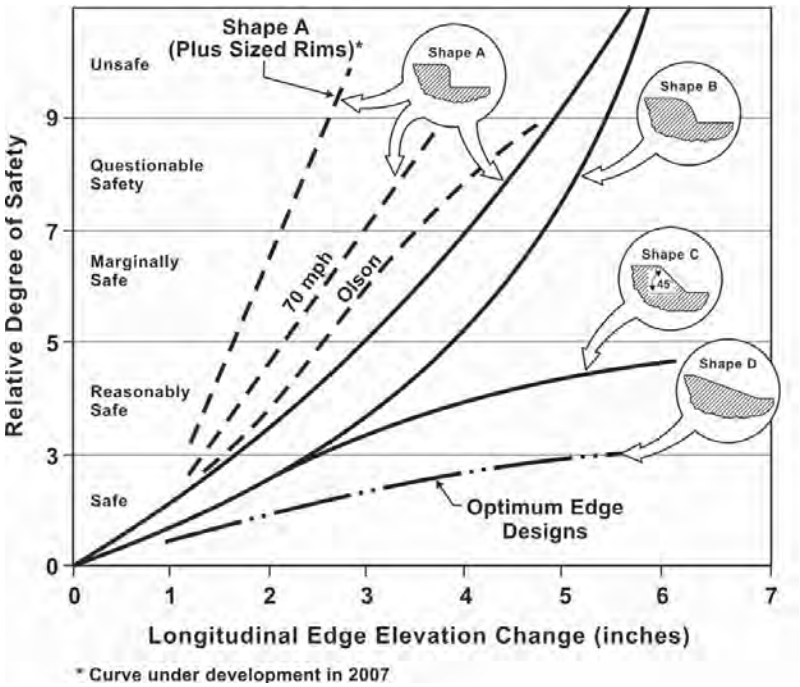


Source: FHWA 2010b

Figure 2.2: Cross Section of the Safety Edge SM

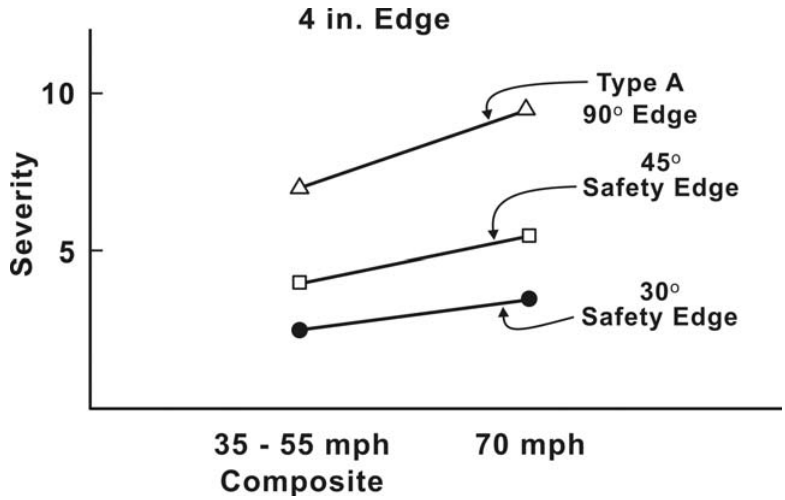
2.2 SAFETY EFFECT EVALUATION

Ivey et al. (*2009*) used the relative degree of safety, in terms of the subjective severity level, to show the expected safety influence for different pavement edge types. Figure 2.3 depicts this relative degree of safety for pavement edge configurations. Shape A represents the sharp vertical edge drop-off. In this configuration, when the vehicle speed is high and the elevation change is large, the drop-off poses a safety hazard to vehicles in motion. Shape B includes a rounded pavement edge with a vertical face and retains many of the safety concerns as observed for the Shape A for larger values of the longitudinal edge elevation change (3.5 inches or greater). Shapes C and D can increase the relative safety by shifting from "Unsafe" or "Questionable Safety" conditions to "Reasonably Safe" or "Safe" conditions. Shape D is the 30-degree Safety Edge SM recommended by the FHWA. When a driver runs off the roadway, it is assumed that the Safety Edge SM can create a smooth transition between the roadway surface and the shoulder and allow the driver to return easily to the roadway. Figure 2.4 shows the safety improvement of using the Safety Edge SM compared with Shape A (90-degree) pavement edge. In the figure, the Y-axis represents the relative degree of safety for a scale ranging from 0 to 10. When the Safety Edge SM treatments, especially the 30-degree Safety Edge SM, are constructed there is an improvement in safety for all speed thresholds.



Source: Ivey et al. 2009

Figure 2.3: Relative Degree of Safety for Four Pavement Edge Types



Source: Ivey et al. 2009

Figure 2.4: Safety Improvement with Safety Edge $_{SM}$

To quantify the effect of the Safety Edge $_{SM}$, the FHWA initiated an eight state pooled-fund study (*Graham et al. 2011*). The states of Colorado, Georgia, Indiana, and New York provided sites for the analysis. The project scope included two road types (see Table 2.1). Their first candidate road type was the rural two-lane highway with a paved shoulder no wider than four feet. The second road type was the multilane highway with a paved shoulder no wider than four feet. All sites were divided into three types: treatment, comparison, and reference sites. The research team used two safety evaluation methods: (1) a before-after comparison using the Empirical Bayes (EB) method, and (2) a cross-sectional comparison of the safety effect between

the treatment and the comparison sites. This study evaluated crashes occurring during a three year period. The results indicated that 70% of the EB comparisons were associated with a positive effect of the Safety Edge $_{SM}$ on safety improvements. The EB analysis also indicated that the best estimate of the safety effect of the Safety Edge $_{SM}$ for rural two-lane highways is an expected reduction of about 5.7% for total crashes; however, this result was not determined to be statistically significant.

FHWA representative, Nick Fortey, subsequently indicated that though previous safety assessments may not be statistically significant there is sufficient evidence that the Safety Edge $_{SM}$ reduces crashes.

Table 2.1: The Safety Evaluation of the Safety Edge $_{SM}$: Scope, Site Types, and Methods

Scope	Site Types	Evaluation Methods
Rural Two-Lane Highways (Shoulder no wider than 4 ft)	Treatment: Sites that were resurfaced and treated with the Safety Edge $_{SM}$	Before-after comparison using Empirical Bayes (EB) method
Multilane Highways (Shoulder no wider than 4 ft)	Comparison: Sites that were resurfaced without the Safety Edge $_{SM}$ treatment	Cross-sectional comparison of the safety effect of the treatment and comparison sites, based on the after period only
	Reference: Sites that were similar to the treatment and comparison sites, but not resurfaced	

Source: Graham et al. 2011

Graham et al. (*2011*) also performed a cross-sectional comparison of sites that were treated with the Safety Edge $_{SM}$ and similar sites that were not treated with the Safety Edge $_{SM}$. After evaluating three years of crash data following resurfacing, they determined that 56 of the 81 comparisons demonstrated a positive safety effect as a result of the Safety Edge $_{SM}$ installation. Graham et al. indicated, though, that only 11 of these comparisons were statistically significant. They hypothesized that this observation could be due to only a small magnitude of the Safety Edge $_{SM}$ effect for the study period. Many of these cross-sectional sites occurred at multilane highways and though there were not enough rural multilane highway locations to provide meaningful results, the authors suggested that the Safety Edge $_{SM}$ appears to have a positive effect for multilane highways, particularly since many of the attributes that make the Safety Edge $_{SM}$ successful on two-lane highways directly apply to multilane locations.

Since the Safety Edge $_{SM}$ is positively associated with a reduction in crashes, it should be considered at high crash locations where a curb is not present and run-off-road crashes are prominent. In addition, the FHWA *Mitigation Strategies for Design Exceptions* (*Stein and Neuman 2007*) recommends the use of the Safety Edge $_{SM}$ at locations with very limited cross-sectional widths, in particular at locations where the width is not adequate to permit paved or partially paved shoulders. This condition is particularly applicable to local road systems.

2.3 CONSTRUCTION TECHNIQUES

The Safety Edge $_{SM}$ is constructed so that a spring-loaded paving machine attachment provides compression to the sloped pavement edge. This section of the report reviews various construction techniques of the Safety Edge $_{SM}$, including pavement types, shoulder considerations, installation devices, use of Safety Edge $_{SM}$ at work zones, and multiple pavement lift configurations.

2.3.1 Pavement Types

The Safety Edge $_{SM}$ can be constructed from asphalt and portland cement concrete (PCC) pavement (*FHWA 2010b*). The earliest installations of the Safety Edge $_{SM}$, constructed with hot mix asphalt (HMA) pavement, date back to 2003 and these sections continue to perform favorably requiring minimal maintenance. After paving with the Safety Edge $_{SM}$, the adjacent material is expected to be re-graded flush with the pavement to provide the safest edge possible. The PCC installations are more recent, but were successfully included in the Iowa demonstration project.

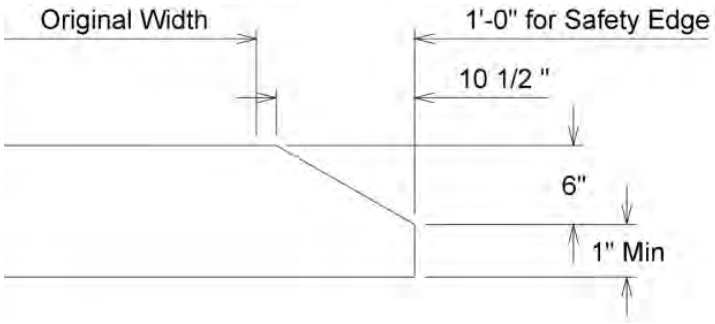
The state of Kansas uses a special safety wedge that uses alternative materials (*Kansas Department of Transportation 2007*). The slope of the special wedge is equivalent to the shoulder slope. The wedge can be constructed of either rock, earth, or recycled asphalt.

A recent demonstration project in Delaware constructed a Safety Edge $_{SM}$ using warm mix asphalt (WMA). They found that the WMA density (percent compaction) of the Safety Edge $_{SM}$ provided better results than for traditional WMA paving procedures; however, they did note that air voids measured along the edge were relatively high but, on average, lower than for the non-Safety Edge $_{SM}$ section. The Delaware team noted that the construction of the Safety Edge $_{SM}$ improved pavement density and reduced air voids which should help to improve pavement performance (*Von Quintus and Mallela 2011*). This WMA Safety Edge $_{SM}$ option, however, has not yet been subjected to a long-term evaluation.

2.3.2 Shoulder Construction and Considerations

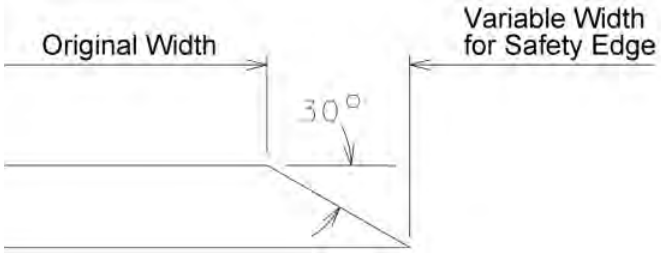
According to the Iowa Department of Transportation (*Iowa DOT*), the Safety Edge $_{SM}$ should be required at roadways with paved shoulder widths smaller than four feet (*Iowa DOT 2010*). They further suggest that the most critical road configuration that benefits from the construction of the Safety Edge $_{SM}$ is a rural two-lane, two-way highway without any paved shoulders (only graded shoulders). Roadways with paved shoulder widths larger than four feet can also benefit from the Safety Edge $_{SM}$ treatment to enhance safety. The Iowa Safety Edge $_{SM}$ design guidance does not explicitly address traffic volume thresholds or crash history values as indicators for the placement of the Safety Edge $_{SM}$; however, their suggestion that the Safety Edge $_{SM}$ may be suitable for locations that would benefit from enhanced safety would imply that locations with high crash history should also be considered as potential candidate locations.

The Safety Edge $_{SM}$ begins at the outermost edge of the pavement or the paved shoulder. Typical cross sections of the Safety Edge $_{SM}$ as deployed in Iowa are depicted in Figure 2.5 and Figure 2.6. In these figures, the paved shoulder width would be included in the region labeled "original width."



Source: Iowa DOT 2010

Figure 2.5: Safety Edge $_{SM}$ Dimensions for PCC Pavements



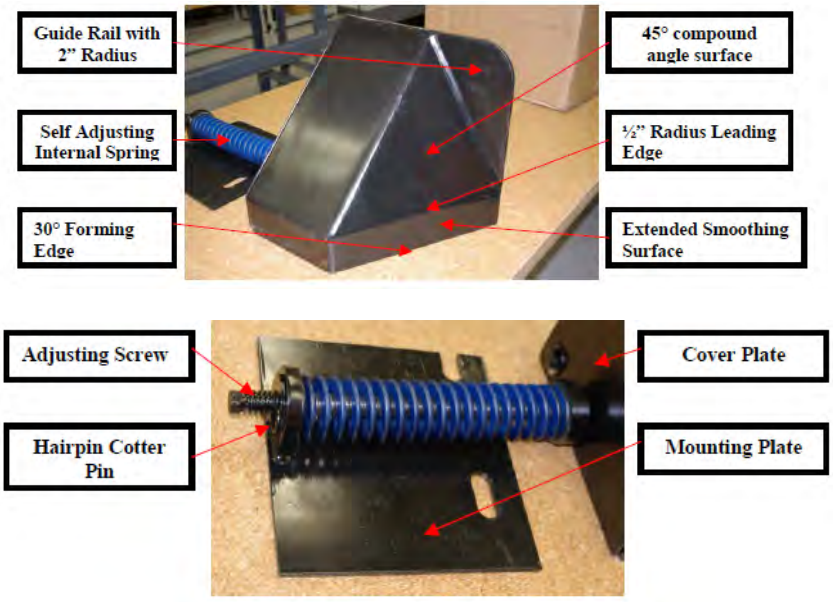
Source: Iowa DOT 2010

Figure 2.6: Safety Edge $_{SM}$ Dimensions for HMA Pavements

The placement of the Safety Edge $_{SM}$ can occur on a variety of surfaces. Most states encourage construction of the Safety Edge $_{SM}$ on a base material such as gravel; however, the Safety Edge $_{SM}$ has been constructed on crushed stone, reclaimed asphalt pavement, and in situ soil. Though it will perform with acceptable durability and compression on these and other surfaces, for best performance the Safety Edge $_{SM}$ should be installed on a conventional base support such as aggregate (*FHWA 2011b*).

2.3.3 Installation Hardware

Currently there are four primary manufacturers who develop or distribute hardware, referred to as a paving shoe, suitable for forming and compressing the Safety Edge $_{SM}$ (see http://safety.fhwa. dot.gov/roadway_dept/pavement/safedge/). Advant-Edge Pavement Equipment LLC has two devices. Their original device is known as the Advant-Edge and is one of the earliest Safety Edge $_{SM}$ devices developed. It creates the approximately 30-degree tapered edge along the shoulder. More recently, they have developed a device known as the Ramp Champ that can be used to create the tapered edge as well as a longitudinal center lane joint (see http://www.advantedgepaving.com/). TransTech Systems (http://www.transtechsys. com/) developed the Shoulder Wedge Maker (also sometimes referred to in literature as the Safety Edge $_{SM}$ Maker). Figure 2.7 depicts this TransTech device and its various components.



Source: TransTech 2005 (http://www.transtechsys.com/)

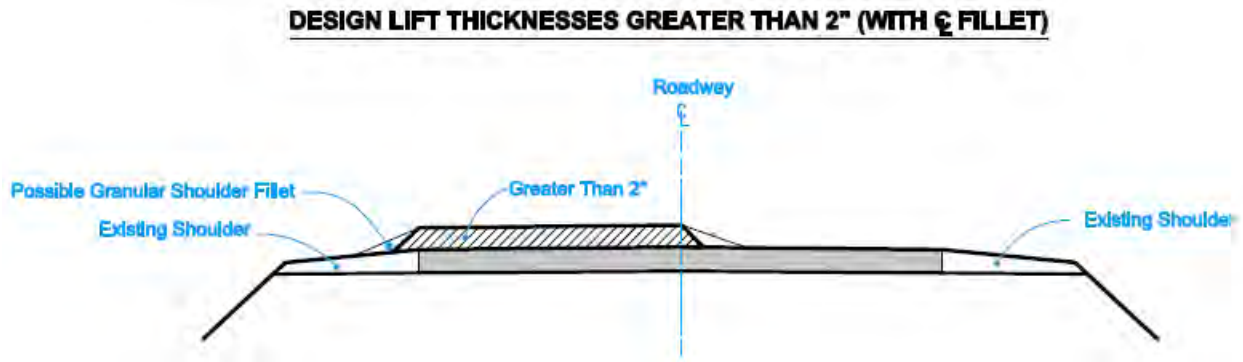
Figure 2.7: TransTech Shoulder Wedge Maker

Carlson Paving Products, Inc. (http://www.carlsonpavingproducts.com/) produces a shoe called the Safety Edge $_{SM}$ End Gate and Troxler Electronic Laboratories (http://www.troxlerlabs.com/products/paving.php) distributes a device called the SafeTSlope Edge Smoother that has the same features as the TransTech shoe. In addition to these devices, the Georgia Department of Transportation (GDOT) also recommends another Safety Edge $_{SM}$ installation tool known as the GDOT Safety Edge $_{SM}$ (*Wagner and Kim 2005*). Each of these devices functions as a spring-loaded "shoe" attachment for the paving machine. The goal of the spring-loaded feature is to allow the shoe to automatically adjust as it traverses uneven surfaces such as driveway approaches. At locations with extended pavement edge obstructions such as curbs or guardrails, the Safety Edge $_{SM}$ shoe should be manually retracted.

Currently commercially available pavement shoes are only available to apply asphalt safety edges, so locations with PCC paving require the fabrication of special forming assemblies. The Iowa Safety Edge $_{SM}$ demonstration projects assessed concrete treatments and local construction companies developed the required forming assemblies (*Iowa LTAP 2011*).

2.3.4 Safety Edge $_{SM}$ at Work Zones

The presence of uneven lanes is a common problem associated with work zones. When uneven lanes with greater than a 2-inch difference in elevation are present on highways, the Iowa DOT recommends using the Safety Edge $_{SM}$ to provide a smooth transition between lanes (*Iowa DOT undated*). Iowa construction crews also construct road signs to inform drivers of the presence of uneven lanes. If a Safety Edge $_{SM}$ is not installed, drivers are not allowed to pass by entering the opposing lane of travel. Figure 2.8 depicts the installation of the Safety Edge $_{SM}$ on uneven lanes.



Source: Iowa DOT undated.

Figure 2.8: Safety Edge $_{SM}$ on Uneven Lanes

2.3.5 Pavement Constructed with Multiple Lifts

A pavement overlay may be constructed with a single pavement lift; however, often the structural design and compaction of pavement requirements dictate that it be constructed as more than one layer or lift. During paving activities if multiple lifts are required and time periods between the placement of the lifts are relatively short (within months), the placement of a Safety Edge $_{SM}$ can be constructed at the time of the final lift or with each individual lift application. Figure 2.9 demonstrates Safety Edge $_{SM}$ placement for locations with new construction. Similarly, Figure 2.10 depicts Safety Edge $_{SM}$ construction for resurfacing projects.

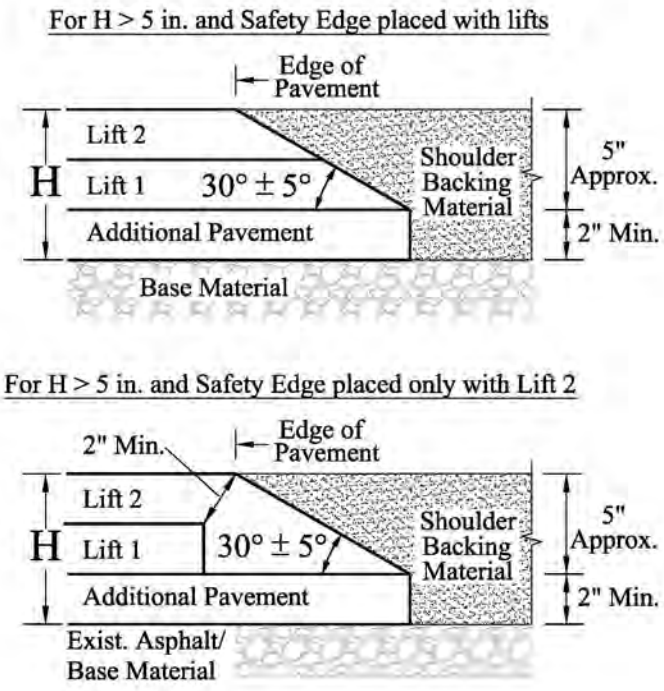


Figure 2.9: New Construction and the Safety Edge $_{SM}$ Treatment

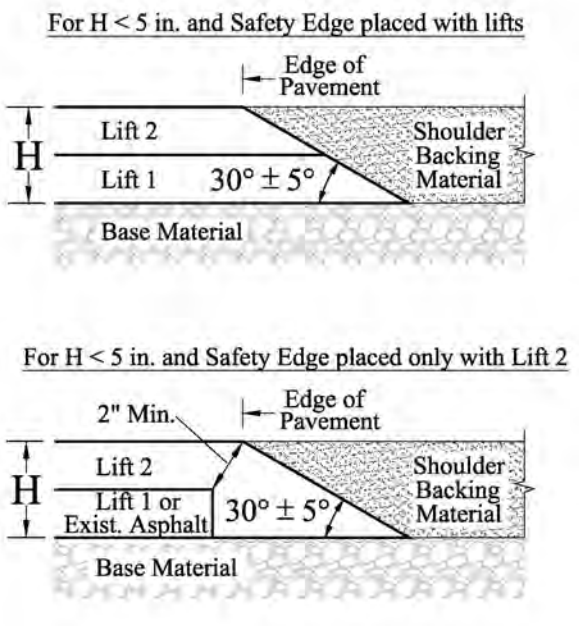


Figure 2.10: Resurfacing and the Safety Edge $_{SM}$ Treatment

2.4 CONSTRUCTABILITY OF SAFETY EDGE $_{SM}$

Wagner and Kim (*2005*) performed research in the State of Georgia where they assessed the constructability of the Safety Edge $_{SM}$. They selected a 13.3-mile roadway section with a typical pavement cross section that consisted of two 12-ft lanes with two foot paved shoulders. The study evaluated two different devices, the GDOT Safety Edge $_{SM}$ and the Safety Edge Maker ^{TM} (SEM) developed by TransTech Systems, Inc. GDOT also analyzed the use of the Safety Edge $_{SM}$ for use with two different asphalt mix designs: a 9.5mm HMA designed using the Marshall mix design procedure and a 12.5mm HMA designed to meet the Superpave design criteria. Wagner and Kim also evaluated the influence of the Safety Edge $_{SM}$ on the pavement density by using a density ratio of the pavement edge measurements to the center of the lane measurement. Their results indicated that the Safety Edge $_{SM}$ had no significant effect on the relative density at the edge of the pavement suggesting that placement of the Safety Edge $_{SM}$ does not adversely affect the pavement section and likely strengthens pavement at the normally less durable edges. In addition, the Georgia researchers conducted smoothness measurements to determine if the Safety Edge $_{SM}$ had an impact on pavement smoothness. Their results suggested that the Safety Edge $_{SM}$ did not have an adverse effect on the smoothness. Finally, a field investigation one year following the construction indicated that the Safety Edge $_{SM}$ did not appear to deteriorate over time. Ultimately the Georgia evaluation demonstrated that the Safety Edge $_{SM}$ provides a good density ratio, does not adversely impact pavement smoothness, and provides a durable edge to the pavement.

2.5 ENVIRONMENTAL CONSIDERATIONS

The published literature does not directly address any perceived environmental concerns associated with the Safety Edge $_{SM}$. Each state has included the cost for the construction of the

Safety Edge SM into the overall pavement bid items, and the total resulting cost typically increases the pavement resurfacing budgets by less than 1% (*FHWA 2011a*). This observation suggests that the increased amount of paving as a result of installing the Safety Edge SM is minor and should, therefore, have minimal environmental impacts due to the small added quantity of impervious surface. The Safety Edge SM will add an increased width in pavement, particularly at the base of the wedge section; however, following construction the shoulder material will then be placed flush with the surface of the pavement.

2.6 MAINTENANCE OF THE SAFETY EDGE SM

An agency may question why a Safety Edge SM would be needed if the shoulder is regularly maintained. At this time, Safety Edge SM installations in many states are relatively recent so many of the maintenance issues have not yet been addressed. Based on the installations to date it appears the Safety Edge SM has at least two direct impacts on future maintenance of the facility. First, constant shoulder maintenance can minimize pavement edge drop-offs but, even at locations with rigorous maintenance schedules, there will be periodic settlement, erosion, and tire wear. If the Safety Edge SM is constructed at these locations, these issues would be minimized or even eliminated completely potentially resulting in less frequent shoulder maintenance. In addition, the presence of the Safety Edge SM will protect the edge of the pavement resulting in a longer pavement life and reduced future maintenance of the actual pavement surface. For these two reasons, the Safety Edge SM will considerably benefit facility maintenance demands (*FHWA 2011b*).

Another concern may be whether graded shoulder material will stay in place on the sloped surface of the Safety Edge SM. Tests show that the shoulder material will perform as well with the Safety Edge SM as it has for traditional paving section edges. In the event the shoulder material does shift, due to tire rutting or similar durability issues, the Safety Edge SM will enhance safety until the shoulder can be repaired (*FHWA 2011b*). At this time, studies do not specify recommended graded shoulder material.

2.7 COST AND BENEFIT OF SAFETY EDGE SM

Prior to the advent of the modern 30-degree Safety Edge SM, Humphreys and Parham (*1994*) indicated that the application of a 45-degree sloped pavement edge treatment cannot be expected to result in excessive use of additional pavement materials. When a 45-degree safety wedge is constructed on both sides of a 24 feet wide, two-lane rural road during the resurfacing project (with a leveling course of 1.5-inches and a surface course of one-inch while no drop-off is present), the additional wedge volume equals less than 1% of the total roadway asphalt overlay. If the roadway has experienced a drop-off of two-inches, the additional wedge volume equals 2.8% of the overall asphalt overlay. Humphreys and Parham (*1994*) did not address volume differences for the approximate 30-degree slope configurations; however, the flatter slope which would require slightly more asphalt can reasonably be expected to increase pavement volume by more than the 1% increase for locations with no drop-off or the 2.8% increase for locations with a two-inch drop-off.

Graham et al. (*2011*) evaluated the cost and benefit of the modern 30-degree Safety Edge $_{SM}$. The cost of the Safety Edge $_{SM}$ was estimated to range from about $536 per mile for a 1.5 inch high overlay to $2,145 per mile for a 3.0 inch overlay. The authors did not explicitly determine the percentage of overall asphalt overlay that these costs represent. Graham et al. also used a benefit cost ratio to estimate the relationship of the benefits and the cost of the Safety Edge $_{SM}$ treatment. Components of the benefit-cost analysis included crash frequencies, the crash reduction effectiveness of the Safety Edge $_{SM}$ treatment, crash costs, service life of the Safety Edge $_{SM}$, minimum attractive rate of return, uniform series present worth factor, and initial treatment cost of the Safety Edge $_{SM}$. An important assumption for their cost-benefit assessment is that the application of Safety Edge $_{SM}$ was estimated to reduce crash frequencies by 5.7% (previously presented in Section 2.2 of this report). The results by Graham et al. (*2011*) indicate that the Safety Edge $_{SM}$ treatment is highly cost-effective. The minimum computed benefit-cost ratios for Georgia two-lane, two-way highways with paved shoulders ranged from 4 (roads with 1,000 vehicles/day) up to 44 (roads with 20,000 vehicles/day). Similar roads in Indiana resulted in benefit-cost ratios from 4 up to 31 for 1000 and 20,000 vehicles per day respectively. For Georgia two-lane, two-way highways with unpaved shoulders, the benefit-cost ratio ranged from 4 (roads with 1,000 vehicles/day) up to 63 (roads with 20,000 vehicles/day), while similar Indiana roads had values from 3 to 13 for the same traffic volume thresholds. A benefit-cost ratio value from 4 to 63, as an example, indicates that for every $1 spent an agency can expect to receive from $4 to $63 of benefits. When the traffic volume increases and the cost of the Safety Edge $_{SM}$ installation decreases, the benefit-cost ratio is expected to increase.

2.8 TRIAL IMPLEMENTATION CONSIDERATIONS

The North Carolina Department of Transportation (NCDOT) indicated that if a trial implementation of the Safety Edge $_{SM}$ is considered and the jurisdiction's primary purpose for considering the Safety Edge $_{SM}$ is to reduce run-off-road crashes, it is important to select roadway segments with a history of high roadway departure crash rates (source is undated NCDOT document retrieved in November 2010). If departure crash information is difficult to summarize, another sampling option is to select corridors with narrower lane widths and shoulder widths or locations with curved horizontal alignments. If there is information indicating that specific corridors require the Safety Edge $_{SM}$, then those segments should be selected. After the site selection, several variables need to be measured to assess the effectiveness of the Safety Edge $_{SM}$. One important data item to be collected is the reduction of the lane departure crashes due to the Safety Edge $_{SM}$. In addition, to evaluate the maintenance impact of the Safety Edge $_{SM}$, it is critical to keep up-to-date maintenance records on corridors before and after the implementation of this pavement edge treatment. Finally, it is also important to evaluate the cost of the Safety Edge $_{SM}$.

2.9 SUMMARY

This literature review illustrates current applications of the Safety Edge $_{SM}$ in the United States, with particular attention to safety, constructability, and cost-effectiveness. These findings may assist the state of Oregon in determining where, when, and how to construct Safety Edge $_{SM}$ treatments along Oregon highways.

3.0 STATE OF PRACTICE

Section 2.0 reviewed known literature and evaluations of the Safety Edge $_{SM}$, but many jurisdictions are in the early stages of evaluating the Safety Edge $_{SM}$. This section, therefore, reviews the current implementation status of the Safety Edge $_{SM}$ in the United States. In the spring of 2011, the research team directly contacted representatives for all fifty states and subsequently received direct responses from 15 of the 50. Of these responding states, 12 are currently using the Safety Edge $_{SM}$, one (North Dakota) intends to test this strategy in the near future, and the other two states (Utah and Washington) are still considering how it may benefit their states. This summary includes information provided by the responding states as well as other state data identified through alternative sources.

Among states with Safety Edge $_{SM}$ projects in place, Georgia, Iowa, North Carolina, and Oklahoma are states that have developed application specifications or special provisions for the Safety Edge $_{SM}$ (Appendix B). In addition, Delaware, Iowa, Minnesota, New York, and Texas have created design guidelines, technical memorandums, or standard drawings. Examples of these individual state documents are included in Appendix C. This section provides a brief review of how these states have incorporated the Safety Edge $_{SM}$ into their pavement process.

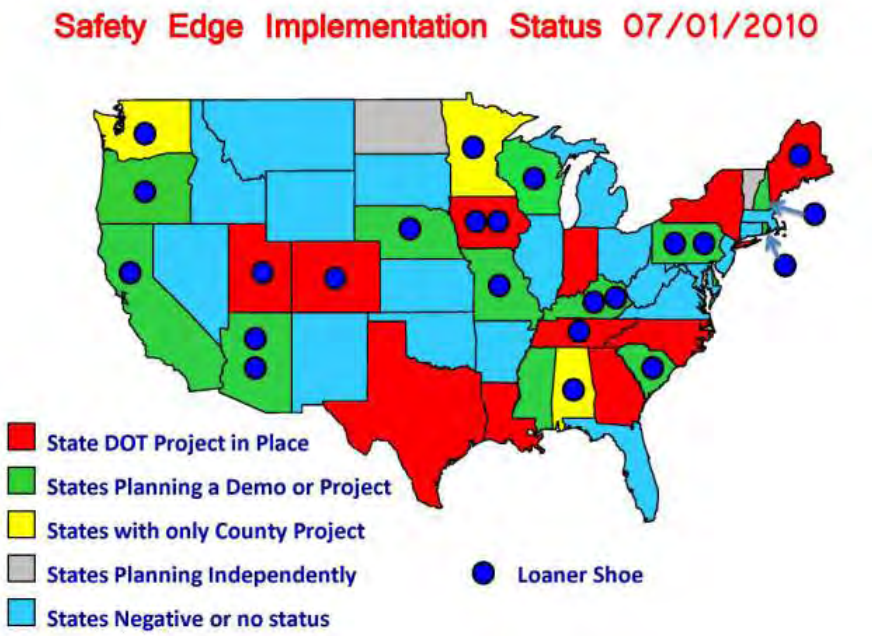
3.1 APPLICATION STATUS OF SAFETY EDGE $_{SM}$ IN UNITED STATES

Many states in the United States have adopted or are planning to consider the use of the Safety Edge $_{SM}$ to improve highway safety. Nicol (*2010*) indicated that by July 1, 2010, 14 states had implemented the Safety Edge $_{SM}$ and 11 states were planning to adopt a similar pavement edge treatment (see Figure 3.1). Currently, additional states are considering the benefits of adopting the Safety Edge $_{SM}$ or have recently conducted demonstration tests. Table 3.1 depicts a summary of the application status of the Safety Edge $_{SM}$ based on the published literature, feedback from states, and information obtained from the websites for the individual state departments of transportation. In addition to the 50 states, Puerto Rico recently (May 2011) implemented their first Safety Edge $_{SM}$ for an asphalt overlay project.

To assist jurisdictions with developing design recommendations, the FHWA has developed a guide specification for the Safety Edge $_{SM}$ (see Appendix B). The states of Georgia and Iowa have deployed several Safety Edge $_{SM}$ projects, developed sample specifications, and fully developed strategies for state-wide applications of the Safety Edge $_{SM}$. The state of North Carolina has developed a Shoulder Wedge special provision and deployed the Safety Edge $_{SM}$ at four different county locations over the last few years. Similarly, the state of Oklahoma created special provisions for an asphalt Safety Edge $_{SM}$ and are proactive in promoting the use of the Safety Edge $_{SM}$ within their state. Appendix B includes copies of these documents.

In addition to specifications and special provisions, several states are in the process of developing supplemental design guidance, technical memorandums, and standard drawings. For example, Delaware has created a design guidance memorandum to assist with the future use of

the Safety Edge $_{SM}$ decisions in their state. In addition to the specification previously identified, Iowa has also developed a Safety Edge $_{SM}$ section for their design manual. Minnesota currently provides design guidance through a technical memorandum while New York and Texas have developed engineering instructions and standard drawings respectively. Appendix C contains copies of these documents.



Source: Nicol 2010

Figure 3.1: Map of Safety Edge $_{SM}$ Implementation Status

Table 3.1: Application Status of Safety Edge $_{SM}$ in United States

Status	States
Project in Place	Alabama, Colorado, Connecticut, Delaware, Georgia, Indiana, Iowa, Maine, Minnesota, Mississippi, New York, North Carolina, Oklahoma, Oregon, Tennessee, Texas, Utah, Washington
Planning a Project	Arizona, California, Kentucky, Louisiana, Massachusetts, Missouri, Nebraska, New Hampshire, Pennsylvania, South Carolina, West Virginia, Wisconsin
States Planning Independently	North Dakota, Vermont
No Status	Alaska, Arkansas, Florida, Hawaii, Idaho, Illinois, Kansas, Maryland, Michigan, Montana, Nevada, New Jersey, New Mexico, Ohio, Rhode Island, South Dakota, Virginia, Wyoming

Source: Nicol (2010); MS Transportation Systems, Inc. (2008); Von Quintus and Mallela (2011); and local information updates

The following sections briefly review the general content of the FHWA guide specification for the Safety Edge $_{SM}$ as well as specific content for the states of Georgia, Iowa, North Carolina, and Oklahoma. This summary does not review in detail the content for the various design guidance, technical memorandums, and standard drawings included in Appendix C as this

information, in general, is the same or similar to that contained in the specifications and special provisions included in Appendix B.

3.2 FHWA GUIDANCE

As shown in the guide specifications for the Safety Edge $_{SM}$ in Appendix B, the Safety Edge $_{SM}$ can be constructed for concrete pavements and overlays as well as asphalt pavements and overlays. The sloping surface can range from a ratio of 1.2:1 up to 1.8:1. This value is equivalent to slopes from 29-degrees up to 40-degrees. If the pavement height is less than 5 inches, the slope should extend the full height. For pavement sections that are of a depth greater than 5 inches, a Safety Edge $_{SM}$ slope for the top 5 inches is recommended. If the road resurfacing will occur with multiple asphalt paving lifts, the Safety Edge $_{SM}$ can also be constructed with the individual lifts or it can be completely constructed with the final lift. The FHWA sample specifications include recommendations for equipment, construction methods, method of measurement, and basis of payment. The equipment specifically provides guidance for HMA and PCC. The recommended construction methods address shoulder preparation, HMA density adjacent to the Safety Edge $_{SM}$, shoulder backing material, and handwork (for HMA as well as PCC applications). The recommendation in the FHWA guide specifications for the method of measurement is that the Safety Edge $_{SM}$ should not be directly measured for payment and that the basis of payment should be incorporated into the contract paving work costs. These recommendations for measurement and payment are consistent for the individual state recommendations. This recommendation is because the measurement of additional materials is perceived as inconsequential when compared to the overall cost of the paving materials. In the event that an agency performs unique shoulder preparation as a separate component of the paving activity, it may be appropriate to include this additional shoulder work as a separate budget line item.

3.3 SAFETY EDGE $_{SM}$ SPECIFICATIONS IN GEORGIA

The Georgia guidance includes two paragraphs as well as a sample drawing that is similar to that included in the FHWA guidance. The Georgia text differs from the FHWA guidance slightly in that it provides general guidance about the paving shoe and how it will extrude the asphalt during paving. The Georgia language also stipulates that the Safety Edge $_{SM}$ shape should be compacted to a 30-degree pavement edge (rather than the range of slopes suggested in the FHWA specifications). The Georgia guidance also addresses how the Safety Edge $_{SM}$ shoe should provide an automatic transition at cross roads, driveways, and other obstructions. Currently, Georgia specifically authorizes the use of the TransTech Shoulder Wedge Maker or the Advant-Edge device; however, they stipulate that a similar proven device can be used. The Georgia guidance also includes information that potential handwork may be needed at transitions, turnouts, and other locations as identified by the project engineer. The Georgia guidance also indicates that the Safety Edge $_{SM}$ should be included in the associated paving pay item. Appendix B includes the complete Georgia specification.

3.4 IOWA SPECIFICATIONS AND COMPANION DESIGN GUIDELINES

Iowa is one of the few states that has fully developed and incorporated the Safety Edge $_{SM}$ in their standard specifications as well as their Iowa DOT *Design Manual* (see Appendices B and C). Iowa currently requires the installation of the Safety Edge $_{SM}$ on all primary highways unless the roadway is an interchange ramp or loop, the roadway or shoulder is curbed, or the paved shoulder width is at least four feet wide (*Iowa DOT, 2010*). The Safety Edge $_{SM}$ is often applied at rural two-lane, two-way highway locations that do not have paved shoulders. Currently the Iowa DOT uses the 30-degree Safety Edge $_{SM}$ recommended by the FHWA; however, since the bevel 30-degree is measured from the level and the existing surface has a slope ranging from 2 to 8%, the actual angle can be expected to be within 30 to 35-degrees (see Figure 3.2). The installation of the Safety Edge $_{SM}$ can occur during new construction or in conjunction with resurfacing projects. In addition, the Safety Edge $_{SM}$ can be applied to both PCC and HMA pavement.

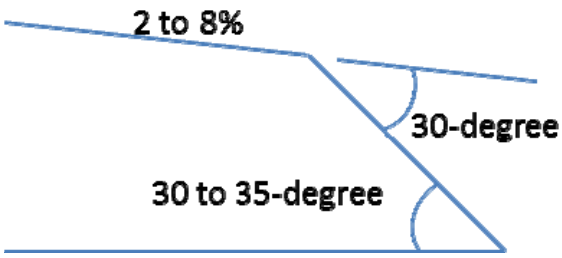
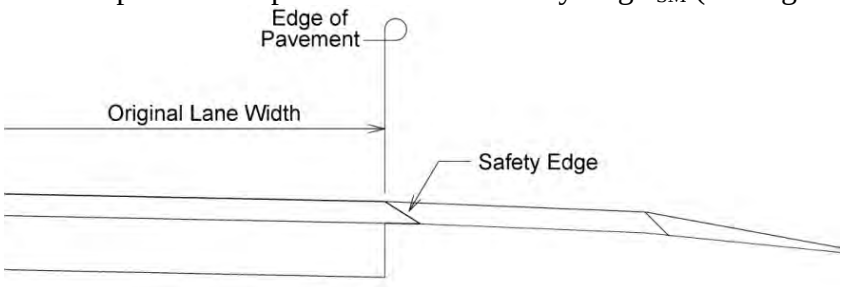


Figure 3.2: Actual Angle of Safety Edge $_{SM}$ as Used in Iowa

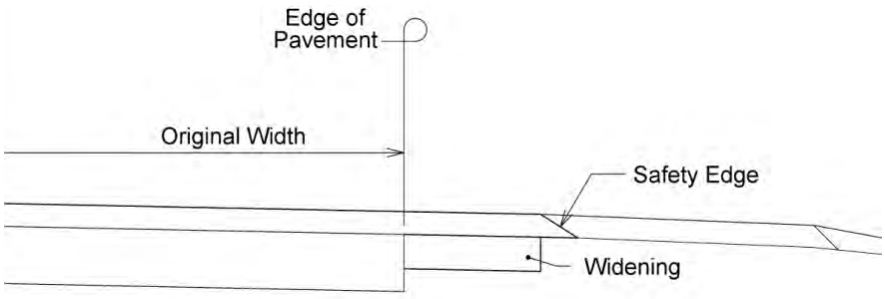
For PCC pavements (*Iowa DOT 2010*), the Safety Edge $_{SM}$ dimensions are depicted in Figure 2.5. The Safety Edge $_{SM}$ is one foot wide and six inches deep with a minimum of a one-inch vertical face required beneath the Safety Edge $_{SM}$. In addition, the PCC pavement should be a minimum of seven inches in thickness. By contrast, the minimum thickness of PCC pavement in Oregon is eight inches (*ODOT 2007*). For HMA pavements (*Iowa DOT 2010*), the Safety Edge $_{SM}$ dimensions are depicted in Figure 2.6.

During resurfacing projects, the Iowa Safety Edge $_{SM}$ can be constructed without additional base widening and the Safety Edge $_{SM}$ is directly applied to the existing base (see Figure 3.3) or with base widening that must precede the placement of the Safety Edge $_{SM}$ (see Figure 3.4).



Source: Iowa DOT 2010

Figure 3.3: Resurfacing Project without Base Widening



Source: Iowa DOT 2010

Figure 3.4: Resurfacing Project with Base Widening

The Iowa Safety Edge $_{SM}$ specification includes a description, materials section, construction section that includes asphalt and PCC similar to the FHWA specification, and a method of measurement and basis of payment that are also similar to those included in the FHWA guide specifications. In addition, Iowa authorizes the use of the TransTech and Advant-Edge paving shoes, but also permits contractors to use an approved device that provides performance characteristics equal to these two pre-approved products.

3.5 NORTH CAROLINA ASPHALT SHOULDER WEDGE SPECIAL PROVISION

The North Carolina provision only applies to asphalt Safety Edge $_{SM}$ configurations with a shoulder wedge of an angle no greater than 30 degrees. They stipulate that the paving shoe must be an approved device. The North Carolina guidance also requires that payment for this shoulder wedge will be incidental to other contract pay items.

3.6 OKLAHOMA SPECIAL PROVISIONS FOR ASPHALT SAFETY EDGE $_{SM}$

The Oklahoma Safety Edge $_{SM}$ special provisions apply specifically to asphalt shoulder applications and supersede applicable sections of their *2009 Standard Specifications for Highway Construction*. Their special provision indicates that they require the Safety Edge $_{SM}$ for permanent or temporary asphalt concrete highway construction, on all routes, for all design speeds and types of traffic when the following condition applies:

- The roadway is an open section (does not have a curb),
- The pavement thickness is increased by 2 inches or more, and
- The paved shoulder is 4 feet or less.

Oklahoma also permits the Safety Edge $_{SM}$ to be used at sites with shoulder widths greater than 4 feet if the project engineer approves this application.

The Oklahoma approved Safety Edge $_{SM}$ slope is 30 degrees ± 5 degrees along the outside edge of the road when measured from the horizontal plane. The requirements for measurement and payment are consistent with those recommended in the FHWA guide specifications.

3.7 SUMMARY OF STATE APPLICATIONS

In summary, many states in the United States have adopted or are planning to adopt the Safety Edge $_{SM}$. Among them, the states of Georgia, Iowa, North Carolina, Oklahoma, Delaware, Minnesota, New York, and Texas have developed specifications, guidance, standard drawing or similar in an effort to standardize the application of the Safety Edge $_{SM}$ in their individual states. The requirements are generally consistent among the states. The slope of the edge should be approximately 30 degrees; however, the acceptable fluctuation from this value varies from approximately 5 degrees up to 10 degrees based on the individual state and specific application. The review of these documents from various states should assist the state of Oregon in determining how to effectively use the Safety Edge $_{SM}$ for Oregon highway applications.

The recommended device type and application varies substantially for the various states. In general, the following summarizes some to the key items included in the state feedback and documents:

- Georgia, Iowa, and Minnesota specifically identify the shoes developed by Transtech Systems and Advant-Edge as approved devices.
- North Carolina refers to their edge treatment as a Shoulder Wedge.
- Locations where the Safety Edge $_{SM}$ is not recommended include:
    - Interchange ramps or loops,
    - Locations where curb is present, and
    - Pavement increase is 2” or greater (Oklahoma).

The shoulder width applications requirements vary per state, but in general rural highways with shoulder widths of approximately four feet are commonly referenced construction thresholds.

4.0 OREGON SAFETY EDGE $_{SM}$ APPLICATIONS AND NEXT STEPS

This section briefly reviews Oregon safety goals and current highway design and construction standards that may apply to the Safety Edge $_{SM}$ application. A first step towards wide-scale implementation of the Safety Edge $_{SM}$ on Oregon highways is to develop draft language to be considered for future Oregon specifications. This section, therefore, contains recommended specification language for consideration. In addition to developing recommendations for standard specifications, future use of the Safety Edge $_{SM}$ can be enhanced by developing an Oregon-specific Safety Edge $_{SM}$ Technical Bulletin. As Oregon's experience with the Safety Edge $_{SM}$ increases, this technical bulletin can then be updated. This draft bulletin is included as Appendix D. This chapter reviews the sample Oregon test site for the Safety Edge $_{SM}$, and concludes with lessons learned.

4.1 SAFETY GOALS

According to the *Oregon Roadway Departure Safety Implementation Plan* (*FHWA* 2010a), there was an average of 307 roadway departure fatalities per year from the period 2002 to 2008. Though the report does not explicitly provide a definition of "roadway departure crashes", these are assumed to be run-off-road crashes that do not occur at or near an intersection.

The Oregon goal is to reduce roadway departure crashes by approximately 20% by the year 2016 (*FHWA 2010a, page 3*). This objective is equivalent to a reduction of about 65 roadway departure fatalities each year. Table 4.1 depicts the roadway departure crashes distributed by road location. As demonstrated in Table 4.1, it can be concluded that roadway departure crash severity is much greater for rural highways than their urban counterparts. In fact, 84% of fatal roadway departure crashes occurred at rural locations.

Table 4.1: Roadway Departure Crashes and Fatalities by Locality (2002-2008)

Locality	Crashes		Fatalities	
	Total	**Percentage**	**Total**	**Percentage**
State	27,911	50.63%	1,234	57.50%
Rural	21,827	39.59%	1,078	50.23%
Urban	6,084	11.04%	156	7.27%
Local	27,218	49.37%	912	42.50%
Rural	15,677	28.44%	726	33.83%
Urban	11,541	20.93%	186	8.67%
Grand Total	55,129	100.00%	2,146	100%

Source: FHWA, 2010a

4.2 OREGON STANDARDS AND THE SAFETY EDGE SM

4.2.1 Shoulder Width

The Oregon *Highway Design Manual* (*ODOT 2003*) indicates that all rural state highway reconstruction projects should follow the ODOT 4-R/New Design Standards, while all rural state highway resurfacing projects should follow the ODOT 3-R Design Standards. In the ODOT 4-R Standards, the rural two-lane highway requires a shoulder width equal to or less than four feet at locations where the average daily traffic (ADT) is 400 vehicles per day and the facility is classified as a rural collector or rural local. All other two-lane rural state highway reconstruction efforts require a shoulder width equal to or greater than four feet. The ODOT-3R Standards require a shoulder width that can be less than four feet when the ADT is under 2000 vehicles per day. In mountainous terrain, the shoulder width may be as narrow as three feet. For non-mountainous roads with ADT values of 2000 vehicles per day or more, the shoulder width should be larger than four feet.

4.2.2 Pavement Types

In the *ODOT Pavement Design Guide* (*ODOT 2007*), there are three common asphalt concrete pavement types. The first pavement type, known as the open graded hot mixed asphalt concrete, has a primary benefit to reduce the spray and therefore reduce the risk of hydroplaning during heavy rains. However, due to cost and longevity problems, ODOT restricts the use of this asphalt concrete type to interstate highways with an ADT larger than 30,000 vehicles per day. Since the use of the Safety Edge SM on interstate highways is not expected, this open graded hot mixed asphalt concrete is not expected to be used for Oregon Safety Edge SM applications.

The second Oregon asphalt pavement type is the emulsified asphalt concrete (EAC). The EAC is recommended for rural projects in Central and Eastern Oregon with low ADT (< 2,500 vehicles per day). During construction, the EAC should be placed in lifts of 2 inches or 2.5 inches. The EAC requires Chip Seal as a finishing lift. The Safety Edge SM applications using chip seal are not yet fully understood and so this pavement configuration may not be appropriate.

The third pavement type is the dense graded hot mix asphalt concrete which is recommended for projects in urban areas with curbed sections or for projects where the open graded asphalt concrete or EAC is not considered. In Oregon, there are three common dense grade mix types: 3/4 inch (19mm), 1/2 inch (12.5mm), and 3/8 inch (9.5mm). Table 4.2 shows the minimum and maximum lift thickness for each dense hot mix asphalt type. The dense graded hot mix asphalt concrete is expected to be a common pavement type for Oregon Safety Edge SM applications.

Table 4.2: Lift Thickness Requirements of Dense Hot Mix Asphalt Pavement

Mix Sizes	Lift Thickness (inch)	
	Minimum	Maximum
3/4 inch	3	3
1/2 inch	2	3
3/8 inch	1	4
The first lift should be 3inch in thickness		

Source: ODOT 2007

The *ODOT Pavement Design Guide* (*ODOT 2007*) also identifies three types of PCC used in Oregon: the continuously reinforced concrete pavement (CRCP), the jointed plain concrete pavement (JPCP), and the jointed reinforced concrete pavement (JRCP). As previously indicated, the minimum thickness of PCC in Oregon is 8 inches. At this time, the Safety Edge $_{SM}$ is expected to be constructed using only asphalt materials; however, reference to PCC materials is included for future reference as the use of the Safety Edge $_{SM}$ expands in Oregon.

4.2.3 Maintenance

The *ODOT Maintenance Guide* should be updated to reflect the use of the Safety Edge $_{SM}$. At this time, it should indicate that there should be no changes in the maintenance procedures. It is possible that the Safety Edge $_{SM}$ may extend the time between scheduled shoulder maintenance activities since the presence of the Safety Edge $_{SM}$ will provide additional short-term mitigation. If a delay occurs in shoulder maintenance and the shoulder at a site has not yet been brought back up to the pavement height, the Safety Edge $_{SM}$ would significantly reduce safety risk until routine maintenance can be resumed.

4.3 TEST SITE AND LESSONS LEARNED

One initial goal of this research effort included deploying and assessing the Safety Edge $_{SM}$ at multiple Oregon locations; however, due to the reduced availability of construction projects in Oregon, ODOT was only able to deploy the Safety Edge $_{SM}$ at one location. In the fall of 2010, a resurfacing project on Highway 157, also known as Highway 18 B(Business), in Sheridan included construction of the Safety Edge $_{SM}$ for the westbound travel direction right edge (extending from mile point 8.50 to 7.59). The contractor used a standard paving shoe for the eastbound direction of travel. Figure 4.1 depicts the approximate beginning and ending location of this construction effort. Members of the research team observed the construction, asked the contractor questions regarding ease of use, and have monitored the project over the last year. This demonstration project was intended to evaluate ease of use for construction.

Feedback from the contractor and project engineer regarding this demonstration included the following:

- Initial mounting of the shoe on the paving equipment was straightforward; however, the contractor did indicate that they had to drill an additional hole to adequately attach the shoe.

- The contractor indicated that they experienced approximately at 15 to 20 minute learning curve at the beginning of their paving activity. Following this initial training period, they felt that the Safety Edge $_{SM}$ shoe did not require any more time or effort than a traditional shoe.

- The site selected was free of guardrail and driveways, so this demonstration project could not assess functionality of the shoe at locations with obstructions.

- The standard construction procedure for shoulder placement is to grade the shoulder material (generally gravel) flush with the pavement surface after the paving is completed. ODOT maintenance performed this task approximately one week after construction and did not encounter any issues with this activity. One issue to note is that the use of traditional paving would normally leave a vertical lip (drop-off) exposed until the scheduling of the shoulder work, so the presence of the Safety Edge $_{SM}$ during this time period would enable any errant vehicles, leaving the newly resurfaced road unexpectedly; to more easily return to the travel.

- The Highway 157 Safety Edge $_{SM}$ application has been in place for approximately one year and continues to perform well.

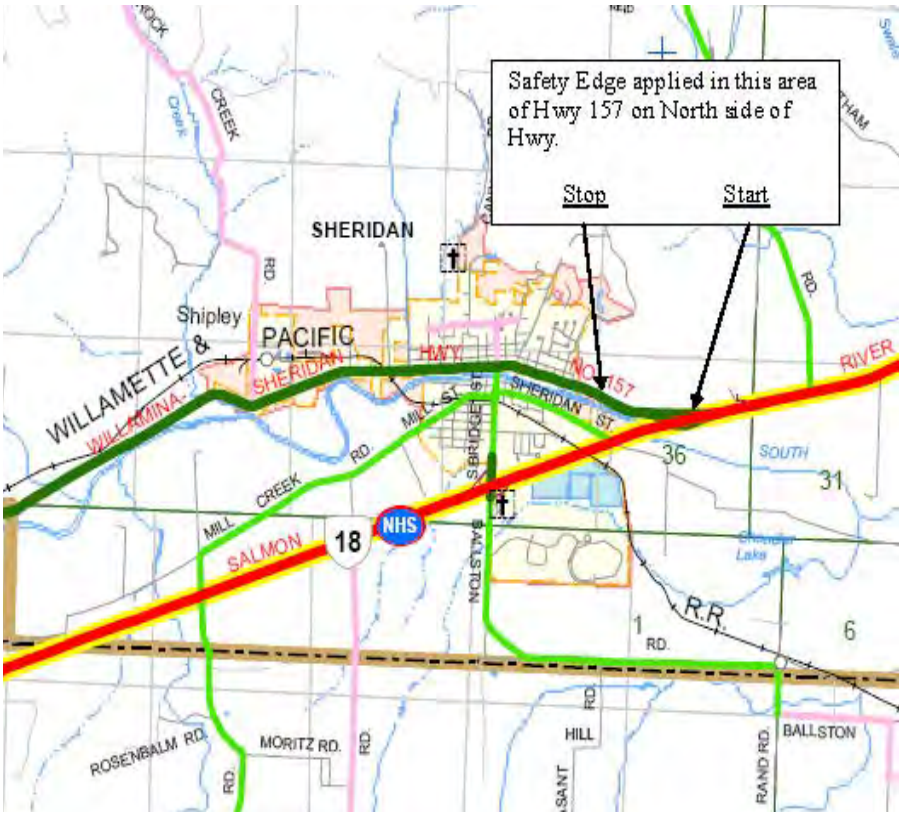


Figure 4.1: Oregon DOT Safety Edge $_{SM}$ Test Site on Highway 157 in Sheridan

The Sheridan Safety Edge $_{SM}$ application occurred with a single lift of asphalt. Figure 4.2 shows the paving activity at the Safety Edge $_{SM}$ location from the perspective of the front of the paving machine, while Figure 4.3 shows a similar perspective behind the paving machine. Finally, Figure 4.4 depicts the completed Safety Edge $_{SM}$ configuration before the shoulder was graded.

Figure 4.2: Safety Edge $_{SM}$ Construction -- Front Perspective

Figure 4.3: Safety Edge $_{SM}$ Construction -- Rear Perspective

Figure 4.4: Final Safety Edge $_{SM}$ Prior to Shoulder Grading

4.4 DRAFT OREGON SAFETY EDGE $_{SM}$ SPECIFICATION

The individual specifications or special provisions developed by the FHWA and various states that are included in the appendix contain different levels of detail. The applicable ODOT categories for standard specifications include description, materials, equipment, construction, measurement, and payment. The specifications by other agencies generally address these categories as well, so the research team used these resources as a starting place for developing draft Oregon specifications for the Safety Edge $_{SM}$.

Figure 4.5 includes draft Safety Edge $_{SM}$ specifications for consideration by ODOT. For the purposes of this draft language, any approved asphalt paving material is included in the specification. Concrete material may be added at a future date if ODOT determines that the Safety Edge $_{SM}$ can provide advantages on roads paved with concrete.

Section 0074X – Safety Edge SM

Description

0074X.00 Scope – This work consists of furnishing and placing a consolidated sloped pavement edge treatment, known as a Safety Edge SM, at locations as designated on the contract documents. The Safety Edge SM should be constructed monolithically with the pavement and to the dimensions shown in the Oregon Standard Drawings.

Materials

0074X.10 Materials – Construct the Safety Edge SM using the same material used to construct the adjoining pavement or paved shoulder.

Equipment

0074X.20 Equipment – Provide for the following material type:

> **Hot Mix Asphalt (HMA)** – Attach a longitudinal Safety Edge SM device to the paver screed to create a sloped pavement edge profile. The Safety Edge SM device must be approved by the Project Engineer. Use a device that compacts the HMA and creates a sloped wedge that ensures a 30 ± 5 degree wedge (measured from the horizontal plane). The device should provide a uniform texture, shape, and density and adjust to varying heights along the road including different pavement thicknesses, cross roads, driveways, and obstructions.

Construction

0074X.40 Shoulder Preparation – Prior to paving activities, place base material consistent with the pavement base so as to provide a foundation that will support the placement of the Safety Edge SM.

0074X.41 Shoulder Backing Material – Following completion of the paving activities and construction of the Safety Edge SM, furnish, place, and compact shoulder backing material to the top of the Safety Edge SM.

0074X.43 Handwork – Receive advance approval from the Project Engineer for short sections of handwork where the Safety Edge SM transitions at locations such as driveways, intersections, interchanges, and bridges.

Measurement

0074X.80 Measurement – No measurement of quantities will be made for work performed under this section.

Payment

0074X.90 Payment – No separate payment will be made for the Safety Edge SM construction. Work associated with the Safety Edge SM should be included in the contract unit price for the paving pay item(s). If a separate shoulder preparation task occurs for Safety Edge SM preparation, this work effort should be included as a lump sum line item.

Figure 4.5: Draft Oregon Safety Edge SM Specification Language

4.5 DRAFT OREGON SAFETY EDGE SM TECHNICAL BULLETIN

For engineers and contractors who will be responsible for identifying, designing, and constructing the Safety Edge SM at candidate locations, the research project included the development of a draft Technical Bulletin (see Appendix D). This document is designed to try to clarify common questions about the Safety Edge SM. The bulletin first includes a brief overview and definitions associated with the Safety Edge SM. Next, it addresses background and application issues including expected crash reductions, costs, benefit/cost, environmental, durability, and maintenance items. Finally, the bulletin explores typical construction issues and associated responsibilities followed by special instructions and contact information.

It should be acknowledged that the guidance included in the Technical Bulletin as well as the details given in the draft specification are based on the findings of the current research effort. As projects begin to incorporate use of the Safety Edge SM and ODOT staff and contractors become more familiar with the application process it is expected that the specific guidance may be modified.

Further explanation of some issues included in the Bulletin may be helpful when implementing the Safety Edge SM in Oregon.

The Technical Bulletin states that there are four manufacturers that provide an approved Safety Edge SM paving shoe. As Safety Edge SM is utilized by more states and local agencies there will continue to be improvements to the paving shoes making them easier and more efficient to use. For additional information on available paving shoes, ODOT staff and contractors is encouraged to visit FHWA's website or the websites of the manufacturers listed in Appendix E.

There was considerable concern expressed by the members of the Technical Advisory Committee regarding the requirement to mitigate for the increase in the impervious surface that would be expected to result when the Safety Edge SM is utilized. ODOT's Geo-Environmental Section has determined that the environmental impact of additional impervious surface required for the Safety Edge SM (up to 5 inches of depth and 8 inches of width) compared to an abrupt edge is not significant and so no mitigation is required.

The Technical Bulletin states that the use of the Safety Edge SM is encouraged for new pavement construction and STIP preservation projects with an overlay depth of two inches or more from edge to edge at locations where there is no curb, limited obstructions, and the paved shoulder has a width of four feet or less. It is expected that implementation of the Safety Edge SM will be gradual. A possible approach may be to select one or two projects in each region where there is likely to be the most significant benefits. Locations with a history of run-off-the-road crashes or roads with numerous sharp horizontal curves subjected to off-road tracking are good choices for the Safety Edge SM.

The Technical Bulletin indicates that including the Safety Edge SM paving technique as part of the overall paving project can require from one percent to around three percent more pavement material. The draft Bulletin states that this cost should be included in the pavement bid item and this approach seems to be working well in other states. The alternative of having the Safety Edge SM bid item written so that it is measured and paid on a per foot basis has been suggested as an

alternative approach. This option should be considered only if there are significant obstructions on a specific paving project. If construction phasing requires special shoulder preparation for the Safety Edge $_{SM}$ that occurs outside of the normal paving activities, it may be appropriate for this cost to be included as an additional lump sum item.

Roadside features such as steep roadside ditches, guardrail, mailboxes, and driveways and intersections all may interfere with the Safety Edge $_{SM}$ construction as they create obstacles that can require manual adjustment of the paving shoe. Safety Edge $_{SM}$ should not be used at locations with steep roadside ditches and guard rail due to limited space. However, it is possible to construct the Safety Edge $_{SM}$ at locations with mailboxes and driveways by manually adjusting the paving shoe at a specific location and then returning it to its original configuration once the paver passes the object or location.

4.6 CONCLUSIONS AND FUTURE DIRECTIONS

This report has included summary information about current knowledge regarding the application of the Safety Edge $_{SM}$ in other states and, where possible, has indicated how this information can translate to Oregon applications. Included with this review are draft ODOT standard specifications and a draft Technical Bulletin for future use of the Safety Edge $_{SM}$ in Oregon.

Due to the lack of available demonstration projects, the project team could not perform multiple field assessments. To fully evaluate the Safety Edge $_{SM}$ for Oregon, it should be tested with a variety of paving materials, base materials, and shoulder material combinations. Since this approach was not feasible, the project team has currently limited the initial specifications to hot mix asphalt paving material.

The funds for this research effort were not fully expended since additional demonstration projects could not be identified; however, as projects become available over the next few years it is advisable to continue to monitor and assess the use of the Safety Edge $_{SM}$ for these future projects. In addition, as Oregon continues to construct safety edges a future safety assessment contrasting sites with the Safety Edge $_{SM}$ as compared to sites without would help to determine overall effectiveness of this treatment in Oregon. Finally, in the absence of field sites a future assessment could include dynamic modeling of the Safety Edge $_{SM}$ contrasted to drop offs. This configuration was field tested with the 45-degree slope several years ago in Texas at a crash lab, but supplemental research in this area would be valuable.

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APPENDIX A:

COMMON ABBREVIATIONS AND ACRONYMS

Table A.1: Common Abbreviations and Acronyms

ADT	Average Daily Traffic
CRCP	Continuously Reinforced Concrete Pavement
EAC	Emulsified Asphalt Concrete
EB	Empirical Bayes
FHWA	Federal Highway Administration
GDOT	Georgia Department of Transportation
HMA	Hot Mix Asphalt
Iowa DOT	Iowa Department of Transportation
JPCP	Jointed Plain Concrete Pavement
JRCP	Jointed Reinforced Concrete Pavement
NCDOT	North Carolina Department of Transportation
ODOT	Oregon Department of Transportation
PCC	Portland Cement Concrete
SEM	Safety Edge Maker
TSAP	Transportation Safety Action Plan
WMA	Warm Mix Asphalt

APPENDIX B:

SPECIFICATION AND SPECIAL PROVISION EXAMPLES

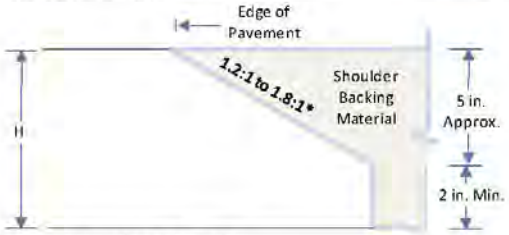
FHWA GUIDE SPECIFICATION FOR SAFETY EDGE SM

Final: December 2nd, 2010

Guide Specification for Safety Edge

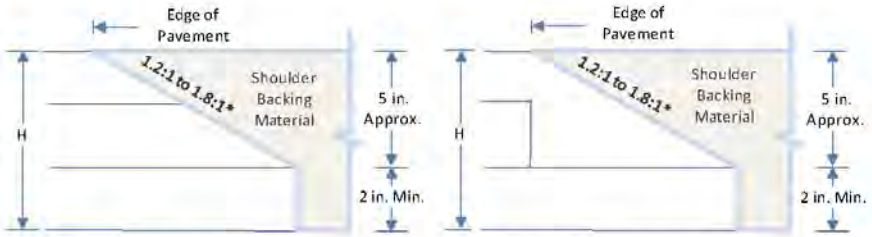
DESCRIPTION

Incorporate a Safety Edge to the dimensions shown and at locations designated on the contract documents. The finished shape of the Safety Edge shall conform to the cross-section drawings shown in Exhibit A and Exhibit B. The Safety Edge shall be constructed monolithically with the pavement.



Note 1: The range of slope is equal to 29° to 40°.

Exhibit A. Safety Edge configuration for concrete pavements and concrete overlays.



For H > 5 in. Configuration 1

For H > 5 in. Configuration 2

For H ≤ 5 in. Configuration 1

For H ≤ 5 in. Configuration 2

Note 1: The range of slope is equal to 29° to 40°.
Note 2: Configuration 1 depicts constructing the Safety Edge with the final two lifts of asphalt while Configuration 2 (alternate) depicts constructing it with only the final lift of asphalt.

Exhibit B. Safety Edge configurations for asphalt pavements and asphalt overlays.

1

EQUIPMENT

A. Hot Mix Asphalt (HMA)

Utilize an approved longitudinal Safety Edge system to create a sloped edge profile onto the roadway shoulder. Utilize an approved Safety Edge system that compacts the HMA and provides a sloped wedge equal to1.2:1 to 1.8:1 measured from the pavement surface cross slope extended. The use of a single plate strike off is not allowed.

Utilize an approved Safety Edge system that is adjustable to accommodate varying paving thicknesses.

All Safety Edge systems to be used for the purpose of creating a Safety Edge must meet the approval of the Engineer. The Engineer may require proof that the system has been used on previous projects with acceptable results or may require a test section constructed prior to the beginning of work to demonstrate the edge shape and compaction to the satisfaction of the Engineer.

B. Portland Cement Concrete

Modify paver screed to create a Safety Edge that meets the final cross-section as detailed on the plans.

CONSTRUCTION METHODS

A. Shoulder Preparation

Prior to placing asphalt or concrete pavement, prepare the shoulder material where the Safety Edge will be placed to provide a foundation that will support the placement of the Safety Edge in accordance with the owner agency's standard practice.

B. HMA Density Adjacent to Safety Edge

For HMA pavements and overlays, the percent compaction of the HMA adjacent to the Safety Edge shall be in accordance with the owner agency unconfined longitudinal edge specification.

C. Shoulder Backing Material

Furnish, place and compact shoulder backing material to the top of the Safety Edge as shown in Exhibits A and B in accordance with the owner agency specifications.

D. Handwork

HMA

Attain approval in advance from the Engineer for short sections of handwork such as transitions at driveways, intersections, interchanges, and bridges.

Final: December 2nd, 2010

Portland Cement Concrete

In areas that do not require a Safety Edge, e.g., intersections, bridges, etc., it is acceptable to saw cut and remove the Safety Edge after paving operations are completed. In areas where it is not possible to place the Safety Edge in conjunction with mainline paving but where the Safety Edge is desired, the Engineer may allow handwork for short sections, for example at driveway transitions, intersections, interchanges, etc.

METHOD OF MEASUREMENT

Safety Edge will not be measured for payment.

BASIS OF PAYMENT

No separate payment will be made for the construction of the Safety Edge. All work associated in the Safety Edge construction shall be integral to the pavement work and shall be included in the contract pricing for those pay items.

GEORGIA SAFETY EDGE $_{SM}$ SPECIFICATIONS

Safety Edge Specification

The contractor shall attach a device to the screed of the paver that confines the material at the end gate and extrudes the asphalt material in such a way that results in a compacted wedge shape pavement edge of approximately 30 degrees (not steeper than 35 degrees). The device shall maintain contact to the road shoulder surface. It shall also allow for automatic transition to cross roads, driveways and obstructions. The device shall constrain the asphalt head reducing the area by 10 to 15% increasing the density of the extruded profile. Conventional single plate strike off are not allowed.

The contractor may use the TransTech Shoulder Wedge Maker or the Advant-Edge or a similar device that produces the same wedge consolidation results. If the contractor uses a similar device, he must provide proof that his device has been used on previous projects with acceptable results or the contractor shall construct a test section prior to the beginning of work and demonstrate wedge compaction to the satisfaction of the engineer. Short sections of handwork will be allowed when necessary for transitions and turnouts or otherwise authorized by the engineer. This work will be included in the pay item_____.

IOWA SAFETY EDGE $_{SM}$ SPECIFICATIONS (SECTION 2305)

Section 2305. Safety Edge

2305.01 DESCRIPTION.
Incorporate a Safety Edge to the dimensions shown and at locations designated on the contract documents.

2305.02 MATERIALS.
Safety Edge material shall match the adjoining pavement or paved shoulder material.

2305.03 CONSTRUCTION.

A. Asphalt Pavement.
Attach a device to the paver screed to confine material at the end gate and extrude the asphalt material in a wedge shape meeting the requirements of the plan details. Maintain contact between the device and road shoulder surface; and allow automatic transition to cross roads, driveways, and obstructions. Use the device to constrain the asphalt head, reducing the area and increasing the density of the extruded profile. Approved devices meeting this specification are listed in Materials I.M. 502. Use of a single plate strike off will not be allowed.

Alternative devices not listed in Materials I.M. 502 may be approved by the Engineer. The Engineer may require proof that the device has been used on previous projects with acceptable results or may require a test section constructed prior to the beginning of work to demonstrate wedge compaction to the satisfaction of the Engineer.

The Engineer may allow short sections of handwork when necessary for transitions at driveways, intersections, interchanges, and bridges.

Placement of a granular fillet, per Article 2121.03, C, 4, b, is not necessary when a Safety Edge is installed.

B. PCC Pavement.
Modify paver screed to ensure the Safety Edge meets the final cross-section as detailed on the plans.

2305.04 METHOD OF MEASUREMENT.
Safety Edge will not be measured for payment.

2305.05 BASIS OF PAYMENT.
Safety Edge will not be paid for separately and shall be included in the contract unit price for the item for which it is required.

October 19, 2010 Matls. IM 502
New Issue

******THIS IS A NEW IM. – PLEASE READ CAREFULLY.******

APPROVED SAFETY EDGE DEVICES

SCOPE

A list of approved devices used to construct a safety edge is provided.

Use one of the following approved devices or an approved equal providing the same end-result cross-section as designated on the plans:

- TransTech Systems, Inc.
  1594 State Street
  Schenectady, NY 12304
  Telephone: 800.724.6306
  Website: www.transtechsys.com

- Advant-Edge Paving Equipment, LLC
  P.O. Box 9163
  Niskayuna, NY 12309-0163
  Telephone: 518.280.6090
  Website:
  www.advantedgepaving.com
  Contact: Gary D. Antonelli
  Cellular Telephone: 518.368.5699
  Email: garya@nycap.rr.com

NORTH CAROLINA SPECIAL PROVISION (SHOULDER WEDGE)

SHOULDER WEDGE:

10-6-10

Page 6-44, Section 610-8 Spreading and Finishing, add the following to the fourth full paragraph:

Attach a device, mounted on screed of paving equipment, capable of constructing a shoulder wedge with an angle of not more than 30 degrees along the outside edge of the roadway, measured from the horizontal plane in place after final compaction on the final surface course. Use an approved mechanical device or a device provided by the Department which will form the asphalt mixture to produce a wedge with uniform texture, shape and density while automatically adjusting to varying heights. If the device is provided by the Department, then the Contractor shall return the device to the Engineer after completion of all shoulder wedge construction.

Payment for use of this device will be incidental to the other pay items in the contract.

OKLAHOMA SPECIAL PROVISIONS FOR SAFETY EDGE SM (SECTION 411)

411-14(a-b) 09
11-01-10

OKLAHOMA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISIONS
FOR
ASPHALT SAFETY EDGE

These special provisions amend and where in conflict, supersede applicable sections of the 2009 Standard Specifications for Highway Construction, English and Metric.

411.01 DESCRIPTION ***(Add the following:)***

The asphalt safety edge is a beveled pavement edge to help lessen the severity of roadway departures. When a driver drifts off the paved surface, the safety edge provides greater ease for re-entering the roadway, and reduces the risk of over steering and loss of control of the vehicle.

Safety edge is required on asphalt concrete highway construction (permanent or temporary), on all routes, for all design speeds and types of traffic, when the following conditions exists:

- the roadway is an open section (no curb),
- the increase in pavement thickness is 2" or greater, and
- the paved shoulder width is 4 feet or less.

With the Engineer's approval, the safety edge may be constructed when the paved shoulder width is greater than 4 feet, and also when specified in the plans.

411.02 MATERIALS ***(Add the following:)***

Construct the safety edge using the same material used to construct the adjoining pavement or shoulder.

411.03 EQUIPMENT

C. Paver ***(Add the following:)***

Equip the paver to ensure a 30 ± 5 degree wedge along the outside edge(s) of the roadway (measured from the horizontal plane) is in place after final compaction of the final surface course. Use an approved mechanical device that will:

- Apply compactive effort to the asphalt mixture to eliminate objectionable voids as the mixture passes through the wedge device, and
- Produce a wedge with a uniform texture, shape, and density while automatically adjusting to varying heights encountered along the roadway shoulder.

411.04 CONSTRUCTION METHODS

I. Spreading and Finishing ***(Add the following:)***

When paving operations result in a drop off of greater than 2 inches at the outside edge(s), or as directed by the Engineer, attach a device to the paver screed to confine material at the end gate and extrude the asphalt material in a wedge shape having an angle between 30 ± 5 degrees (see Figure 411:1).

Ensure the wedge is compacted sufficiently as to eliminate objectionable voids. Maintain contact between the device and road shoulder surface; and allow automatic transition to cross roads, driveways, and obstructions. Use the device to constrain the asphalt head, reducing the area and increasing the density of the extruded profile.

The Engineer may allow short sections of handwork when necessary for transitions at driveways, intersections, interchanges, and bridges.

Do not construct the safety edge at longitudinal joints in the pavement section.

Safety edge shape can be constructed on each lift of asphalt, or on the full specified depth on the final lift. The dashed lines in Figure 411:1 indicate possible lift edge shape configurations.

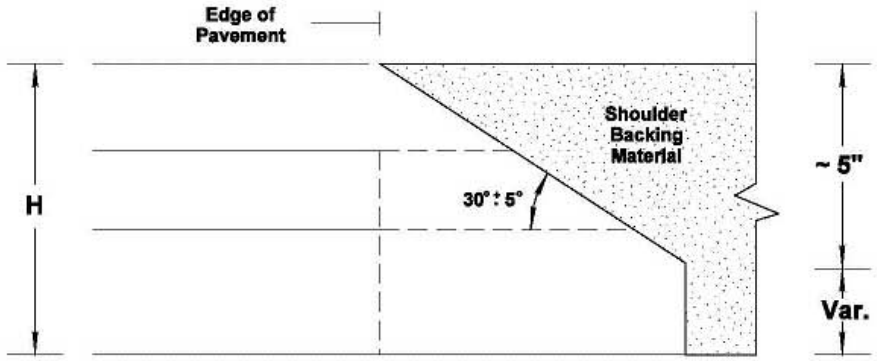


Figure 411:1

411.05 METHOD OF MEASUREMENT ***(Add the following:)***

Asphalt safety edge will not be measured for payment.

411.06 BASIS OF PAYMENT ***(Add the following:)***

Include the cost of constructing the asphalt safety edge in the price bid for the asphalt concrete paving pay item(s) included in the contract.

APPENDIX C:

EXAMPLE SAFETY EDGE $_{SM}$ POLICIES, TECHNICAL MEMORANDUMS, OR DRAWINGS

DELAWARE SAFETY EDGE $_{SM}$ POLICY (DESIGN GUIDANCE MEMORANDUM)

Delaware Department of Transportation
Division of Transportation Solutions
Design Guidance Memorandum

Memorandum Number 1-25 Revised

1. Road Design Manual 2. Bridge Design Manual 3. Utilities Design Manual
4. Real Estate Manual 5. Standard Specifications 6. Standard Construction Details

---

Title: Safety Edge Effective date: January 24, 2011

Sections to Implement:

X Project Development	X Planning	__ DTC
X Bridge	X Quality	X Traffic
X Team Support	X Maintenance & Operations	__ Other _____
__ Utilities		

I. Purpose

To reduce the occurrence of roadway departure crashes and to minimize the consequences of such crashes by providing a pavement edge treatment termed Safety Edge which has better performance compared to a vertical edge.

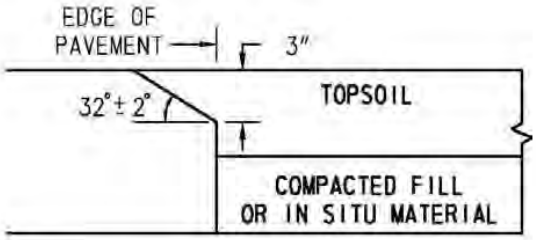
II. Design Guidance

A Safety Edge is a $32^{o} \pm 2^{o}$ fillet of pavement installed along the edge of the road in place of a vertical drop-off. The Safety Edge should be implemented during all pavement overlay operations and new pavement road construction where the road surface is not adjacent to curb or guardrail regardless of shoulder width. Safety Edge is constructed only on the final lift of the top wearing course 1¼" or greater in thickness at the edge of the roadway. (Note that throughout this document, "bituminous concrete" is being used as a general term which refers to both hotmix asphalt (HMA) and warm mix asphalt (WMA).) Safety Edge does not replace the requirement for securing pavement edge drop-offs during construction operations. The requirements of Table 6G-1 Vertical Difference of the *Delaware Manual on Uniform Traffic Control Devices* still apply for treating pavement vertical edges during construction operations.

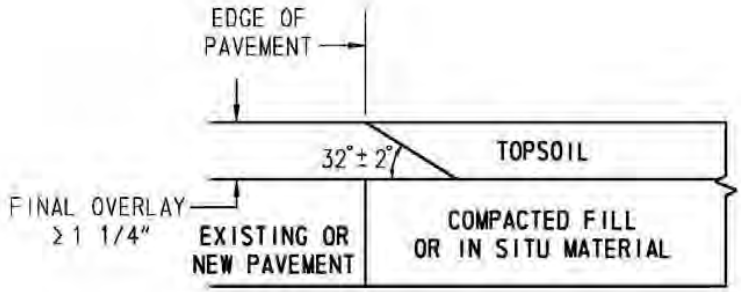
Pavement-edge drop-off is the uneven edge or vertical drop-off between the paved travel lane/edge of roadway and the unpaved shoulder area. A drop-off of 2 inches or more is considered to be a hazard to errant vehicles, especially if the edge is at a 90^{o} angle to the shoulder surface.

Pavement-edge drop-offs result from overlays, pavement-edge breaking, erosion, wear of unpaved shoulders, inadequate maintenance, or when the shoulder is not flush with the pavement following a construction project. A combination of shoulder erosion and edge rutting caused by vehicles repeatedly leaving the paved travel lane are typically found at these locations.

Safety edge is a relatively easy and inexpensive countermeasure to pavement-edge drop-offs. It is a tapered (rather than vertical) transition between the paved surface and the unpaved shoulder of a paved highway. The recommended 32° ± 2° degree angle with the horizontal tapered pavement edge or fillet can help drivers make a smoother, more controlled reentry back onto the paved travel lane compared to a more abrupt or vertical edge. The tapered edge helps prevent drivers from overcorrecting if they drift onto the shoulder, thus decreasing the likelihood of the vehicle crossing into opposing traffic or leaving the roadway.



CONCRETE PAVEMENTS
N. T. S.



BITUMINOUS CONCRETE PAVEMENTS AND OVERLAYS
N. T. S.

Figure 1
Safety Edge Configuration

Prior to placing concrete or bituminous concrete pavement, prepare the shoulder material where the Safety Edge will be placed to provide a foundation that will support its placement.

The Safety Edge is installed during a bituminous concrete resurfacing project using a special, removable wedge shape compaction device attached to and extending below the screed strike-off plate of the paver. This device is used to construct a pre-compacted, long lasting, low angle wedge fillet on the outside edge of the paved mat. The device has a self-adjusting internal spring that allows it to follow the surface independent of other paver components. The device has an angled surface that compacts the asphalt as it enters the device while another fixed-angle surface forms the tapered edge. As the asphalt continues under the wedge-forming surface, the asphalt is smoothed to create a finished surface on the tapered edge. Two wedge shape compaction devices that are commercially available are TransTech's Shoulder Wedge Maker and Advant-Edge Paving Equipment's Advant-Edger. The use of a single plate strike off is not allowed. Compaction of the edge should not be done with the first pass of the roller in order to give the Safety Edge a chance to harden some.

For concrete pavement or overlay, modify the paver screed to create the shoulder wedge as per the Safety Edge cross section.

Fill or in situ material shall be placed and compacted as shown in the figures.

In conjunction with the placement of the Safety Edge, there may be handwork, such as at transitions at driveways, intersections, interchanges and bridges, as approved by the engineer.

The Safety Edge shall be included on all roadway improvements projects on state maintained roads. The Safety Edge will be detailed on the typical sections as well as the construction details. Notes will be added to the plans to provide any necessary information to the Contractor.

The Divisions of Maintenance and Operations and Planning will also ensure that the Safety Edge is incorporated when paving work is authorized on a state maintained roadway.

III. Justification

According to the Federal Highway Administration, it is estimated from studies that about 11,000 injuries and 160 deaths occur annually in the United States from crashes related to unsafe pavement edges. In Delaware, road departure crashes accounted for about 47% of all fatal crashes from 2007 through 2009. Although rural roads were only 29% of the vehicle-miles traveled in 2007 through 2009, 57% of fatal roadway departure crashes occurred on rural roads. Additionally, 40% of fatal roadway departure crashes occurred on collector roads; collector roads only accounted for 16% of vehicle miles traveled in 2007 through 2009.

Once a vehicle has slipped off the pavement and onto the unpaved or deteriorated shoulder, abrupt or vertical pavement-edge drop-off can make it difficult for a driver to reenter the paved travel lane. Studies show that drivers tend to attempt to return immediately to the paved travel lane; in doing so, they tend to oversteer when "scrubbing" (the intense rubbing of the right-side vehicle tires against the pavement edge) prevents the vehicle from climbing back onto the pavement. This oversteering can result in loss of control when the tire climbs back onto the pavement, and may result in a crash. When crashes related to pavement-edge drop-off occur, they are often more severe than other crash types, according to studies, primarily because the vehicle often leaves the roadway, rolls over, hits a roadside object, or is involved in a head-on

collision. A Safety Edge provides an easily traversable transition for an errant vehicle to reenter the roadway from the unpaved shoulder/edge of road.

The Safety Edge can be constructed with no impact to production with minimal additional material cost.

A demonstration project using Safety Edge was constructed in 2010 on Old Furnace Road in Seaford.

Prepared by: Quality Section Revised Date: January 19, 2010

J. T. Papa III — 1-19-11
Recommended by: Assistant Director - Design Date

Natalie Barnhart — 1-19-11
Approved: Chief Engineer Date

Distribution:
Transportation Solutions Assistant Directors
Maintenance & Operations
District Engineers
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IOWA DESIGN MANUAL (CHAPTER 3 – CROSS SECTIONS) SAFETY EDGE $_{SM}$

Iowa Department of Transportation
Office of Design

3C-6

Safety Edge

Design Manual
Chapter 3
Cross Sections
Originally Issued: 04-15-10
Revised: 06-15-10

Introduction

The safety edge is a beveled pavement edge to help lessen the severity of roadway departures. When a driver drifts off the paved surface, the safety edge provides greater ease re-entering the roadway, and reduces the risk of over steering and loss of control of the vehicle.

Additional information about the safety edge is detailed in the FHWA brochure titled "The Safety Edge" (FHWA Publication Number FHWA-SA-09-023).

At the February 2010 meeting, the Highway Division Management Team decided to incorporate safety edge into DOT projects as detailed in this section effective with the October 2010 letting.

Where to Use

Safety edge is required on all primary highways unless one of the following conditions is met:

- the roadway is an interchange ramp or loop,
- the roadway or shoulder is curbed, or
- the paved shoulder width is 4 foot or greater.

Generally, this criterion will limit the number and types of projects that need safety edge. Most likely, the projects that will need safety edge will be 2 lane, rural highways without paved shoulders. These projects could be either new construction or rehabilitation.

Cross Sectional Design

The angle of the bevel is critical for the safety edge to function properly. Measured from level, the bevel is 30 degrees with an equivalent run to rise ratio of 10½ to 6.

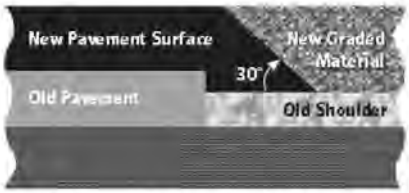


Figure 1: General Safety Edge detail from FHWA.

Note the 30 degree angle *does not* account for surface slope. Existing surface slopes range from 2 to 8 percent, which add an additional 1.1 to 4.6 degrees to the bevel angle when measured from level. The resultant angle is within the 30 to 35 degree recommendation from the FHWA.

It is our expectation that paving equipment will be adapted to furnish the 30 degree bevel.

PCC Paving and Overlays

For PCC pavements with safety edge, the nominal dimensions are as follows:

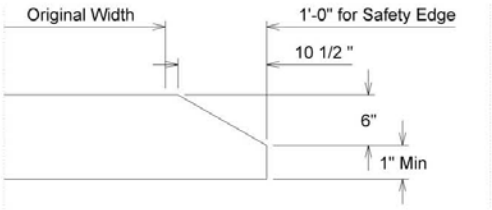


Figure 2: Safety Edge Dimensions for PCC Pavements

These details prescribe a 1 foot widening to accommodate the safety edge, and for the safety edge to be 6 inches deep. To allow proper finishing with a paver, a minimum 1 inch vertical face is required beneath the safety edge.

On the primary highway system, there are no cases where PCC paving is less than 7 inches thick.

HMA Paving and Overlays

For HMA pavements with safety edge, the nominal dimensions are as follows:

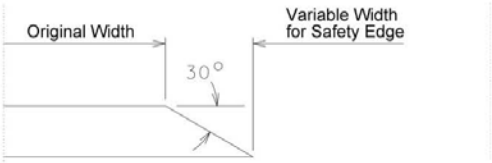


Figure 3: Safety Edge Dimensions for HMA Pavements

These details prescribe a 30 degree safety edge beginning at the edge of the original pavement width for the full depth of the paving.

Plan Details

Show the safety edge on the appropriate roadway typical when it is required.

On projects that are either new construction or reconstruction, remember that a 14 foot lane width includes 2 foot of paved shoulder. Without any additional paved shoulder, a roadway with 14 foot lanes will need the safety edge.

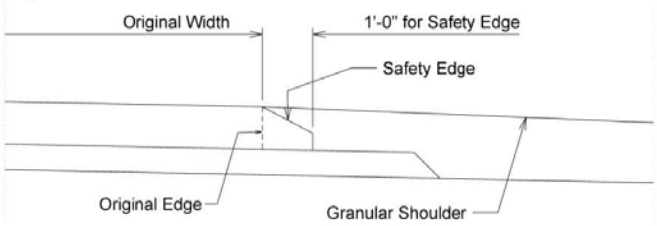


Figure 4: Addition of Safety Edge to a 14' PCC Lane

For PCC pavement, the additional width for the safety edge is included in the paving area computation.

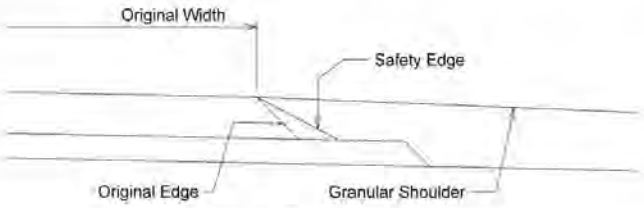


Figure 5: Addition of Safety Edge to a 14' HMA Lane

For HMA pavement, the additional quantity for the safety edge is included in the tonnage computation.

Alternately, when resurfacing an existing roadway that has granular shoulders or paved shoulders less than 4 foot, a safety edge is constructed as shown in Figures 6 and 7. The safety edge may also be used when the paved shoulder width is 4 foot or more to provide a better construction sequence for the contractor.

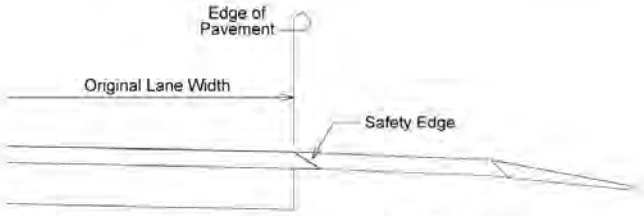


Figure 6: Resurfacing Project without Base Widening

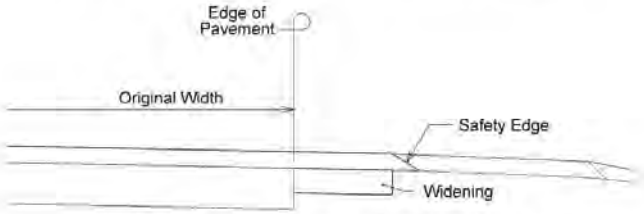


Figure 7: Resurfacing Project with Base Widening

As shown in Figure 7, the safety edge is not required on widening units placed with or prior to a resurfacing project. However, the width of the base widening should be maintained on the surface of the overlay.

It is acceptable to overhang the safety edge onto the existing shoulder, provided it is stable condition. In areas where the shoulders are soft or problematic, support the safety edge with a widening unit to ensure the edge will not deteriorate.

Include Standard PV-3 in the Index of Standard Road Plans tabulation.

Also refer to PV-3 for areas around intersections and interchanges that are not required to have safety edge.

MINNESOTA TECHNICAL MEMORANDUM NO. 11-01-T-01 (PAVEMENT EDGE TREATMENT – SAFETY EDGE $_{SM}$)

MINNESOTA DEPARTMENT OF TRANSPORTATION
Engineering Services Division
Technical Memorandum No. 11-01-T-01
January 19, 2011

To: Electronic Distribution Recipients

From: Bernard J. Arseneau, P.E.
Deputy Commissioner/Chief Engineer

Subject: Pavement Edge Treatment – Safety Edge

Expiration
This is a new Technical Memorandum, and will remain in effect until January 19, 2016 unless superseded or incorporated into Mn/DOT Standard Plans or the Mn/DOT Road Design Manual prior to that date.

Implementation
This Technical Memorandum applies to all Mn/DOT projects let on or after July 1, 2011.

The design guidance contained in this Technical Memorandum must be incorporated into the scoping process for all pavement/shoulder project types, including maintenance, preservation, re-construction, and new construction projects. Refer to the Guidelines section below for further clarification.

Local Road authorities are encouraged to adopt these or similar guidelines.

Introduction
This is a new Technical Memorandum outlining the requirements and design details for the implementation of a pavement edge treatment called the Safety Edge.

Lane departures are the most common type of rural fatal and serious injury crash in Minnesota. Effective low cost strategies designed to keep vehicles on the roadway are currently being pursued by various jurisdictions throughout the state and include: the use of rumble strips and stripes, wider pavement markings, chevrons at curves, and the Safety Edge.

The presence of a drop-off at the edge of the paved surface has been directly linked to some types of lane departure crashes. Recent studies have demonstrated a relationship between drop-offs exceeding 2 inches and lane departure crashes. When a driver leaves the pavement surface and tries to steer back onto the roadway, the vertical edge of the drop-off can cause "tire scrubbing" and tends to make the driver over-steer and lose control of the vehicle.

Construction of a Safety Edge at the edge of the paved surface significantly reduces the potential of "tire scrubbing", minimizing the consequences of drifting off the pavement surface. The additional cost associated with construction of the Safety Edge is considered to be minimal.

Purpose
The purpose of this Technical Memorandum is to incorporate the safety edge as a standard design and construction practice for most bituminous pavement edges six feet in width or narrower as well as to provide guidance and technical information for safety edge construction on both bituminous and concrete pavements.

-MORE-

Guidelines
The safety edge construction is done by shaping the edge of the pavement material with a 30-degree slope during the paving process (measured from the pavement/shoulder cross slope plane). The following Safety Edge criteria shall apply:

1. Safety Edge is required along bituminous pavement edges on projects where all of the following are true:
   a. New bituminous pavement/shoulder or bituminous overlay is being constructed with at least 2 (two) inches of paving depth.
   b. Paved shoulders are 6 (six) feet or less in width. (Safety Edge is optional on wider shoulders.)
   c. Pavement/shoulders do not have curbing.
2. For divided highways, the safety edge must be added to both median and outside bituminous shoulders when the paved shoulder width is 6 feet or narrower and the travel lanes are also bituminous. On concrete divided highways with bituminous shoulders, the median shoulder safety edge will be optional.
3. Safety edge will be optional for concrete shoulders.
4. Safety Edge is required on Maintenance/Repair projects where it has previously been incorporated into the pavement/shoulders.
5. Safety Edge requirements will not apply to preventive maintenance type projects; chip seals, crack sealing, slurry sealing, etc., with less than 2 inches of thickness.
6. The safety edge must be constructed as an integral operation of the roadway pavement placement process.
7. Bituminous pavement safety edges are easily constructed with the use of a manufactured shoe device, which attaches to the screed of the paving machine. The device uses a spring-loaded shoe that constrains the asphalt head, thus increasing the density of the extruded edge profile. The shoe is capable of applying variable pressure to ensure some compaction of the edge during paving operation. Currently, there are at least two manufacturers producing equipment that can create a Safety Edge (listed below). An approved equivalent is permitted.

   Transtech Systems, Inc.
   1594 State Street
   Schenectady, NY 12304
   1-800-724-6306
   518-370-5558
   www.transtechsys.com

   Advant-Edge Paving Equipment LLC
   1197 Hillside Avenue, Suite B47
   Niskayuna, NY 12309
   518-280-6090
   www.advantedgepaving.com
8. A single-plate strike-off method is not allowed for bituminous paving, as the single-plate strike-off method has been found to produce a non-durable edge.
9. Short sections of handwork are allowed, when necessary, for transitions and turnouts.
10. The installation of the safety edge in limited clear zone areas or in front of guardrails is optional if the designer concludes that it interferes with operational aspects or is too onerous to construct. The decision must be documented in the permanent project file.

-MORE-

11. During construction, a 2-4 inch depth of non-bituminous shoulder material adjacent to the pavement edge may be removed prior to installing the safety edge to allow for a thicker edge section.

12. District Materials input must be solicited on each project where safety edges are to be installed. In certain cases, additional subgrade support may be needed to support the installation of the safety edge.

13. Concrete construction of the safety edge requires adequate base support for the paver track.

14. Labor and/or equipment necessary to construct the Safety Edge will be considered incidental.

15. Material quantity changes need to be computed, noted, and included in the pavement/shoulder quantity tabulations.

16. It is the best practice to pull the adjacent material flush with height of the final pavement surface. The purpose of the Safety Edge in this practice is to provide short-term mitigation to edge drop-offs and a longer window for practical maintenance scheduling. For those jurisdictions that do not typically bring shoulders back up following an overlay, use of the Safety Edge would significantly lower the safety risk.

Additional information about the safety edge is detailed in the FHWA brochure titled "The Safety Edge" (FHWA Publication Number FHWA-SA-09-023).

Please see the attached figures for further Mn/DOT specific guidance.

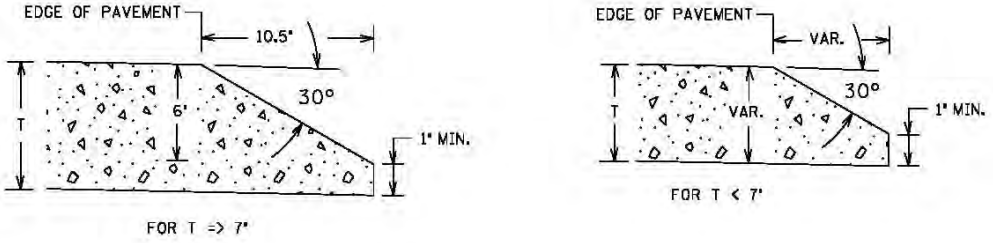
Questions
For information on the technical content of this Technical Memorandum, please contact **Bradley Estochen, State Traffic Safety Engineer, at 651-234-7011.**

Any questions regarding publication of this Technical Memorandum should be referred to the Design Standard Unit, designstandards.dot@state.mn.us. A link to all active and historical Technical Memoranda can be found at http://techmemos.dot.state.mn.us/techmemo.aspx.

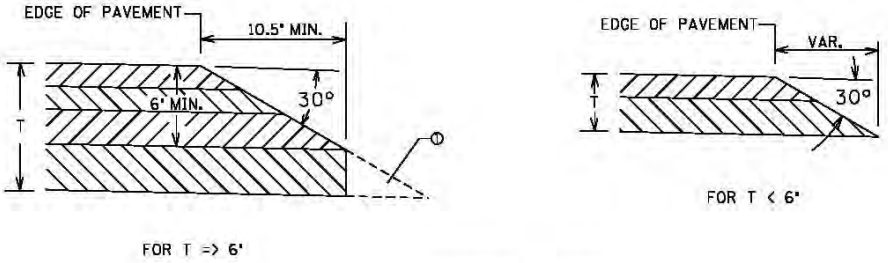
Attachments: Safety Edge Figures 1 and 2

-END-

Technical Memorandum 11-01-T-01
Pavement Edge – Safety Edge
January 19, 2011
Attachment Figure 1



CONCRETE PAVEMENT



BITUMINOUS PAVEMENT

Φ OPTIONAL DESIGN EXTENDS SAFETY EDGE DEEPER THAN 6" AND WIDER THAN 10.5". SEE PLAN DESIGN DETAILS.

Safety Edge Details
Figure 1.

Technical Memorandum 11-01-T-01
Pavement Edge – Safety Edge
January 19, 2011
Attachment Figure 2

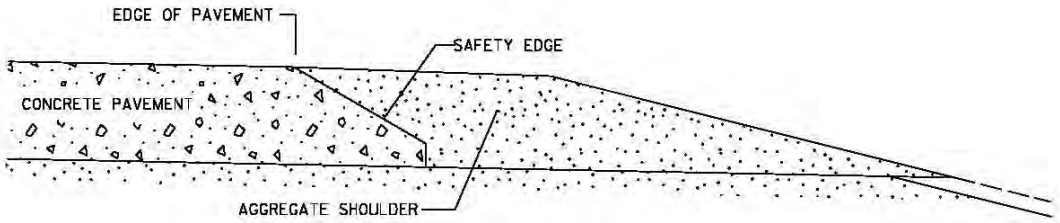


FIGURE A
CONCRETE PAVEMENT

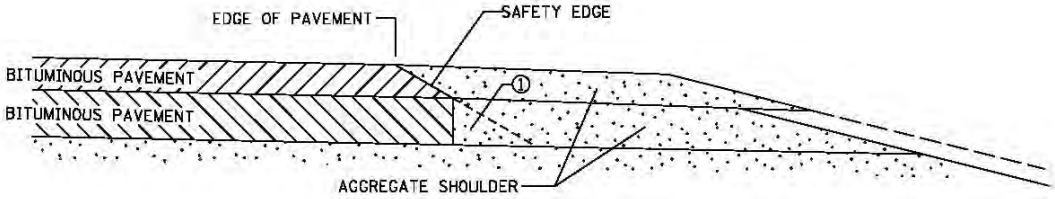


FIGURE B
BITUMINOUS PAVEMENT

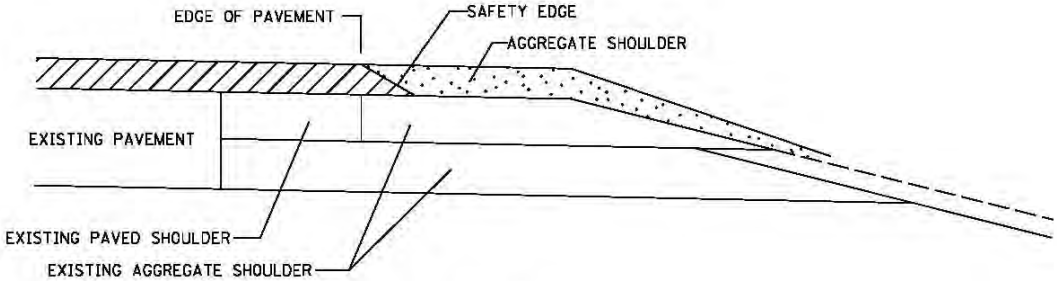


FIGURE C
BITUMINOUS OVERLAY

① OPTIONAL DESIGN EXTENDS SAFETY EDGE DEEPER THAN 6" AND WIDER THAN 10.5". SEE PLAN DESIGN DETAILS.

Safety Edge Construction Details
Figure 2.

NEW YORK ENGINEERING INSTRUCTION MEMORANDUM E1 10-012 (SHOULDER EDGE WEDGE FOR HOT MIX ASPHALT (HMA) PAVEMENTS)

To:		*New York State Department of Transportation* **ENGINEERING INSTRUCTION**	**EI 10-012**
Title: **SHOULDER EDGE WEDGE FOR HOT MIX ASPHALT (HMA) PAVEMENTS**			
Distribution: ☒ Manufacturers (18) ☒ Local Govt. (31) ☒ Agencies (32) ❑ Surveyors (33) ☒ Consultants (34) ☒ Contractors (39) ❑ _____( )		Approved: /s/Richard W. Lee for Daniel D'Angelo, P.E. Deputy Chief Engineer, Design	4/14/10 Date

ADMINISTRATIVE INFORMATION:

- This Engineering Instruction (EI) is effective beginning with projects submitted for the Letting of 09/02/2010.
- This EI does not supersede any issuance.
- The revisions issued with this EI are incorporated into the revision of Section 402 issued with EI 10-009.
- Design guidance will be incorporated into a future update of the Highway Design Manual's Chapter 3, Typical Sections.

PURPOSE: The purpose of this EI is to announce the requirement for the use of shoulder edge wedges for Binder and Top courses under Section 402, *Hot Mix Asphalt (HMA) Pavements*.

TECHNICAL INFORMATION: This EI implements the use of shoulder edge wedge during the construction of Binder and Top courses under Section 402 of the Standard Specifications.

Cost Impact. It is anticipated that there will be a minimal cost increase due to implementation of this EI. The cost increase may be attributed to the fabrication or purchase of the shoulder wedge former on the paving machines and additional HMA material in and under the wedges.

Design Guidance: For new and reconstructed pavements, where curbs are not present, the top and binder courses of asphalt concrete shall be built with a shoulder edge wedge. The designer shall detail the shoulder edge wedge in the plans. The angle, to the horizontal, of this wedge shall be specified as 35° maximum. Typical CADD cell details have been created for roadways with and without underdrain and can be found in Microstation. Designers can find the shoulder edge wedge details in the nym_detail_miscellaneous.cel (Metric) and nyu_detail_miscellaneous.cel (US Customary) cell libraries. The cell names are:

OMSE - DETAIL, MISCELLANEOUS, SAFETY EDGE
OMSEU - DETAIL, MISCELLANEOUS, SAFETY EDGE WITH UNDERDRAIN

Please modify these details as necessary for your project.

IMPLEMENTATION: The requirement for the shoulder edge wedge will be implemented with the use of revised Section 402. Main Office Design Quality Assurance Bureau will be inserting the revised Section 402 shelf note into contract proposals beginning with projects submitted for the letting of 09/02/10.

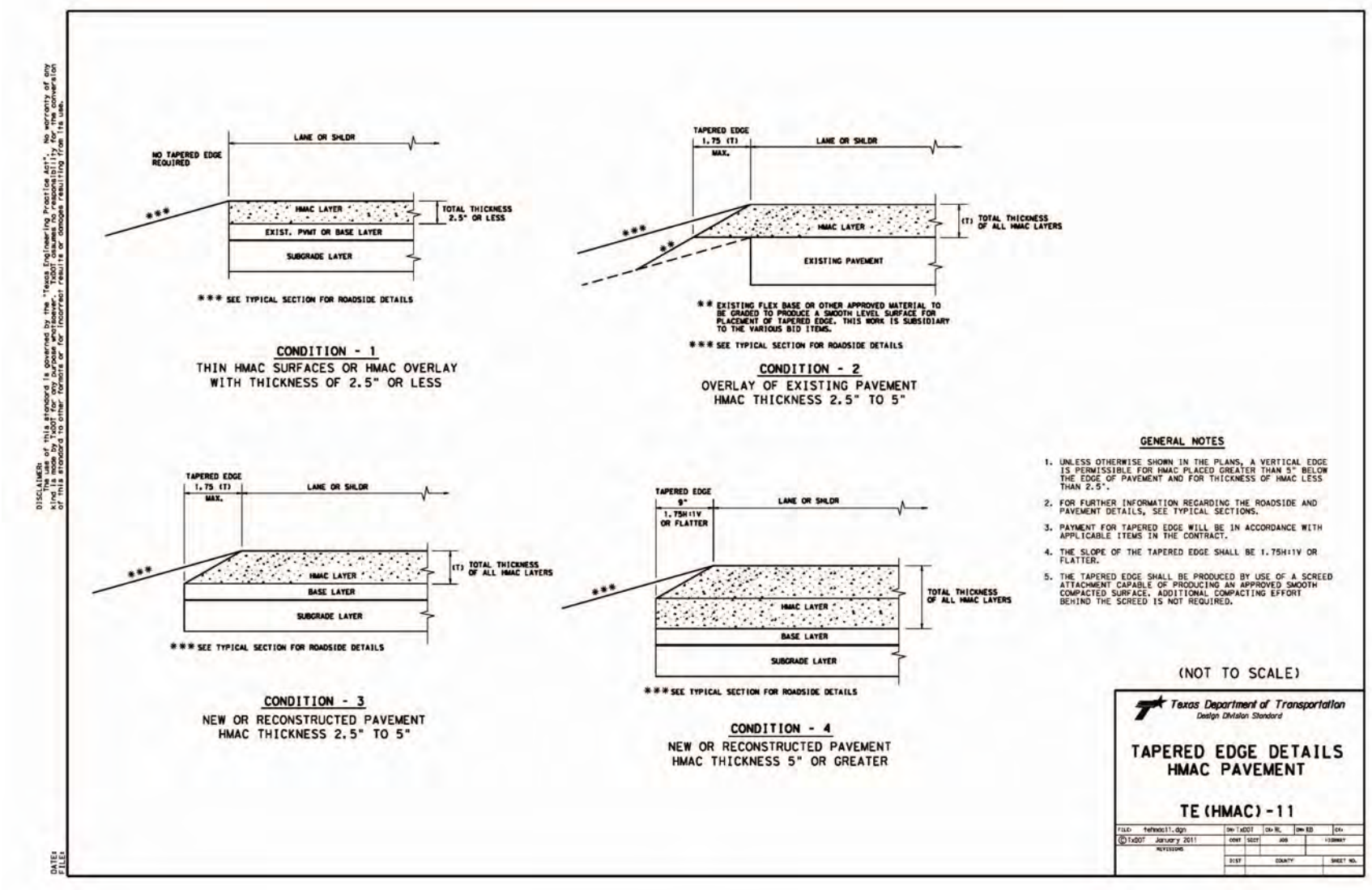
TRANSMITTED MATERIALS: None.

EI 10-012 Page 2 of 2

BACKGROUND: A requirement for shoulder edge wedge is included in the revised Section 402 for Binder and Top courses. This safety feature is recommended by the FHWA based on the study done in New York, Georgia, and other states. The wedge at the edge of the shoulder is expected to improve safety. The wedge is intended to allow vehicles that have wandered off the edge of pavement to smoothly traverse the wedge, back up onto the pavement, rather than fighting against a steep edge, catching and shooting across into opposing traffic.

CONTACT: Direct questions regarding this issuance to Pratip Lahiri of the Design Quality Assurance Bureau at (518) 457-4092 or via e-mail at plahiri@dot.state.ny.us.

TEXAS STANDARD DRAWING (TAPERED EDGE DETAILS, HMAC PAVEMENT, TE(HMAC)-11)



APPENDIX D:

DRAFT OREGON SAFETY EDGE $_{SM}$ TECHNICAL BULLETIN

The following document is a draft version of the Safety Edge $_{SM}$ Technical Bulletin to provide guidance for the use of the Safety Edge $_{SM}$ in Oregon.

OREGON DEPARTMENT OF TRANSPORTATION TECHNICAL

Traffic/Roadway Section BULLETIN

SUBJECT	FINAL NUMBER	EFFECTIVE DATE	VALIDATION DATE	SUPERSEDES or RESCINDS
Use of Safety Edge SM on Asphalt Paving Projects		00/00/0000	00/00/0000	00/00/0000
	WEB LINK(S) http://www.oregon.gov/ODOT/HWY/TECHSERV/technicalguidance.shtml			
TOPIC/PROGRAM	APPROVED SIGNATURE /s/ Section Manager or Chief Engineer			

PURPOSE

Use of the Safety Edge SM shoe during paving helps to consolidate the edge material at an approximately 30-degree slope. The Safety Edge SM functions as an effective safety technique that can assist the re-entry of an errant vehicle (including motorcycles and bicycles) by improving the transition from the edge of the road to the paved surface.

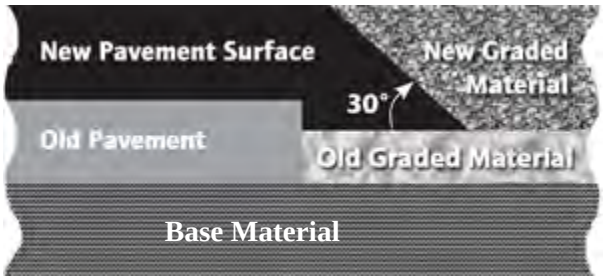
The Safety Edge SM paving technique enhances pavement edge durability by constructing a compressed sloping edge that is protected by shoulder material. This will also extend the life of the pavement section. During conventional paving, the pavement edge is not compacted. The graded shoulder material is then backfilled to be even with the top of the paved surface so that drivers are not exposed to this vertical edge. However, over time the shoulder begins to settle and the vertical edge becomes exposed. At a location with an edge drop-off, a driver who runs off the roadway and tries to steer back onto the active roadway may be prevented from returning by the sharp vertical edge of the pavement. The vehicle may enter the opposing lane of travel and collide with an oncoming vehicle or possibly even overturn.

GUIDANCE

This Bulletin may supersede guidance given in ODOT's Maintenance Manual http://www.oregon.gov/ODOT/HWY/OOM/guide_index.shtml (100-119 under Surface & Shoulder Activities, page 7; 111 Shoulder Blading and 112 Shoulder Rebuilding) regarding the frequency of shoulder pulling.

DEFINITIONS

Safety Edge SM. The Safety Edge SM is a 30 degree (±5 degrees) pavement wedge along the pavement edge. The pavement tapers down into the shoulder instead of dropping off vertically. This wedge provides a smooth, strong, and durable transition between the pavement and the graded material. Figure 1 depicts the typical cross section of the Safety Edge SM.



Source: Publication FHWA-SA-10-034 (2010)

Figure D-1: Cross Section of the Safety Edge SM

Safety Edge SM Paving Shoe. During the construction of the Safety Edge SM, the paving material is compressed by a spring-loaded paving shoe that forms the edge at a 30 degree angle. Currently there are four manufacturers who provide an approved Safety Edge SM paving shoe. Key features are the transition slope and the spring feature that help to compact the pavement edge. Alternative devices can be developed and approved as long as they conform to these general criteria and are tested and approved as providing comparable pavement edge conditions.

Edge Drop-offs. Edge drop-offs are vertical drop-offs (a 90 degree angle to the pavement surface) between the edge of the pavement and the aggregate or graded shoulder. Vertical edge drop-offs of three or more inches are typically considered unsafe.

Run-off-the-road Crashes. Run-off-the-road crashes occur when a single vehicle departs the road and either impacts roadside features such as trees and rocks resulting in a collision or encounters uneven terrain that causes the vehicle to overturn or crash.

BACKGROUND/REFERENCE

Safety Edge SM has been used by agencies outside of Oregon since 2003 and is still performing effectively. Numerous states are using the Safety Edge SM or are planning Safety Edge SM projects. The Safety Edge SM treatment was identified by the FHWA in 2008 as one of nine proven safety countermeasures expected to help achieve local, state, and national safety goals.

In Oregon two-thirds of the fatal and serious injury crashes are run–off-the-road crashes that occur most frequently on two lane roads. The rural two-lane road, therefore, is the type of roadway where the Safety Edge SM can have the most benefit. Factors associated with pavement edge drop-off crashes include speed, driver experience, vehicle/tires, the drop-off height, and the slope of the pavement edge. Agencies typically try to control the edge drop-off height, but this edge height can fluctuate due to common construction practices and wear and tear, so this pavement edge requires regular maintenance efforts. A sloped pavement edge can help to mitigate abrupt shoulder drop-offs.

Drivers who drive off the pavement surface where there are vertical pavement edge drop-offs have a difficult time climbing the edge to get back onto the pavement. The vertical edge creates a ‘scrubbing’ effect that must be overcome by over-steering. As drivers over-steer to re-enter the roadway, they are prone to lose control of their vehicles, they may veer into the adjacent lane colliding with oncoming vehicles, or may leave the other side of the roadway, even overturning.

Crash Reduction: The major benefit of Safety Edge $_{SM}$ is a reduced number of crashes over the life of the pavement by aiding in vehicle re-entry onto the pavement. FHWA research indicates that the Safety Edge $_{SM}$ can reduce run-off-the-road crashes by 5.7%. Although relatively low overall effectiveness, the application is so inexpensive the Safety Edge $_{SM}$ is highly cost effective, even on low volume roads.

Site Selection: The Safety Edge $_{SM}$ should particularly be considered if the following conditions are present:

- A history of run-off-the-road crashes;
- Numerous sharp horizontal curves subjected to off-road tracking;
- Locations subject to roadside erosion; or
- Locations where vehicles can be expected to frequently exit and re-enter the active lane (i.e. rural mailbox clusters).

Costs: The additional hardware for the Safety Edge $_{SM}$ is an initial cost of about $3000. The additional material costs are minimal but depend on the condition of the shoulder. The Safety Edge $_{SM}$ typically costs from less than 1% up to 3% of the total material costs. Following initial setup, there is no change in paving speed and the Safety Edge $_{SM}$ hardware requires minimal monitoring with no additional operational costs. FHWA estimates a reasonable range of costs to be between $536 and $2,145 per mile.

Benefit/cost: The benefit/cost analyses performed in the states of Georgia and Indiana compared the costs of crashes prevented to the cost of the treatment. These analyses indicate a varying degree of benefit depending on the ADT and road type, the higher the ratio the better the return on investment. Low ADTs (1000 to 2000 ADT) naturally have lower instances of crashes and have shown a benefit cost ratio of 3 to 1, a good benefit for the cost. Roadways with higher ADTs (up to 20,000 ADT) have shown benefit cost ratios ranging from 12 to 1 up to 60 to 1. These results indicate the Safety Edge $_{SM}$ is a highly effective treatment.

Environmental Impact: With regard to the environmental impact of additional impervious surface from up to 5 inches of depth for the Safety Edge $_{SM}$ (approximately 8 inches of additional width), the Geo-Environmental Section has determined that the difference between the Safety Edge $_{SM}$ and an abrupt edge is not significant and therefore no mitigation is needed.

Pavement Edge Durability: Studies show that the Safety Edge $_{SM}$ improves pavement edge durability. The lateral confinement of the paving material produces better compaction at the pavement edge. This provides additional support to the pavement and reduces edge raveling.

Maintenance: Tests show the Safety Edge $_{SM}$ performs as well as traditional procedures in keeping shoulder material flush with the pavement surface, but in the event material does shift (as it will for conventional pavement edges) the Safety Edge $_{SM}$ is then available to provide a more traversable surface that does not cause tire scrubbing and has additional durability. The

Safety Edge $_{SM}$ will then enhance operations until maintenance can be scheduled. As a result, the pavement life is extended when a Safety Edge $_{SM}$ treatment has been applied to a road.

EXPLANATION

A Safety Edge $_{SM}$ is encouraged for new pavement construction and STIP preservation projects with an overlay depth of two inches or more from edge to edge at locations where there is no curb, limited obstructions, and the paved shoulder has a width of four feet or less. Locations with shoulder widths greater than four feet can also benefit from the placement of a Safety Edge $_{SM}$.

The Safety Edge $_{SM}$ is installed using a Safety Edge $_{SM}$ paving shoe in lieu of a traditional paving shoe. The Safety Edge $_{SM}$ can be used for new construction (see Figure 2) and for reconstruction or resurfacing (see Figure 3). For asphalt applications, a minimum lift thickness of one inch is recommended. If multiple lifts are used in a resurfacing project, the Safety Edge $_{SM}$ can be placed with each lift or it can be constructed in its entirety with the final lift. The Safety Edge $_{SM}$ is constructed as the pavement is placed.

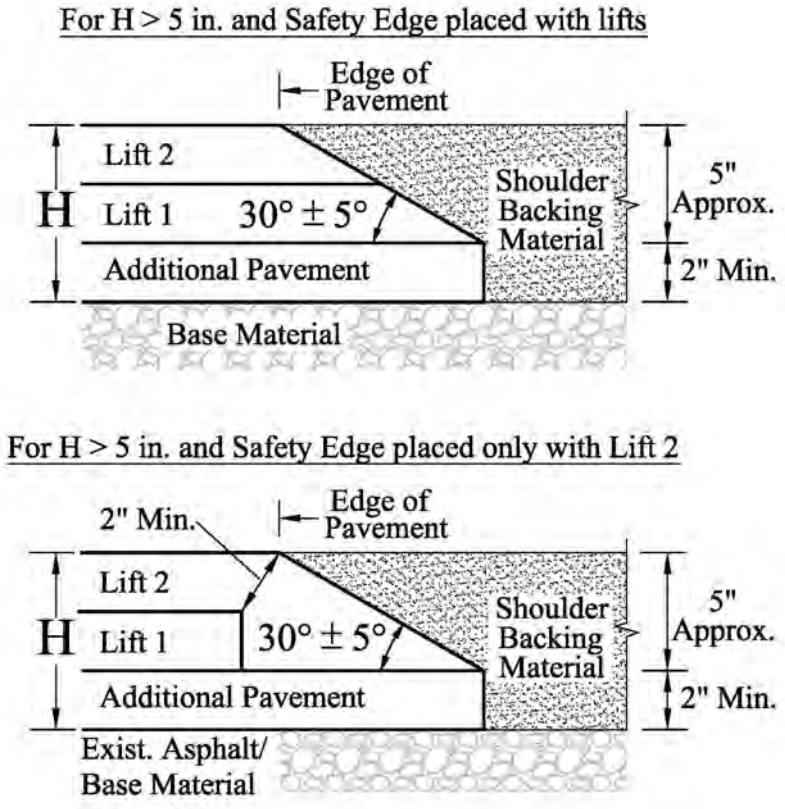


Figure D-2: Safety Edge $_{SM}$ for New Construction

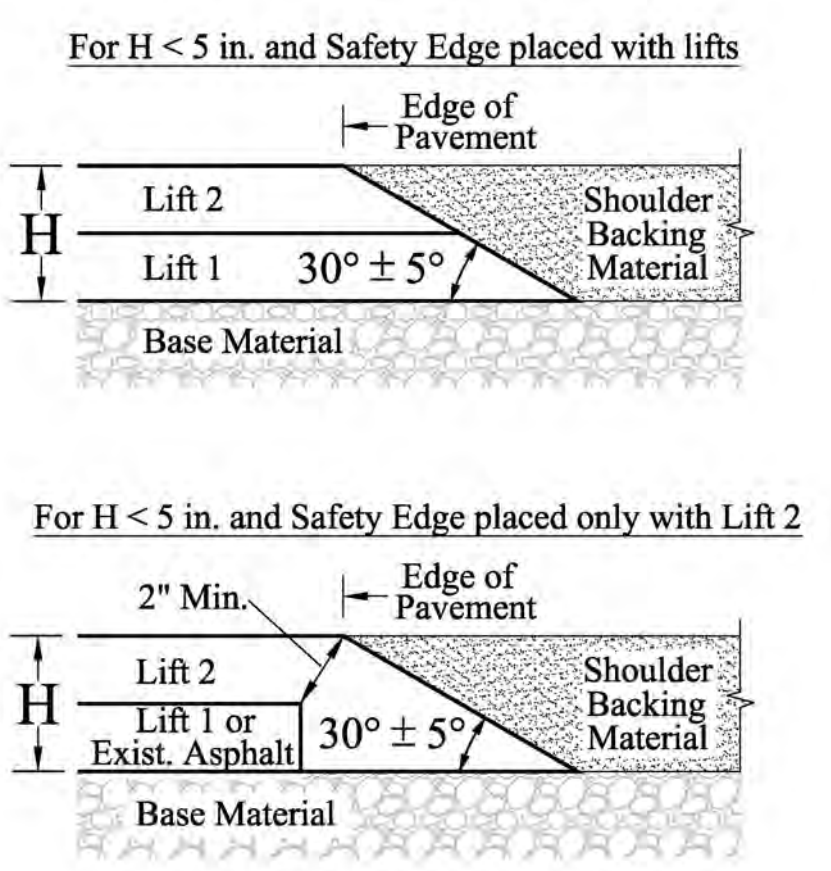


Figure D-3: Safety Edge $_{SM}$ for Resurfacing Projects

All Safety Edge $_{SM}$ applications should maintain a uniform texture, shape, and density and adjust to varying heights along the road including different pavement thicknesses, cross roads, driveways, and obstructions.

RESPONSIBILITIES

Contracting, construction, and maintenance personnel are key parties responsible for the implementation of the Safety Edge $_{SM}$.

Design: All contractual documents should note locations where the proposed construction includes the Safety Edge $_{SM}$ paving technique as part of the overall paving project. The Safety Edge $_{SM}$ can require from 1% to around 3% more pavement material (depending on the number of lanes and thicknesses of the overlay). This cost should be included in the pavement bid item.

Construction: The shoulder should be prepared using existing ODOT shoulder grading practices prior to initiation of paving.

The Safety Edge $_{SM}$ has been constructed with most Superpave and Marshall Mix designs commonly used for resurfacing. The nominal aggregate sizes of 1/2 inch (12.5 mm) and 3/8 inch (9.5 mm) are the most common used for Safety Edge $_{SM}$ construction. Open Graded Friction

Courses (OGFC) or similar have not been thoroughly tested and so use of these materials should be tested prior to large-scale applications.

At the time a contractor first installs the Safety Edge $_{SM}$, there will be a short learning period (usually less than 30 minutes) to understand how to monitor the Safety Edge $_{SM}$ paving shoe. Following that training time loss, there is no change in paving speed and so installation of the Safety Edge $_{SM}$ does not affect production rate. The only key change in the process is the addition of the specially designed shoe to the paver and then monitoring of the shoe and occasional adjusting of the shoe during paving so that the bottom edge of the device stays in contact with the road shoulder surface.

On resurfacing projects roadside features may impede the paving operation and successful construction of a Safety Edge $_{SM}$. The construction of the Safety Edge $_{SM}$ at these locations should be based on site features and as approved by the project engineer. Steep roadside ditches, guard rail, mailboxes, and driveways and intersections all may intrude on seamless Safety Edge $_{SM}$ construction as they create obstacles that can require manual adjustment of the paving shoe. Locations with steep roadside ditches and guardrail can directly impede Safety Edge $_{SM}$ construction by limiting available space adjacent to the road where the Safety Edge $_{SM}$ can be constructed. At these locations, the Safety Edge $_{SM}$ cannot be effectively constructed. At locations with mailboxes and driveways, the Safety Edge $_{SM}$ can be modified with manual adjustment of the paving shoe at a specific location and then returned to its original configuration once the paver passes the object or location.

Following paving, the adjacent shoulder material should be regraded flush with the top of the pavement. Ideal material for shoulder grading is gravel, crushed stone, or compacted soil.

SPECIAL INSTRUCTIONS

Refer to Oregon Standard Drawing Asphalt Pavement Details, RD610 for additional recommendations
http://www.oregon.gov/ODOT/HWY/ENGSERVICES/roadway_drawings.shtml#Roadway_600___Pavement

CONTACT INFORMATION

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APPENDIX E:

CURRENT SAFETY EDGE SM SHOE MANUFACTURERS

- Transtech Systems, Inc.
  1594 State Street
  Schenectady, NY 12304
  1-800-724-6306
  518-370-5558
  www.transtechsys.com

- Advant-Edge Paving Equipment LLC
  33 Old Niskayuna Road
  Loudonville, NY 12211
  814-422-3343
  www.advantedgepaving.com

- Carlson Paving Products
  18425 50th Ave. E
  Tacoma WA 98446
  253-278-9426
  http://www.carlsonpavingproducts.com

- Troxler Electronic Laboratories, Inc.
  3008 E. Cornwallis Rd. • PO Box 12057
  Research Triangle Park, NC 27709
  877-876-9537
  http://www.troxlerlabs.com/products/paving.php