

Federal Highway Administration
Every Day Counts
Innovation Initiative



Safety Edge_{SM} Design and Construction Guide

Final Report
January 5, 2012



U.S. Department of Transportation
Federal Highway Administration

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FOREWORD

The main focus of this document is to explain the important design, construction, and materials-related considerations for constructing the Safety Edge_{SM}. The target audience of this report is pavement design and construction personnel who will specify and construct the Safety Edge_{SM}.

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<p>In a coordinated effort with highway authorities and industry leaders, the Federal Highway Administration (FHWA) Every Day Counts initiative serves as a catalyst to identify and promote cost effective innovations to bring about rapid change to increase safety of our nations highway system, decrease project delivery time, and protect our environment. The Safety Edge_{SM} concept is an example of one such initiative in which the edge of the road is beveled during construction for the purpose of helping drivers who migrate off the roadways to more easily return to the road without over correcting and running into the path of oncoming traffic or running off the other side of the roadway.</p> <p>This Design and Construction Guide shares the findings from ten demonstration projects in multiple states and other ad hoc projects in which the Safety Edge_{SM} was implemented. This Guide supports the FHWA's efforts to implement the Safety Edge_{SM} technology by providing standards, guidance, and specifications for adopting this treatment as a standard practice on all applicable new and resurfacing pavement projects.</p> <p>The Guide provides information on the various elements to consider when designing and constructing pavement projects with the Safety Edge_{SM}. The Guide provides insights and lessons learned on previously constructed projects, highlighting items that may vary from conventional pavement design and construction.</p>			
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SI* (MODERN METRIC) CONVERSION FACTORS				
APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
(none)	mil	25.4	micrometers	µm
in	ft	25.4	millimeters	mm
yd	feet	0.305	meters	m
mi	yards	0.914	meters	m
	miles	1.61	kilometers	km
AREA				
in ²		645.2	square millimeters	mm ²
ft ²	square inches	0.093	square meters	m ²
yd ²	square feet	0.836	square meters	m ²
ac	square yards	0.405	hectares	ha
mi ²	acres	2.59	square kilometers	km ²
VOLUME				
fl oz		29.57	milliliters	mL
gal	fluid ounces	3.785	liters	L
ft ³	gallons	0.028	cubic meters	m ³
yd ³	cubic feet	0.765	cubic meters	m ³
	cubic yards			
NOTE: volumes greater than 1000 L shall be shown in m ³				
MASS				
oz		28.35	grams	g
lb	ounces	0.454	kilograms	kg
T	pounds	0.907	megagrams (or "metric ton")	Mg (or "t")
	short tons (2000 lb)			
TEMPERATURE (exact degrees)				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
ILLUMINATION				
fc		10.76	lux	lx
fl	foot-candles	3.426	candela per square meter	cd/m ²
	foot-Lamberts			
FORCE and PRESSURE or STRESS				
lbf lbf/in ²		4.45	Newtons	N
(psi) k/in ²	poundforce	6.89	kiloPascals	kPa
(ksi)	poundforce per square inch	6.89	megaPascals	MPa
	kips per square inch			
DENSITY				
lb/ft ³ (pcf)		16.02	kilograms per cubic meter	kg/m ³
	pounds per cubic foot			
APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
µm	micrometers	0.039	mil	(none)
mm	millimeters	0.039	inches	in ft
m	meters	3.28	feet	yd
m	meters	1.09	yards	mi
km	kilometers	0.621	miles	
AREA				
mm ²	square millimeters	0.0016	square inches	in ²
m ²	square meters	10.764	square feet	ft ²
m ²	square meters	1.195	square yards	yd ²
ha	hectares	2.47	acres	ac
km ²	square kilometers	0.386	square miles	mi ²
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m ³	cubic meters	35.314	cubic feet	ft ³
m ³	cubic meters	1.307	cubic yards	yd ³
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
TEMPERATURE				
°C	Celsius	1.8C+32	Fahrenheit	°F
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m ²	candela per square meter	0.2919	foot-Lamberts	fl
FORCE and PRESSURE or STRESS				
N	Newtons	0.225	poundforce	lbf
kPa	kiloPascals	0.145	poundforce per square inch	lbf/in ² (psi)
MPa	megaPascals	0.145	kips per square inch	k/in ² (ksi)

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

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SECTION 1: INTRODUCTION

1.1 Introduction

The Safety Edges_{SM} is a relatively simple but effective solution that can help save lives by allowing drivers who drift off highways to return to the road safely.

During conventional paving processes, the pavement is constructed with vertical or near vertical edges. Instead of a vertical drop-off, the finished Safety Edges_{SM} forms the edge of the pavement with a slope of approximately 30 degrees. Research has shown this “transition from on-roadway surface to shoulder and back is so smooth it defies assignment of any degree of severity.” The Safety Edges_{SM} provides a strong, durable transition for all vehicles and helps prevent pavement edge raveling.

The recommended practice of bringing the adjacent soil or aggregate material (unpaved shoulder or modified soil) flush with the top of the pavement often requires frequent maintenance. When the vertical edge is exposed due to wear/erosion, it can contribute to drivers losing control of the vehicle when attempting to recover from a roadway departure. The Safety Edges_{SM} concept is when drop-offs along the pavement edge occur, the edge will not be vertical, but has a shape that will not induce tire scrubbing. By including the Safety Edges_{SM} detail while paving, this safety countermeasure can be implemented system-wide at little or no cost.

1.2 Purpose of the Guide

The Federal Highway Administration (FHWA) works with States and Industry to accelerate the use of innovative technologies. This Guide supports efforts to implement the Safety Edges_{SM} technology by providing information and guidance to assist agencies in developing standards and specifications for adopting this treatment as a standard practice on all applicable new and resurfacing pavement projects.

The Guide provides information on the various elements to consider when designing and constructing pavement projects with the Safety Edges_{SM}. The Guide provides insights and lessons learned on previously constructed projects, highlighting items that may vary from conventional pavement design and construction.

1.3 Scope of the Guide

The information for this Guide draws significantly from experiences obtained from 10 formal construction project evaluations conducted in 2010 and 2011, as well as several ad hoc evaluations. It is expected that significant enhancements in equipment and procedures will be forthcoming as the Safety Edges_{SM} is implemented into standard practice.

The Guide is grouped into four sections, including this introductory section. Section 2 is focused on general design and construction considerations that are applicable to all pavement types and rehabilitation projects. Sections 3 and 4 identify specific considerations for

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constructing a Safety EdgesSM for asphalt concrete materials (AC) and Portland cement concrete (PCC) pavements, respectively.

SECTION 2: SAFETY EDGE_{SM} – GENERAL DESIGN AND CONSTRUCTION CONSIDERATIONS

In terms of paving operations, there is little difference between the placement and construction of AC and PCC materials (refer to Figure 1) with and without the inclusion of the Safety Edge_{SM}. However, there are important considerations that should be accounted for when incorporating the Safety Edge_{SM} into a paving operation. This section of the Guide highlights the general design and construction details when constructing a Safety Edge_{SM} in conjunction with AC or PCC pavements.

2.1 Safety Edge_{SM} Use

The Safety Edge_{SM} provides two important safety related functions. It serves as a mitigating measure to help with pavement edge drop off that occurs after an AC layer is placed, but before shoulders can be reconstructed flush with the paved surface. The Safety Edge_{SM} also serves as a long-term safety feature for areas susceptible to material displacement and/or erosion adjacent to the paved surface.

An additional benefit of the Safety Edge_{SM} is that the density of the AC mat adjacent to the pavement edge was found to be higher in most areas with the Safety Edge_{SM} in comparison to areas without the Safety Edge_{SM}. The Safety Edge_{SM} is believed to serve as a restriction to the lateral movement of the AC mat along an unconfined edge. This observation was found from multiple demonstration projects. Visual assessment of many Safety Edge_{SM} treatments have shown that trucks loaded with asphalt do not deform/damage the finished edge.



(a) AC Project.

(b) PCC Project.

Figure 1. Safety Edge_{SM} placed on an AC and PCC project.

Where the Safety Edges_{SM} Can Be Placed

The Safety Edges_{SM} can be used in almost every situation to provide a condition towards preventing near vertical lane-shoulder drop offs during construction and over time. It also provides added insurance until such time that maintenance personnel are able to repair eroded areas of the shoulder adjacent to the paved surface.

Where the Safety Edges_{SM} Should Not Be Placed

A site condition where the Safety Edges_{SM} should not be used is where the foreslope/embankment or ground surface has a steeper slope than the slope of the Safety Edges_{SM}. This condition may exist for a portion of the road being paved, thus the Safety Edges_{SM} should be considered for use on the remainder of the road. Figure 2 depicts this condition.



Figure 2. Example of where a foreslope/embankment is too steep for the Safety Edges_{SM}.

The Safety Edges_{SM} should be excluded in areas where curb and gutter have been or will be placed as the Safety Edges_{SM} is appropriate for the interface of a paved material and an unpaved/unbound material. In areas where there is a restriction for vehicles leaving the paved surface (for example; guardrails and other safety features) whether or not to use the Safety Edges_{SM} must be assessed on a case-by-case situation. The agency may see value in using the Safety Edges_{SM} for its pavement quality benefit, and thus may want to use it in these applications.

2.2 Pre-Construction and Discontinuous Paving Operations

The pre-construction activities for Safety Edges_{SM} projects are to review the paving plan and make sure the Safety Edges_{SM} can be placed in suitable areas along the project. If there are areas with restrictions along the edge of the pavement (for example, guardrails, intersections, and bridges), the width of the roadway and width of paving should be considered so that there is sufficient room for the Safety Edges_{SM} device for resurfacing projects. As an example, narrow bridges along some low volume roadways can result in conditions where the AC paver screed extensions cannot be moved-in sufficiently when using Safety Edges_{SM} devices that are bolted to the paver screed, so the paver operator must steer the paver more towards the center of the roadway during paving operations (center line crown or other cross slope changes need to be considered in these conditions). Other areas where the foreslope is steeper than the Safety Edges_{SM} slope should be noted. These conditions should be discussed in the contractors quality control plan and/or pre-paving meeting and how the condition will be resolved.

Paving across intersections and driveways with the Safety Edges_{SM} device in place is generally no different than when paving without the Safety Edges_{SM}. The differences for both AC and PCC paving are noted below. All of these conditions or paving anomalies should be identified and addressed prior to beginning paving operations.

- For AC paving, extra attention from the paver and screed operators may be necessary to accommodate the Safety Edges_{SM} at transitions for intersections, driveways, and changes in longitudinal elevations or profile. The reason for this extra attention is discussed in Section 3 of the Guide. Specifically, Section 3.2 discusses the different Safety Edges_{SM} devices and their attachment to the paver. For devices attached to the screed, the screed operator can keep the Safety Edges_{SM} device lowered or can raise the device above the bottom of the screed so that the Safety Edges_{SM} is not placed through some intersections (refer to Figure 3). The capability for lowering and raising the device allows the paving operation to continue without disruption when discontinuous features or adjacent features are encountered. For devices attached to the end plate, the screed operator needs to monitor the height of the end plate ski to ensure the desired shape is placed.
- For PCC slip-form paving, the PCC material at the intersection or driveway will need to be sawcut to remove the Safety Edges_{SM} (refer to Figure 4) or build up the Safety Edges_{SM} by hand in order to tie into pavement intersections.



Screed operator raised the Safety Edge_{SM} device in paving across this intersection. The Safety Edge_{SM} device can be kept lowered when paving across driveways. Agreement on how to treat this condition should be established before paving starts.

Figure 3. Placing an AC overlay at an intersection of a Safety Edge_{SM} project.



Figure 4. Sawcut on a PCC project at an intersection to remove the Safety Edge_{SM}.

2.3 Pavement Edge/Shoulder Preparation

The pavement edge should be prepared in accordance with standard agency paving operations for both AC and PCC surfaces (refer to Figure 5).




	<p>Motor grader is used to remove vegetation and soil build-up along the edge of the pavement.</p>
	<p>A motorized broom cleans the surface of the pavement prior to applying the tack coat to the surface of the existing pavement.</p>
	<p>A tack coat is applied to the cleaned pavement surface prior to placing the asphalt overlay.</p>

Figure 5. Surface preparation activities performed prior to placing an AC overlay.

The following items are highlighted to ensure the agency considers them as they have been shown to adversely impact Safety Edges_{SM} construction on some projects.

- If vegetation exists along the pavement edge consideration should be given to removing this vegetation in the area supporting the Safety Edges_{SM} prior to paving. Good asphalt paving practice includes not paving on vegetation as the asphalt will not adequately compact and thus will not perform adequately. Figure 6 shows an example of a Safety Edges_{SM} edge placed over vegetation. For asphalt paving, a clean/clearly visible pavement edge will help the screed operator monitor the material placement along the pavement's edge.
- If the agency removes vegetation/soil from the edge of the pavement (edge clipping), ensure a reasonable grade elevation and slope of the pavement edge/shoulder is established to minimize use of excess pavement material along the edge.
- Edge clipping should extend far enough to accommodate the additional width of the Safety Edges_{SM} which may be a change in standard operating practice. The wedge part of the Safety Edges_{SM} is typically additional width, therefore paving a vertical edge depth of 3 inches will require clipping an additional 6 inches of width to accommodate the Safety Edges_{SM}.



Figure 6. Example of Safety Edges_{SM} placed on heavy vegetation – due to lack of adequate compaction the Safety Edges_{SM} will deteriorate.

2.4 Slope Measurement

Including the Safety Edges_{SM} on a new construction or resurfacing project does not impact the agency's material and construction specifications. The only difference in determining the quality between projects with and without the Safety Edges_{SM} is the measurement of slope for the as-built Safety Edges_{SM} itself. This part of the Guide discusses measuring the slope of the Safety Edges_{SM}.

Figure 7 illustrates how the slope is measured or determined for an AC resurfacing project. The length of line B is determined as the distance of a vertical virtual line from the edge or toe of the Safety Edges_{SM} to the pavement surface cross slope extended. The toe of the Safety Edges_{SM} can be defined as where a straight line along the surface of the Safety Edges_{SM} contacts the ground surface. This point becomes important for asphalt mixtures with larger nominal maximum sized aggregate where the removal of one coarse aggregate particle can significantly change the measured slope. The length of line A is determined as the distance from the point where there is space between the straight edge placed on the pavement surface at the edge, defined as the break point, and the vertical virtual line through the toe of the Safety Edges_{SM} or vertical line B. The angle, θ , is calculated as $\theta = \arctan B/A$. This angle measurement is the angle that the vehicle tire encounters when the vehicle is attempting to return to the pavement. The slope of a PCC Safety Edges_{SM} is determined in the same manner. The angle measurement is made on the sloped portion of the Safety Edges_{SM} and does not include the vertical portion of the PCC edge.

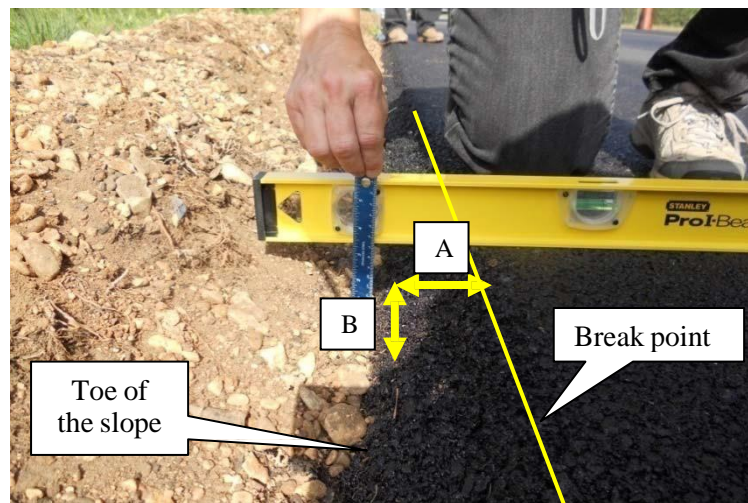


Figure 7. Measurement of Safety Edges_{SM} slope or angle.

2.5 Backing Material Placement

It should be remembered that the Safety Edges_{SM} is a mitigation of the drop off created by the AC or PCC overlay or new paved layer; it is not intended to substitute for a shoulder that is flush with the paved surface. After the paved layer or overlay has been placed, the shoulder or backing material needs to be graded back flush with the paved surface. The shoulder material should be placed in accordance with standard equipment and procedures specified

by the owner agency for both AC and PCC pavements. The only cautionary note is to grade the backing or shoulder material over and along the Safety Edge_{SM} as soon as possible but, in the case of an AC pavement, after the mat has cooled sufficiently so that any scuffing or tearing of the surface from construction equipment is minimized. Similarly, PCC should be allowed to cure and gain sufficient strength so that the construction equipment grading the backing material does not damage the PCC Safety Edge_{SM}. After construction is completed, the Safety Edge_{SM} will be covered with the backing material and not seen by the road user as shown in Figure 8.



Figure 8. Safety Edge_{SM} completely covered by shoulder backing material.

SECTION 3: SPECIFIC CONSIDERATIONS FOR CONSTRUCTING THE SAFETY EDGE_{SM} IN CONJUNCTION WITH NEW AC PAVEMENTS OR AC OVERLAYS

This section of the Guide identifies issues that need to be monitored during the placement and compaction operations of the AC pavement.

3.1 Design Features and Shape

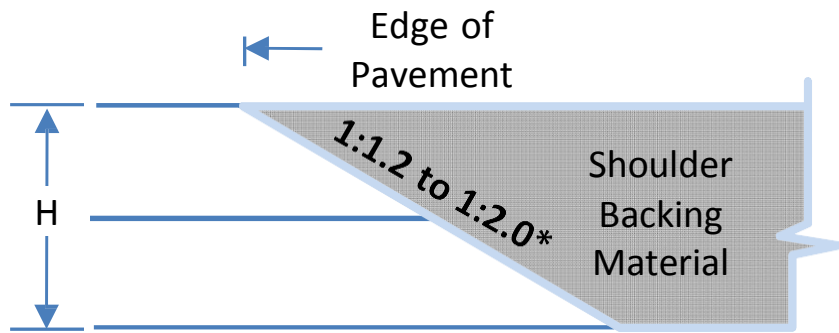
The paved lane/shoulder width and location of the Safety Edge_{SM} break point should be discussed and established prior to paving. The Safety Edge_{SM} can be constructed on the unimproved or improved shoulder with the break point lining up directly over the existing pavement edge or over any portion of the previously paved surface as shown in Figure 9.



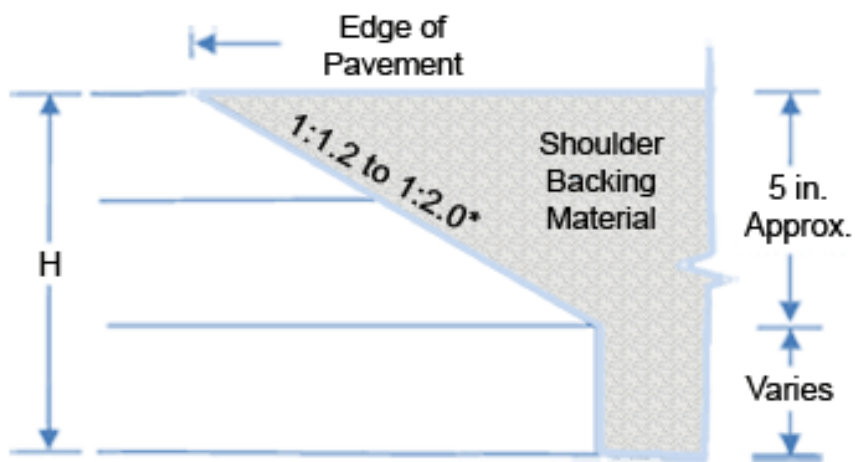
Figure 9. Paver positioned to align the Safety Edge_{SM} break point over the existing pavement.

The intent is not to sacrifice paved lane/shoulder width to construct the Safety Edge_{SM}. Constructing the Safety Edge_{SM} onto the unimproved shoulder does not result in a decrease in paved lane/shoulder width.

The Safety Edge_{SM} is designed to create a 30 degree finished angle, relative to the pavement cross slope, on the edge of the pavement. Agency-specific tolerances may vary from those shown in Figure 10 which is from the FHWA guide specification. On projects where multiple AC layers are used, it is recommended each AC layer (except leveling layer) of the final 5 inches of AC receive the Safety Edge_{SM} as shown in Figure 10. For new construction or reconstruction with thicker AC layers, consideration should be given to widening the underlying paved layers to accommodate the Safety Edge_{SM} without decreasing lane width as shown in Figure 10. On projects with multiple AC layers, it is expected the additional volume of AC required to form the Safety Edge_{SM} will increase bid quantities.



For $H \leq 5$ in.



For $H > 5$ in.

* Note, Recommended Rise to Run ratio range 1:1.2 to 1:2.0. The range of slope is equal to 26° to 40°.

Figure 10. Recommended Safety Edges_{SM} configuration for AC pavements and overlays.

3.2 Equipment – AC Safety Edges_{SM} Devices

The current commercial Safety Edges_{SM} devices can be grouped into two categories: (1) devices attached to the paver screed, and (2) modifications or attachments to the paver end plate. The devices listed below do not constitute an approved products list. Highway agencies should evaluate any new Safety Edges_{SM} hardware for compliance with specifications before approving for use on a project.

Devices Attached to the Screed

Currently, there are three devices available from two different manufacturers, which are the “Shoulder Wedge Maker” manufactured by TransTech, www.transtechsys.com and the “Advant-Edger” and “Ramp Champ” manufactured by the Advant-Edge Paving Equipment LLC, www.advantedgepaving.com. Each manufacturer provides detailed installation instructions for attaching their devices to the paver screed. The devices can be easily attached to and removed from the paver screed with a simple two-bolt connection. The Safety Edges_{SM} device should fit closely to the end plate to prevent AC from getting between the device itself and end plate. The Ramp Champ can be set to a range of angles, while the other devices have a fixed angle.

End Plate Modifying Devices

The end plate modification devices are available from Carlson Paving Products, Inc. (Safety Edge End Gate) <http://www.carlsonpavingproducts.com>, and Willow Designs LLC, <http://www.willowdesignsllc.com/>. The ski of the devices form the slope of the Safety Edges_{SM} and can be set to a range of angles. The screed operator can adjust the angle of the ski while paving to ensure the final angle of the Safety Edges_{SM} after rolling is close to 30 degrees.

3.3 Asphalt Concrete Materials

The Safety Edges_{SM} can be placed with all dense-graded AC materials that have been properly designed in accordance with existing mixture design methods, including: Hot Mix Asphalt (HMA), Warm Mix Asphalt (WMA), HMA with high amounts of Recycled Asphalt Pavement (RAP), HMA with Recycled Asphalt Shingles (RAS), polymer modified asphalt (PMA), rubberized gap graded and open graded mixes, and other specialty mixtures. The demonstration projects included HMA, RAP, RAS, WMA, and PMA mixtures.

There are two critical material issues in terms of placing a Safety Edges_{SM} for AC mixtures: (1) lateral movement of the AC mix during compaction and (2) the size or amount of coarse aggregate in the AC mixture.

- Most AC mixtures exhibit some lateral movement under the rollers during compaction and that movement is mixture and application dependent. Lateral movement of the AC mix should not prevent the contractor from achieving an acceptable Safety Edges_{SM} slope after final rolling. Ensure that after rolling is

- completed the Safety Edges_{SM} break point lines up directly over the existing pavement edge or over any portion of the previously paved surface. If the break point is over the unimproved shoulder (i.e. different support structure) the potential of a longitudinal crack forming is greater (Figure 11). This material related issue is discussed in more detail in Section 3.4 - Safety Edges_{SM} Construction, under Rolling.
- The maximum nominal size aggregate of the mixture or amount of coarse aggregate can affect the surface texture or appearance of the Safety Edge_{SM} and measurement of the slope. Fine-graded AC mixtures were observed to have a tighter surface appearance and texture along the edge. Rough surface texture makes the measurement of the slope more difficult to quantify – increasing variability in slope measurements.



Figure 11. Longitudinal crack due to Safety Edges_{SM} break point located on unimproved shoulder.

3.4 Safety Edge_{SM} Construction

This section discusses items of interest to asphalt paving projects when a Safety Edge_{SM} is to be placed as part of the new construction or rehabilitation project.

Safety Edges_{SM} Device Installation

Manufacturers of commercially available devices provide detailed instructions for attaching the Safety Edge_{SM} devices to the paver. Proper installation of the devices was discussed in a previous part of this section (Equipment – AC Safety Edges_{SM} Devices). A key issue for devices attached to the screed without guide rails is to ensure close installation to the end plate so loose mix does not get trapped between the device and end plate during paving operations. At the beginning of the day's production, when pulling off a transverse joint, the screed operator needs to monitor the position of the device as the auger chamber and extension are being charged to ensure the device is in contact with the end plate. These issues do not affect the end gate type device.

AC Placement

The Safety Edge_{SM} can be placed with normal paving procedures, and no changes to the operation of the paver need to be made. More importantly, the Safety Edge_{SM} device has no impact on how the paver operates, whether paving on an embankment or crushed stone layer, recently placed AC, existing AC or PCC layers, or milled surface.

For those agencies that require trial or control sections as part of standard AC paving operations, the slope of the Safety Edge_{SM} should be measured after all rolling has been completed to ensure the Safety Edge_{SM} slope did not “stand up” (substantial increase in the slope). Trial sections provide an opportunity for the screed operator to make adjustments to the Safety Edge_{SM} and screed before high production paving begins. For example, to obtain the 30° finished angle, the target angle to be achieved behind the paver by the Safety Edge_{SM} device may need to be shallower for a given mix, e.g., 25 degree. Trial sections can also be used to assess if the edge will “stand up” during the AC rolling operation. The issue of maintaining the slope of the Safety Edge_{SM} is discussed under the next subsection – Rolling.

The screed operator needs to watch and adjust three items during the paving operation when using a Safety Edge_{SM} device attached to the screed, described in Section 3.2: (1) the Safety Edge_{SM} device itself, (2) the end plate, and (3) the screed (refer to Figure 12). If the Safety Edge_{SM} device with too much downward pressure rides on the AC or other stiff base material that has been previously placed, this can result in undesirable paving results, as described below.

- When the Safety Edge_{SM} device rides on a base with a rough positive surface texture (e.g. coarse aggregate protruding upward such as in a chip seal) in some cases it may cause the screed to vibrate or jerk. The toe of the Safety Edge_{SM} can get caught on larger aggregate particles and when the particle breaks loose, the screed jerks. The screed operator will need to monitor the downward pressure of the Safety Edge_{SM} device so this does not happen in extreme cases.
- When the Safety Edge_{SM} device rides on a base with a varying longitudinal profile, the screed operator will need to monitor the downward pressure of the Safety Edge_{SM} device to keep the screed functioning as designed within the free-floating principle. The spring around the shaft of the Safety Edge_{SM} is designed to keep a relatively uniform pressure on the mixture being placed under the Safety Edge_{SM} – assuming the vertical operational limit of the Safety Edge is not exceeded.
- The screed operator also needs to monitor the downward pressure of the Safety Edge_{SM} device when it rides on soft surfaces. The leading edge of the device can dig into the soft shoulder pulling soil/aggregate into the asphalt wedge of the Safety Edge_{SM}. This is the same condition experienced in conventional paving when the paver end plate ski digs into the soft shoulder.



Figure 12. Safety Edges_{SM} adjustment for raising and lowering the device.

When paving begins the screed operator should pay close attention to the following items when using a Safety Edges_{SM} device attached to the screed.

- In charging the auger chamber with AC, the screed operator should ensure that the device is in close contact with the end plate so that mix does not get between the device and end plate and that there is sufficient material surrounding the device to keep it held against the end plate.
- After the paving operation begins and the full AC lift thickness has stabilized, the screed operator should adjust the Safety Edges_{SM} device by lowering the device into contact with the underlying surface. This adjustment should not be made prior to the paver moving off the shims at the start of a day's paving operation. The screed operator should look behind the paver to ensure that the slope of the edge will produce a slope of about 30 degrees after rolling.

- The paver end plate ski needs to remain in contact with the surface being paved over. AC can extrude out under the end plate ski if not in contact with the existing surface which can reduce the amount of AC available for the Safety Edges_{SM} – affecting the slope and density of the wedge itself.
- When placing an AC overlay, the Safety Edges_{SM} can ride on the underlying layer. However, the screed operator should closely monitor the downward force on the Safety Edges_{SM} device relative to underlying hard surfaces with variable longitudinal profiles, which can change the forces on one side of the screed (free floating screed principle or mode). This concern is heightened at intersections or areas of increased variation of longitudinal profile. The spring around the shaft of the Safety Edges_{SM} is designed to keep a relatively uniform pressure on the mixture being placed under the Safety Edges_{SM} – assuming the vertical operational limit of the Safety Edge is not exceeded.
- The operator needs to be aware that the height adjustment screw can be bent from paving with too much downward force, especially if the shoe is in contact with a variable elevation of a hard surface. The height adjustment screw can also be bent from or hitting objects while in transport.
- The screed operator should monitor the surface texture and condition of the Safety Edges_{SM}.
- When drawing in the hydraulic extension, the screed operator needs to closely monitor the process to ensure that the Safety Edges_{SM} device does not come in contact with the cross feed auger. If this occurs, it can damage both the Safety Edges_{SM} device and auger.
- If the hydraulic extension of the screed is extended during mainline paving, the amount of mix in the extension can be reduced near the paver end plate. When this occurs the screed operator should monitor the amount of mix to ensure it is not getting between the end plate and Safety Edges_{SM} device itself, as the screed moves out.
- The flow of AC material to the Safety Edges_{SM} device should be closely monitored to make sure enough material is available to form a continuous edge and that the material feed augers are properly positioned.
- Paver manufactures commonly recommend material feed augers be no greater than 18 inches from the end plate.
- When the paver is being moved, the Safety Edges_{SM} device should be removed or raised to its mounting height or uppermost position. This will ensure that the bottom of the device will not strike/get caught on any obstruction.

When using a Safety Edges_{SM} device the screed operator needs to continually be aware of the position of the break point of the Safety Edges_{SM} slope and keep the break point on the structural base or existing pavement.

At the beginning of the project, it is recommended that slope measurements be made immediately behind the paver and after each roller pass. The focus is on the final Safety Edges_{SM} slope angle after all rolling to determine how rolling impacts the final slope angle.

The contractor may want to periodically make these measurements as part of the quality control process.

Rolling

No special rollers are required for compacting the AC mix along and adjacent to the Safety Edges_{SM} (refer to Figure 13).



Figure 13. Rolling the Safety Edges_{SM} with standard rollers – No special rollers are required.

Most AC mixtures exhibit some lateral movement under the rollers during compaction. Lateral movement of the AC mix should not prevent the contractor from achieving an acceptable Safety Edge_{SM} slope after final rolling. For some of the demonstration projects, the contractor did change or revise the standard rolling pattern to maximize the density of the AC mat, while retaining an appropriate Safety Edge_{SM} angle. Just like for any AC paving project, the optimum rolling pattern is AC mixture specific. A rolling pattern used to compact a low stiffness mix and high stiffness mix may be different to meet the density requirements.

The following recommendations are made based on the findings from multiple demonstration projects.

- The contractor should roll the AC mat and pavement edges based on normal or standard compaction operation. This should ensure adequate density along and near the pavement edge. Multiple demonstration projects have been constructed successfully where the pavement edge was rolled with the contractor's standard rolling pattern.
- After final rolling, the slope of the Safety Edge_{SM} should be measured. If the slope of the edge is too steep, the contractor should determine if the slope of the edge was steepened because of excessive rolling, the use of a mix that exhibits tenderness, or the AC mixture is simply too soft to retain the targeted slope angle. A variable angle Safety Edge_{SM} device can be used to place the Safety Edge_{SM} at an angle less than 30 degrees behind the paver, which should assist the contractor in achieving 30 degrees after rolling.
- Delaying the rolling of the edge of the mat should be the last resort taken to retain the slope of the Safety Edge_{SM}. This becomes a decision between durability along and near the pavement edge and retaining a slope of the Safety Edge_{SM}.
- Continually monitor the slope of the Safety Edge_{SM} after final rolling. The slope of the Safety Edge_{SM} varied between 30 to 40 degrees on multiple demonstration projects without delaying the rolling of the Safety Edge_{SM}.

3.5 Quality Measurement

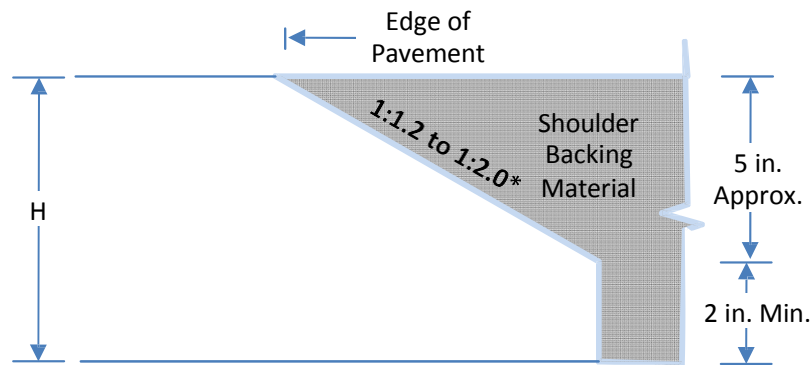
The same properties used or identified by the owner agency to measure the quality of AC pavement layers for acceptance should also be used on projects that include the Safety Edge_{SM}. The acceptance plan should not be modified for projects that include the Safety Edge_{SM}. More importantly, the density, strength, and/or smoothness requirements appropriate for a typical project should not be relaxed simply because the Safety Edge_{SM} is added to a resurfacing or new construction project. Thus, the only difference between projects with and without the Safety Edge_{SM} is the slope of the edge itself.

SECTION 4: SPECIFIC CONSIDERATIONS FOR CONSTRUCTING THE SAFETY EDGE_{SM} IN CONJUNCTION WITH NEW CONCRETE PAVEMENTS OR CONCRETE OVERLAYS

This section identifies issues that need to be monitored during the construction of PCC pavements. All of the PCC demonstration projects that were used for preparing this Guide included the use of slip-form paving to form the Safety Edge_{SM}. A benefit of forming the Safety Edge_{SM} during PCC slip-form paving is the sensitivity to edge slump is reduced.

4.1 Design Features and Shape

The Safety Edge_{SM} is designed to create a 30 degree finished angle relative to the pavement cross slope as shown in Figure 14 and should be constructed on a similar structural base as the adjoining monolithically placed lane/shoulder. During design, the structural base width needs to account for the Safety Edge_{SM} width.



* Note, Recommended Rise to Run ratio range 1:1.2 to 1:2.0. The range of slope is equal to 26° to 40°.

Figure 14. Recommended Safety Edge_{SM} configuration for PCC pavements and overlays.

4.2 Equipment – PCC Safety Edge_{SM} Devices

This part describes the modifications that must be made to a slip form concrete paver to form a Safety Edge_{SM}. It also notes the essential attributes of a concrete paver that are necessary to create an effective Safety Edge_{SM}. When a slip form paver is not being used, the Safety Edge_{SM} needs to be manufactured or created as part of the forms – one side of the forms will have an angle of 30 degrees rather than being vertical.

Currently, there are no commercially available Safety Edge_{SM} devices for PCC pavers or forms. Custom devices, however, can be fabricated by modifying the finishing pan of the paver (refer to Figure 15). The pan is essentially configured to form an inverted curb under the pan close to the end gate. The steel components of the assembly need to be robust in order to resist bending during paving operations from the force of the plastic PCC. The following provides a description of the modifications that were made to a Gomaco paver that

was used on one of the PCC demonstration projects and identifies some of the issues or items that should be considered in fabricating the Safety Edge_{SM} profile.

- A template was created for the Safety Edge_{SM} profile to ensure correct dimensions. The template was used to manufacture a stainless steel profile pan of the desired shape and dimensions. Portions of the existing profile pan were removed to fit in the new Safety Edge_{SM} profile.
[Note: The contractor decided against welding the Safety Edge_{SM} profile to the bottom of the existing profile section or pan because of a concern that the welds might tear the finished PCC.]
- A 2-inch finish tail on the stainless steel Safety Edge_{SM} profile was fabricated to help finish the portion of the edge where it goes from slope to vertical. When going through existing intersections, driveways, or where the grade is not exact on the outside edge, the 2-inch finish tail did drag in some locations. For the demonstration project, the contractor cut one inch off of this tail and it performed well, but cutting 0.5 inches from the tail would have also worked well.
- Adjusting bolts were fitted to the Safety Edge_{SM} profile pan. One adjustment bolt was on the sloped section in case an adjustment had to be made if the edge profile was not finishing properly.
- In setting up the paver, care was taken to position the vibrators in the specific locations for proper consolidation of the Safety Edge_{SM}—near the breakpoint.

Unlike the Safety Edge_{SM} attachments for AC layers or overlays, the modifications made to the concrete paver cannot be easily removed and replaced. The modifications can be removed, but the parts must be cut from the pan using a torch or grinder. Touchup of the pan is required to return the unit to service on standard PCC pavements.

4.3 Concrete Mixtures

Demonstration projects completed to date have used standard concrete mixes. No changes to the mix were needed to accommodate the SE.

4.4 Safety Edge_{SM} Construction

This part of the Guide discusses items of interest to PCC paving projects when a Safety Edge_{SM} is to be placed as part of the new construction or rehabilitation project.

PCC Placement

Normal paving procedures are usually sufficient for forming the Safety Edge_{SM} on mainline sections of the roadway using slip form paving operations and equipment. Material

properties of the hardened concrete from the edge and the interior of the pavement have been demonstrated to be similar.



Figure 15. View of the Safety Edges_{SM} device from front of paver.

Transitioning Between Different Edge Profiles

It is recommended to have a transition from a no Safety Edges_{SM} section to a Safety Edges_{SM} section to avoid a vertical edge perpendicular to traffic (i.e. similar to beginning section of bridge concrete rail/parapet where the bottom of the rail/parapet is modified to reduce the probability of vehicle tire snagging).

An important issue to be addressed is the intersection of cross roads where a vertical edge is required. Due to the fixed nature of the edge and shoe assembly, the contractor can consider different options depending on the number and extent of sections with different edge profiles. In either case, additional labor should be anticipated to tie into intersections or other areas requiring different edge profiles when paving using the Safety Edges_{SM} concept. The following provides an overview of the two options that were used on some of the demonstration projects.

- If there are only a few intersecting roadways, driveways or limited areas where a vertical face is required along the edge of the pavement, the contractor can consider placing the safety edge using normal paving operations. The Safety Edges_{SM} is sawcut

and removed to create a vertical edge. The sawing of the Safety Edges_{SM} can be completed at the same time the transverse joints are sawed. This option has worked fine, but does waste some PCC and requires additional sawing.

- Another option is to box out the areas requiring different edge profiles and place forms. The PCC in these limited areas is placed by hand using normal construction practices in order to tie into pavement intersections, driveways, and other features.

Vibration

Generally, the standard spacing of the vibrators are sufficient to properly consolidate the fresh concrete at the Safety Edge_{SM}. Consolidation of the material within the Safety Edge_{SM} should be checked at the start of any project. If slip form pavers are not being used, hand vibrators need to be used to ensure that the PCC flows into the lower part of the Safety Edge_{SM}. As noted at the beginning of this section, all demonstration projects included the use of slip form pavers in construction the Safety Edge_{SM}.

Curing

Care should be taken to insure the specified curing procedures are properly followed for all surfaces at the edge of the pavement, including the Safety Edge_{SM}. The Safety Edge_{SM}, however, does not require any special curing requirements beyond that for typical PCC layers.

Sawcutting

Transverse control joint sawcutting can be stopped at the breakpoint of the Safety Edge_{SM} and not continued through the sloped surface of the edge. Experience shows the contraction cracks normally form at the end of the sawcut and extend through the Safety Edge_{SM} as planned (refer to Figure 16).



Figure 16. Sawcut and crack at the formed joint on one of the Safety Edges_{SM} demonstration projects.

4.5 Quality Measurement

The same properties used or identified by the owner agency to measure the quality of PCC pavement layers for acceptance should also be used on projects that include the Safety Edges_{SM}. The acceptance plan should not be modified for projects that include the Safety Edges_{SM}. More importantly, the air void content, strength, and/or smoothness requirements appropriate for a typical project should not be relaxed simply because the Safety Edges_{SM} is added to a PCC overlay or new construction project. Thus, the only difference between projects with and without the Safety Edges_{SM} is the slope of the edge itself.

REFERENCES

EDC Safety EdgesSM field reports can be found at:

http://www.fhwa.dot.gov/everydaycounts/technology/safetyedge/field_reports.cfm

APPENDICES

Safety EdgeSM guide specification can be found at:

<http://www.fhwa.dot.gov/everydaycounts/technology/safetyedge/specs.cfm>