

**AASHTO Technology Implementation Group**  
**Nomination of Technology Ready for Implementation**  
**2005 NOMINATIONS DUE BY FRIDAY, SEPTEMBER 9, 2005**

<b>Sponsoring DOT</b>	1. Sponsoring DOT (State): Georgia Department of Transportation and FHWA Resource Center Safety & Design Team and FHWA Resource Center Pavement & Material Team
<b>Primary Technical Contact</b>	2. Name: Frank Julian Organization: Federal Highway Administration Address: 61 Forsyth Street SW, Suite 17T26 City: Atlanta State: Georgia Zipcode: 30303 E-mail: frank.julian@fhwa.dot.gov Phone: 404-562-3689 Fax: 404-562-3700
<b>Technology Description</b>	3. Name of Technology: The Safety Edge
	4. Briefly describe the technology. This is a 30 degree sloped pavement edge compacted and shaped by a shoe attached to the inside of the paver box. Compaction is attained by the weight of the screed and the extrusion action of the shoe. The shape of the pavement edge mitigates vehicle re-entry problems that often lead to severe crashes. This benefit is immediate for errant vehicles during construction and also for the life of the roadway if erosion occurs after the shoulder is constructed. The shoe can be made from a generic drawing developed by Georgia DOT or purchased from Transtech.
	5. Briefly describe the history of its development. The research that definitively developed the safety benefits of a pavement wedge was done in the early 1980's at Texas Transportation Institute and is described in the AASHTO Roadside Design Guide and NCHRP 500. The benefit of this pavement detail was widely known, but very few states attempted to implement it. FHWA worked with the Georgia DOT to demonstrate the construction feasibility of the device in 2003. Since then several states have constructed pilot projects and a pool fund of 7 states has been established to develop a crash reduction factor.
<b>State of Development</b>	6. For how long and in approximately how many applications has your organization used this technology? In 2003, two demonstration projects were successfully completed by the Georgia DOT. Since that time, the detail was incorporated into resurfacing contracts on a statewide basis in 2005.
	7. What additional development is necessary to enable routine deployment of the technology? None and a shoe is being marketed by a New York company, Transtech.
	8. Have other organizations used this technology? If so, please list organization names and contacts.
<b>Potential for Payoff</b>	9. What benefits has your organization realized from using this technology? Include cost savings, safety improvements, transportation efficiency or effectiveness, environmental benefits, or other advantages over other existing technologies. Currently a 7 state poolfund is evaluating the safety benefit and will attempt to quantify the safety benefits which could be translated to a cost savings. However the cost to implement this detail during the resurfacing process is negligible. Another benefit would be reduction in tort cases. Often times a lawsuit is brought against a state when an edge drop-off is present at the crash scene when in many cases it may not have anything to do with the resulting crash. The research has proven when this detail is incorporated into the pavement, it mitigates most crash types associated with edge drop-offs and thus a case could be made that reasonable due care was provided to the traveling public and thus reducing unfounded tort cases.

**AASHTO Technology Implementation Group**  
**Nomination of Technology Ready for Implementation**  
**2005 NOMINATIONS DUE BY FRIDAY, SEPTEMBER 9, 2005**

<b>Implementation Potential</b>	10. Please describe what actions another transportation agency would need to take to adopt this technology. If Transportation Agencies were to specify the compacted pavement wedge, contractors could build the shoe from the free drawing (attached) developed in the demonstration project or buy a device made by Transtech.
	11. What is the estimated cost, effort, and length of time required for procurement or adoption by another transportation agency? The device can be made for less than \$500 or bought for around \$2000 from Transtech. Although this is not exactly the same device they are very similar. Theoretically there is a slight amount of pavement material needed, but much of the material in the wedge comes from material that spills from the unconfined edge of the paver and was previously loose asphalt. Georgia DOT calculated that it took less than 1% additional asphalt material cost.
	12. What organization(s) currently supply and provide technical support for this technology? The FHWA Office of Safety has available materials documenting the cost, construction, and benefits of the safety edge. Transtech supports their device that makes the same shape.
	13. Please describe any legal, regulatory, social, intellectual property, or other issues that could affect ease of implementation. None on the generic device and shape of the pavement, but the Transtech device has been patented.
<b>Willingness to Champion</b>	14. Is the sponsoring DOT willing to promote this technology to other states, if partially supported by the AASHTO Task Force on Technology Implementation? <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No
<b>Date Submitted</b>	15. Date: September 9, 2005

16. Please include image(s) of sketches or photographs, if available  Image(s) are attached.\*

\*

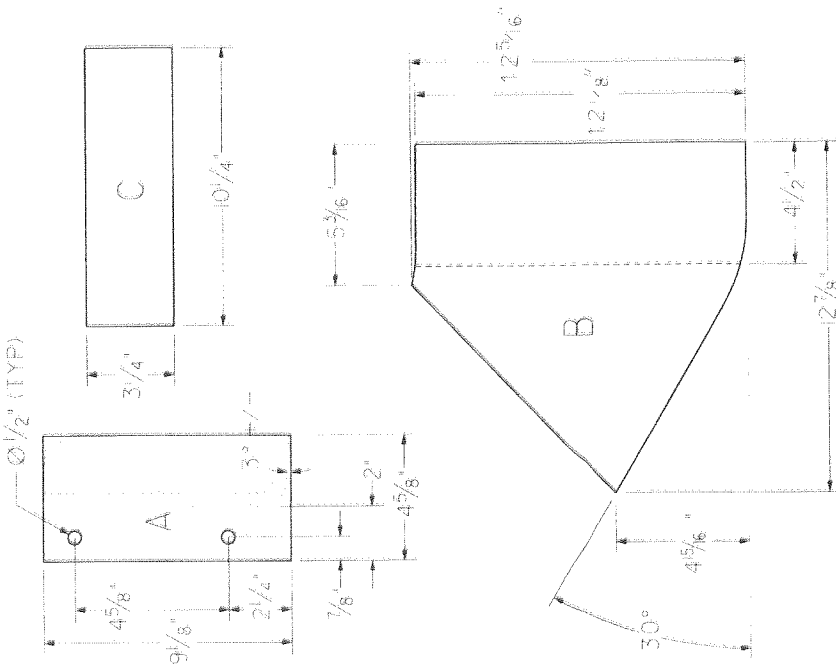
<b>AASHTO CONTACT</b>	MARTY VITALE ADMINISTRATIVE COORDINATOR FOR ENGINEERING AASHTO	PHONE: 202.624.5862 FAX: 202.624.5469 <a href="mailto:mvitale@aaashto.org">mvitale@aaashto.org</a>
-----------------------	--	--

Selected Mainstreaming Tactics for Business Plan (1 <sup>st</sup> 2 years)					
Selected Tactic for Business Plan	Product	T2 Options	Lead State (if relevant)	Resource Issues/Vehicle	Timing
<p><b>1. Policy Strategy Priorities</b>  <u>Strategy:</u> <i>Gaining Governor's support, tied to economic growth (freight movement, tourism, etc.)</i></p> <p><u>Tactic:</u> Targeted and persuasive briefing material for separate stakeholder groups on value of SO&amp;M designed to generate support for more aggressive program</p> <p>a) Agency policy Bd  b) economic development  c) freight  d) tourism</p>	<p>Short paper or brochure (power point?) to be used by SDOT staff in stakeholder contact contexts.</p> <p>Targets: CEO/SDOT Commission/Legislative Committees-interest groups</p> <p>Should be aggressive (problem of accommodating current SDOT posture?). <u>Should include safety benefits as well as congestion.</u></p>	<p>Consultant produced</p> <p>Working with ad hoc SSOM TF</p> <p>Trial run at SSOM meetings?</p> <p>CEO Roundtable topic MT?</p> <p>Participation in F-SHRP research on reliability</p> <p>Build on existing AASHTO publications, 20-24, etc</p>	<p>MD -- CHART BD  MN -- GuideStar)  CA -- Performance TF and ops policy  MT -- stakeholder input  WA -- Ops review</p>	NCHRP	3rd Q 05  (high priority)
<p><b>2. Planning Strategy Priorities</b>  <u>Strategy:</u> <i>Getting Operations into the Long-Range Plan</i></p> <p><u>Tactic:</u> Develop incremental agenda for inserting operations into statewide plans via identification of place in plans, methods, formats, relationship to G &amp; O etc</p>	<p>Document? Website?</p> <p>Built on agreed-upon agenda (recognizing different types of state plans)</p> <p>Use of consultant support from FHWA/FSHRP activity</p>	<p>Lead state program (joint SSOM/SCOPT selection</p> <p>Develop agenda via joint SSOM/SCOP TF with FHWA/NTOC</p>	<p>MD -- LR plan  WA -- DOT business Plan  CA -- TMS Master Plan  FL -- SW ITS Plan  KA -- IS in projects/SW TOC plan  IL -- Ops and security  MN -- ITSOP plan  PA -- SW Ops Plan</p>	FHWA Planning Division  FHWA PCB Program	3rd Q 05

<p><b>3. Organizational Structures Strategy Priorities</b>  <u>Strategy: Human Resources required for non-traditional Operations</u></p> <p><u>Tactic:</u> Identify core capacities needed and development of Knowledge/Skills/Abilities and training program curricula at various scales investment and develop appropriate in-house training</p> <p><u>Clearinghouse of course offerings? – NTOC plans to consider developing this, and it was discussed in this group as the most critical need.</u></p>	<p>Could include G &amp; O structure (related tactic)</p>	<p>input</p> <p>See existing NTOC matrix related to Statewide and Regional planning process and methods</p> <p>Collaborate with UTCS on curriculum for training course</p> <p>Compile existing material KSA</p> <p>Material from TMC</p> <p>Pooled fund – extend to cover other capacities</p> <p><u>Work with related NTOC Action Team</u></p>	<p>WI -- ITS Business Plan</p> <p><u>MO, TN, NY</u></p>	<p>FHWA – NHI/LTAP</p> <p>NCHRP</p>	<p>Start up 3<sup>rd</sup> Q 05 (discussion already underway)</p>
<p><b>4. Partnerships Strategy Priorities</b>  <u>Strategy: Advancing Public Partnerships (public-public and public-private)</u></p>	<p>Partnering Guidebook?  <u>– I'm not in favor of this. There are a ton of guides on partnering. Lets focus on implementing the ETO</u></p>	<p>Lead State/Pooled program?</p> <p>Special joint group with PSAG?</p>	<p>FL – IM workshops  MD – Interagency TF &amp; MPO -- rel  MN -- Guidestar Bd  MO -- KC Scout</p>	<p>FHWA</p> <p>NCHRP</p> <p>SCOTS?</p>	<p>Build around ETO and MTIMC</p>

<p><u>Tactic:</u> Review techniques for formalizing State DOT/Public Safety Agency relationships  e)MOUs  f) joint training  g)legislation, etc.</p>	<p>guide and supporting the PSAG and NTIMC  I'd like to see a concerted political push by AASHTO, ITSA and PSAG/NTIMC partners to make this a national agenda item – a crisis linked to traffic fatalities.</p> <p>Joint DOT/PSA workshop,</p>	<p>Guidebook: Piggy back on ETO and NTIMC work for guidelines</p>		<p>timing  (Start up  1<sup>st</sup> Q  06?)</p>
<p><b>5. Performance Measures Strategy Priorities</b>  <u>Strategy:</u> Identify Performance Measures</p> <p><u>Tactic:</u> Warrants/Benchmarks (“Standards of Practice”) for Operations application  h)CWZ need for ITS  i) Ramps  j) FSP  k) IM Clearance time</p> <p>NOTE: tie this in with Dimension No. 6  Tactic: Synthesis/White paper to provide some sense of scale on needed Operations investments – staffing, technology</p>	<p>Draft Warrants Convert to AASHTO Guidance</p> <p>I'd rather see focus on implementing the NTOC developed PMs and benchmarking. Lets move beyond naming performance measures to using them, facilitating exchange about implementation and data and establishing benchmarks. Lets start with the ones we have on build on those over time.</p>	<p>Pooled Fund  See FHWA DMS SOP)</p>	<p>FHWA</p> <p>FL – Clearance times  MD – C/E studies  MN PM in Annual Report  MO --Tracker system  VA – NOVA study  WA – Greybook  WI --.Maint. System</p>	<p>2<sup>nd</sup> Q 06</p>

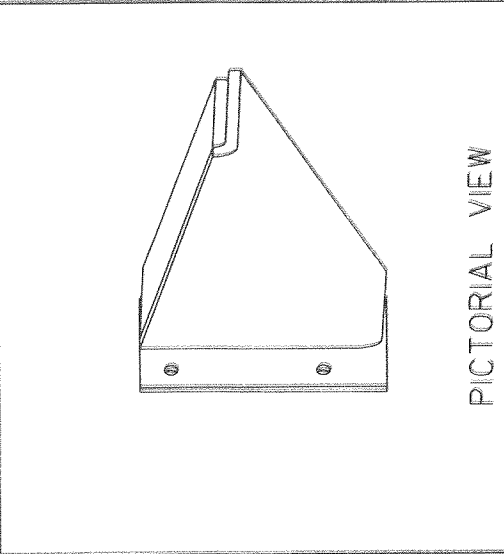
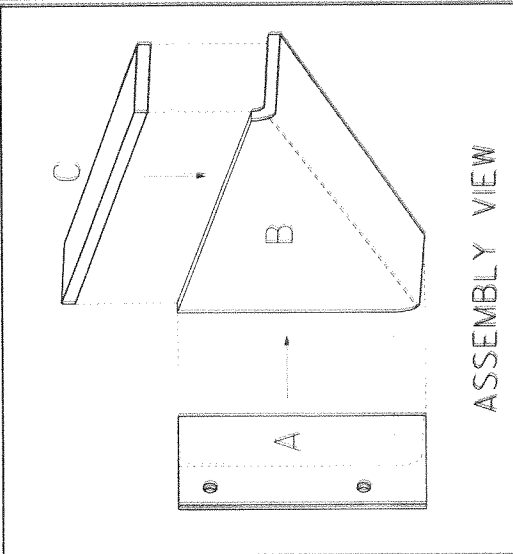
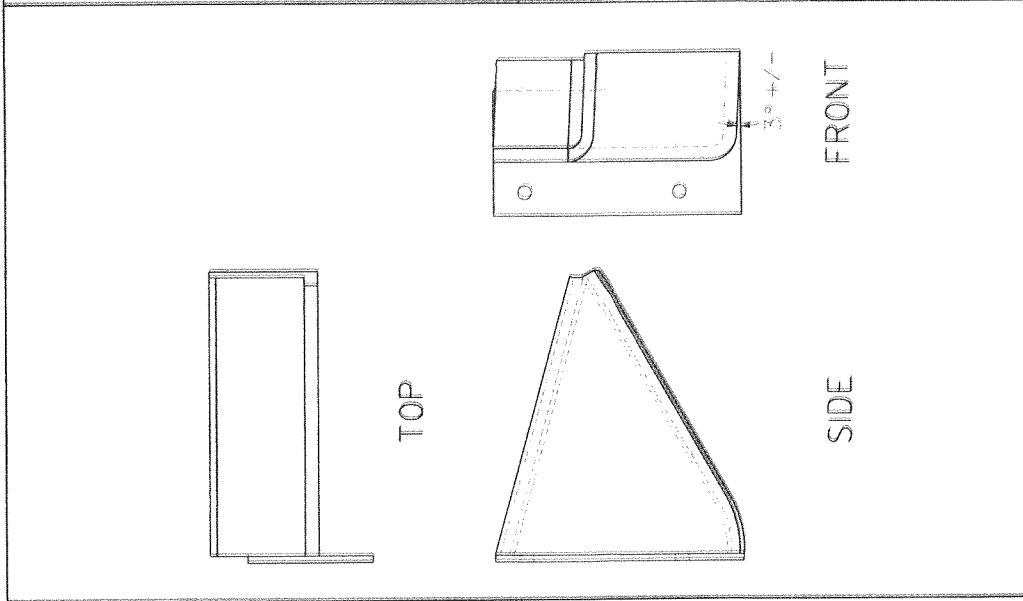




NOTE:  
 PIECE A TO BE 1/4" PLATE STEEL.  
 PIECE B AND C TO BE 1/2" PLATE STEEL.  
 ALL WELDS TO BE 1/4" FILLET.



# SAFETY WEDGE



REVISIONS		DATE	REVISIONS	DATE	REVISIONS	DATE

GEORGIA  
 DEPARTMENT OF TRANSPORTATION  
 DISTRICT 2  
 DRAWN BY: SEAN BUSH  
 SCALE: HALF  
 DATE: JUNE 11, 2004  
 SHEETS: 1 OF 1

C:\My Documents\SAFETY WEDGE\ASPHALT\Wedge.dwg  
 C:\My Documents\SAFETY WEDGE\ASPHALT\Wedge.dwg

## **Construction of a Safe Pavement Edge: Minimizing the Effects of Shoulder Dropoff**

Principle Author: Christopher Wagner  
Pavement and Materials Engineer

Federal Highway Administration  
61 Forsyth St., SW Suite 17T26  
Atlanta, GA 30303

Phone: 404-562-3914  
Fax: 404-562-3700  
Email: christopher.wagner@fhwa.dot.gov

Co-Author: Yeonsoo Stanley Kim, Ph.D.  
Research Engineer

Georgia Department of Transportation  
Office of Materials and Research  
15 Kennedy Drive  
Forest Park, GA 30297

Phone: 404-675-1435  
Fax: 404-363-7684  
Email: stanley.kim@dot.state.ga.us

Word Count:	4,538
Tables and Figures:	8
Total Equivalent Words:	6,538

August 1, 2004



## ABSTRACT

Crashes on two-lane undivided highways result in nearly sixty percent of the total fatalities on our nations highways. One major concern for driver safety on these facilities is the interface of the paved surface and the unpaved shoulder. Vertical dropoffs found along the edge of the pavement can lead a driver to overcorrect upon re-entry onto the paved surface. This overcorrection may lead the vehicle to cross into opposing traffic or leave the opposite side of the roadway.

One solution to this problem is to form a thirty-degree tapered transition at the edge of the paved surface called the "safety edge". A safety edge provides an easily traversable transition for an errant vehicle to reenter the travel lane from the unpaved shoulder. The Georgia Department of Transportation constructed a 13.3 mile (26.6 lane miles) asphalt overlay on a rural, two-lane, undivided highway using the safety edge. The objective of this paper is to report on the research conducted on this project. This research studied the construction and the durability of a safety edge placed at the interface of the paved surface and the grassed shoulder.

This report documents the construction of a safety edge using two different devices. Findings of this research indicate that the safety edge can be constructed with no impact to production and at less than one percent additional material costs. Based on field evaluations the safety edge is likely to serve as temporary safety feature while an asphalt overlay is constructed and a permanent safety feature where dropoff locations emerge in the future.

3. Turnarounds,
4. Shaded areas,
5. Eroded Areas,
6. and Asphalt Pavement Overlays.

Horizontal curves have a greater occurrence of edge rutting than tangent roadway sections. This is due to vehicles departing the paved surface more frequently than on straight sections. Similarly, turnarounds, intersection gore areas, and areas near mailboxes exhibit pavement edge drop off frequently due to tire departure.

Areas underneath trees or other objects that cast a shadow on the pavement edge for a majority of the day have little or no vegetation on the unpaved shoulder. This lack of vegetation can allow the area to erode away and a pavement edge dropoff may develop over time. (6) Other areas can have excessive erosion due to roadway geometry or soil characteristics.

An asphalt pavement overlay is also a common source of pavement edge dropoff. This situation can be compounded by the existing edge rutting caused by any of the other situations mentioned. Consider a common scenario of a two-inch asphalt overlay on a tree lined two-lane roadway. These types of roadway are prone to having existing edge dropoffs due to the shaded areas. Compound this existing dropoff with the two-inch dropoff due to the overlay and there could be many places along the roadway with a 4 to 6 inch near vertical dropoff.

Construction of a safety edge when a road surface is repaved can serve two important functions. The safety edge serves as a mitigating measure to help with pavement edge dropoff that occurs after a pavement overlay is placed, but before shoulders can be reconstructed flush with the travel way. This temporary exposure may exist for several months depending on the sequence of construction operations. The safety edge also can serve as a permanent safety feature for future areas of edge rutting or soil erosion.

All six of the dropoff conditions noted were found during the pre-construction investigation of the research test sections. These situations are not all inclusive, and significant edge dropoff can be found in other locations. Whatever the cause of a pavement edge dropoff, the result is an unsafe condition for the motorist.

An additional benefit to including the safety edge into the normal paving operation is the reduction of tort liability. Pavement edge dropoff is a common source of tort claims against many highway agencies and it is not unusual to find legal cases in which monetary awards were given to a motorist due to a dropoff condition caused by a pavement overlay. (7,8,9,10) In these cases, the public entity was found guilty of creating an unsafe condition for the motorist and not properly informing them of that condition. The use of the safety edge may aid in such litigation by demonstrating that the public agency or private contractor is proactively taking steps to prevent unsafe pavement edge conditions in workzones.

## **OBJECTIVE**

Although the safety hazards of pavement edge dropoff have been well documented and the benefits of having a tapered transition at the edge of the paved surface are known, there has been little research documenting the construction of a tapered edge. This lack of published data on the construction, material performance, and durability of the safety edge is believed to have inhibited the use of this safety feature by federal, state, and local highway agencies. While public agencies are often aware of the safety implications of pavement shoulder dropoff, they are often unaware of the mitigating effects a safety edge produces.

This report documents a project that incorporated a tapered edge in the construction of a 1.5 inch pavement overlay. The primary objective of this research was to evaluate the feasibility of construction and the performance of two safety edge hardware systems, one fabricated by the Georgia Department of Transportation (GDOT) and a commercial device developed by TransTech Systems, Inc. The durability of the safety edge was also observed and is discussed in this report.

## **SAFETY EDGE DESIGN AND CONSTRUCTION**

The safety edge is designed to create a tapered edge approximately 6 to 8 inches in length between the paved travel way and the unpaved shoulder. Consideration was given to constructing the edge over the existing paved surface. This design would provide more support under the fillet section, but would decrease the width of the travel way. With this design, the benefits of the safety edge during construction would be limited, as it would not correct an existing edge drop-off. For these reasons, the safety edge design should be constructed over the unpaved shoulder as seen in Figure 1.

The safety edge is constructed with the angle break lining up directly over the existing paved surface. Constructing the edge onto the unpaved shoulder does not result in a decrease in lane width. This design will also adjust to the varying height differentials between the paved surface and the unpaved shoulder. The benefits to this design allow for varying dropoff heights existing before construction. The edge is placed in the same paving operation as the asphalt pavement wearing layer and does not require second construction operation.

The safety edge design is not intended to substitute for a shoulder that is flush with the paved travel way. The safety edge is a mitigation of the dropoff created by the asphalt overlay. After the pavement overlay is complete the shoulder should be graded back flush with the paved surface. The safety edge will also serve as a permanent safety feature in areas where edge rutting occurs in the future.

The safety edge can be implemented on any type of roadway facility as an integrated part of the asphalt paving process. Two lane undivided highways typically do not have paved shoulders, have a higher occurrence of shoulder dropoff, and are the location of the majority of highway fatalities. For these reasons incorporation of the safety edge design is likely to have the most impact on this type of facility.

## Safety Edge Installation Hardware

Two different devices used to construct the safety edge were evaluated. One device, hereto referred to as the GDOT safety wedge, was fabricated “in house” by the GDOT maintenance department. Several iterations of the GDOT wedge were fabricated and evaluated before a final design was achieved. The GDOT hardware seen in Figure 2, is a steel wedge that is bolted onto the screed end gate. This device has a rounded leading edge that is crucial to providing a smooth finished appearance to the safety edge. Previous GDOT hardware did not include the rounded leading edge and did not produce a smooth finished surface.

The hardware is connected to the end gate of the paver screed. The shoe of the end gate rides on the shoulder of the pavement and is able to freely move vertically allowing it to continually adjust to height differentials. It is important that this steel wedge is able to free float with the end gate in order for the safety wedge to be able to adapt to differing shoulder dropoff heights and pavement overlay thicknesses. The GDOT safety wedge is connected with a simple two-bolt connection allowing it to be easily attached and removed. The hardware should fit closely to the screed (approximately 1/4”) to prevent asphalt material from falling behind the device. However, the triangle should not contact the screed in order to insure that it is not affecting the angle of attack of the screed or limiting the device from moving vertically. The GDOT safety wedge demonstrated the ability to create the safety edge from a dropoff depth of 0 to 6 inches.

A proprietary device developed by TransTech Systems, Inc was also evaluated. TransTech Systems, Inc describes their Safety Edge Maker™ (SEM) hardware as a mounting plate that easily attaches to all varieties of paving machines with a self-adjusting spring that allows the device to follow the roadside surface. The adjusting screw allows for setting the initial height and the edge-making component itself includes a radius edge that helps the device to adapt to obstacles it may encounter. The unit provides a compound angled surface that pre-compacts the asphalt as it enters the device. As the asphalt continues under the 30-degree edge it is then smoothed, as it would be under the screed bottom, to create a better surface finish on the angled mat.

Figure 3 shows a technical drawing of the device along with the mounting plate. It should be noted that the SEM used in this research was a prototype device and that additional refinements to the SEM are being made and evaluated by TransTech Systems, Inc.

Both of these devices force the HMA material under the hardware. In essence this action extrudes the material into the tapered edge shape. This extrusion process allows for some reorientation of the aggregate particles and compaction of the material.

## SCOPE

A 13.3-mile (26.6 lane miles) section of roadway on Georgia State Route 88 was chosen to evaluate the constructability of the safety edge. The project consisted a 1.5-inch asphalt overlay of a two lane undivided highway. The project was located just south of August,

Georgia. This area of Georgia is located in a temperate climate with an average rainfall of 45 inches per year. Soils at the project location consisted of a sandy clay. During the preconstruction investigation it was observed that this type of soil was susceptible to erosion where grassing was not established.

The typical cross section of the pavement includes two 12-foot lanes with two foot paved shoulders. Adjacent to the paved surface the roadway had grassed shoulders of varying width. A total of 11 miles (22 lane miles) were constructed with a tapered edge at the transition of the paved surface and the grassed shoulder. A control section of two miles in length was constructed without the safety edge. An additional two-mile section of the project had in place concrete curb and gutter and therefore did not incorporate the safety edge.

Two different devices were evaluated along with two different asphalt mix designs. The first section included hot mix asphalt (HMA) designed using the Marshall mix design procedure. This HMA mix design procedure results in a higher asphalt content, a smaller nominal maximum aggregate size (in this case 9.5 mm), and a finer aggregate gradation. This type of mixture typically has greater workability and is therefore more easily extruded under the safety wedge hardware. The second section incorporated a 12.5 mm HMA designed to meet superpave design criteria. Superpave HMA designs typically have a lower percentage of asphalt and a coarser aggregate gradation as compared to Marshall mix designs. The resulting superpave mixes are typically less workable. (11) These two HMA designs were chosen to study a range of different mixtures that are typically specified in resurfacing low volume roadways in Georgia.

## **Research Plan**

This research was conducted to answer critical questions about the constructability, performance, and durability of the safety edge. As stated, the safety benefits of a tapered edge have been proven through previous research efforts and therefore no measurements of vehicle dynamics or crash data analysis were conducted for this research.

The most critical question that this research plan was designed to address is the constructability of the safety edge. Before this research project was undertaken no efforts had been taken to construct this type of tapered pavement edge in Georgia. Qualitative information was gathered from field visits before, during, and after construction to determine the impact of using the safety edge design on production and to document the finished appearance of the safety edge. This evaluation included input from the project personnel on the performance of the hardware and the ease of implementation of the safety edge.

An initial site investigation was made to locate areas where dropoffs were present. These locations were measured, photographed, and located with Global Positioning System (GPS) instrumentation.

Pavement density measurements were taken at three places transversely across the pavement cross section. These measurements were taken at the center of the lane, at the edge line, and

on the wedge section itself. The density measurements were performed on core samples taken from the mainline and from saw cut specimens taken from the safety edge. Three sets of samples were taken longitudinally for one lot, which is equal to one day's production.

The center of the lane cores were used as a baseline comparison and are considered the maximum density achieved on the cross section. Achieving compaction at the edge of a pavement can be difficult due to the lack of edge confining pressure. Density measurements were taken at the edge line of the pavement to determine the degree of compaction that was achieved due to the lateral confining pressure of the safety edge hardware. This measurement was taken on the sections that included the use of the safety edge and the control sections. A comparison of density measurements was made to determine the effect of the confining pressure applied by the edge hardware on the edge of the pavement section. Also, a comparison of the relative compaction between the edge of pavement and the center of the lane was made.

An important assumption made in this research is that the pavement density at the edge of the pavement would be affected by the addition of the safety edge device due to the lateral confinement provided by the additional paving material and the extrusion forces applied by the hardware. Also, the edge density is assumed to be an indicator of the compaction performance of each of the devices used.

Smoothness measurements for a six-mile segment of roadway were obtained before and after the pavement overlay was constructed. These measurements were taken for both the control section(s) and the section incorporating the safety edge. Statistical comparisons of control and test sections were evaluated to determine the effect of using the safety edge on roadway smoothness. These measurements were made using calibrated South Dakota Profiler equipment and are reported as an International Roughness Index (IRI).

## **EVALUATION OF PAVEMENT DENSITY MEASUREMENTS**

Bulk specific gravity and density values were determined on all of the core samples taken by both the AASHTO T-166 method and the ASTM D6752-03 standard using the automatic vacuum sealing method. Unfortunately, the sawn wedge section samples did not survive transportation and testing. This was due to the irregular shape of the triangular wedge sections. For this reason, density measurements of the safety edge are not available.

In order to determine the effectiveness of the safety edge hardware, the density measurements near the edge of pavement were used as an indicator of compaction effort. The assumption made is that the lateral confining pressure of the hardware will be reflected in the density of the edge of pavement.

A density ratio of the edge of pavement measurements to the center of the lane measurements ( $\rho_{EP} / \rho_{CL}$ ) was determined. By using this ratio in the analysis the effects of other variables that effect density are minimized. The intent is to not to compare the raw density value, but to look at the relative compaction as compared to the center of the lane. This statistic was

then used to evaluate the effects of mix type and device on the density of the pavement edge. The average values of the test sections were also calculated and the results are discussed below.

As expected, the average densities at the center of the lane are higher than corresponding average densities at the edge of pavement in all of the six test sections (Figures 4 and 5). This is due to the lack of confining pressure at the edge of the pavement. A comparison of the density ratios of the different test sections was conducted to determine the differences in compaction levels by the two different devices and for the two different mix types.

As seen in Figures 4 and 5, the average densities of sections using the SEM are lower than the densities of the control section and GDOT wedge section at both of the center of lane and the edge of pavement for the 9.5 mm Marshall HMA. A comparison of the density ratios of the three sections was conducted in order to determine if these two sections were different. The results shown in Table 1 indicate that there is no statistical difference between the control section and the GDOT section or the SEM section. It is worth noting that the density ratios were calculated for only 4 of the 9 locations (see Table 2) in the SEM section built with the 9.5 mm Marshall HMA. This is due to the degradation of the pavement cores during shipping and testing.

The density measurements obtained from the 12.5 mm Superpave HMA sections were considerably higher and had less variability than those samples taken from 9.5 mm Marshall HMA sections for both of the devices. Similar conclusions can be drawn from the analysis of the Superpave test sections as compared to 9.5 mm Marshall test sections. The density ratios and the average densities of both the center of the lane and the edge of the pavement are similar for all three of the test sections. The conclusion can be made that the sections that did not have the safety edge had no significant difference in density at the edge of the pavement than the test sections that included the safety edge.

An outlier observation analysis was conducted on two values (Test Lot 1, Location 6; and Test Lot 5, Location 3). Based on this analysis these values were found to be outliers and therefore excluded in the calculation of the averages, standard deviations, and density ratios.

Based on the analysis of the density measurements taken at the pavement edge, it is unclear as to whether this measurement properly identifies the compaction of the tapered edge section. The results discussed the post construction observations section may be a better indicator of the durability of the safety edge.

## **EVALUATION OF SMOOTHNESS DATA**

Smoothness measurements using a high-speed inertial profiler were made in both wheelpaths to determine if the addition of the safety edge had an effect on the smoothness of the finished pavement. The results of the smoothness data presented in Table 3 indicate that there is no degradation in smoothness profile due the addition of the safety edge.

The one-mile safety edge test section has an IRI value less than all but one of the segments tested for both wheel paths. This data suggests that the safety edge can be constructed without an adverse effect on pavement smoothness. No additional irregularities were noticed

by project personnel that would indicate any effect on smoothness by the addition of the safety edge hardware.

## **POST CONSTRUCTION PERFORMANCE OBSERVATIONS**

A field investigation the safety edge test sections was made in July 2004, approximately one year after the project was constructed. This field investigation consisted of a visual inspection of the areas where dropoffs were documented before the pavement overlay was constructed. Ten sites were located where dropoffs were initially measured in June 2003. After one year, these sites had remarkably similar dropoffs as were found before the pavement overlay. This can be expected because many of these sties were located in areas of shade where it is difficult to reestablish grassing. At these sites the safety edge was visible and still in "like new" condition. No visible distress was seen along any of the observed sections of the safety edge. This evaluation was made for both sections made with the SEM and the GDOT hardware. In contrast, the control sections paved without the safety edge exhibited a near vertical edge where the dropoffs had re-emerged. Over the majority the length of the project grass had been successfully re-established and the shoulders remain flush with the paved surface. There were no observations made that indicate that the safety edge will contribute to shoulder erosion or that the safety edge will substantially deteriorate over time.

## **CONCLUSIONS AND RECOMMENDATIONS**

The safety edge was constructed on a two lane undivided highway in rural Georgia. Both the GDOT Safety Edge Hardware and the Safety Edge Maker hardware successfully produced the safety edge with little impact on production and at negligible cost in materials or equipment. The safety edge was produced successfully for both a 9.5 mm Marshall HMA design and a 12.5 mm Superpave HMA, which are the typical HMA designs for this type of roadway. Neither the GDOT safety wedge nor the SEM hardware had a significant effect on the relative density at the edge of the pavement. However, based on the field observations conducted one year after construction the safety edge has no visible signs of deterioration. Both edges placed by the GDOT wedge and the TransTech SEM are performing adequately and there is no evidence to suggest that the safety edge will deteriorate over time. Long term evaluation of the test site is planned in order to observe the durability of the safety edge over an extended period of time. On Georgia highways the safety edge can be readily constructed as an integral part of the paving operation.

This research did not attempt to quantify the safety benefits of the safety edge. Other projects should be constructed to evaluate the construction, durability, and performance of the safety edge under several different highway conditions and at several locations throughout the country. The crash data of these sites should be monitored for several years in order to quantify the benefits of the safety edge design.

The safety edge shows promise as a low cost solution to mitigate pavement shoulder drop off. Federal, State, and Local Highway Agencies should pursue implementation of the safety edge design as a low cost means to mitigate shoulder dropoff. The implementation of the



safety edge design would be most applicable to asphalt resurfacing projects on two lane undivided roadways with limited paved shoulders.

## **ACKNOWLEDGEMENTS**

This research was made possible through a grant by the Federal Highway Administration Office of Safety. The research and documentation was administered by the FHWA Resource Center in Atlanta in conjunction with the FHWA Georgia Division Office and the Georgia Department of Transportation.

The authors of this paper would be remiss if Mr. Lynn Bean of the Georgia Department of Transportation was not acknowledged for his expertise and efforts in the development of the safety edge. Mr. Bean was an integral participant in the design of the safety wedge hardware, development of the research plan, and oversight of the project construction.

The authors would also like to thank the Georgia Department of Transportation Office of Maintenance and the Office of Materials and Research for their involvement in the construction, evaluation, and testing of the safety edge.

## REFERENCES

1. *AASHTO Strategic Highway Safety Plan, A Comprehensive Plan to Substantially Reduce Vehicle-Related Fatalities and Injuries on the Nation's Highways*. American Association of State Highway and Transportation Officials, Washington, DC., 1998.
2. *Traffic Safety Facts 2002. A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System*. National Highway Traffic Safety Administration, Washington, D.C., 2003.
3. J. B. Humphreys and J. A. Parham. *The Elimination or Mitigation of Hazards Associated with Pavement Edge Dropoffs During Roadway Resurfacing*. AAA Foundation for Roadway Safety, Washington, D.C., 1994.
4. R. A. Zimmer and D. L. Ivey. *Pavement Edges and Vehicle Stability-A Basis for Maintenance Guidelines*. In Transportation Research Record 946, TRB, National Research Council, Washington, D.C., 1984.
5. *A Policy on the Geometric Design of Highways and Streets*. American Association of State Highway and Transportation Officials, Washington, DC., 2001.
6. R.O. Rogness and J.B. Burley. *Correction and Repair of Road Edge Scour for Grassed Shoulders on Parkways*. In Transportation Research Record 1409, TRB, National Research Council, Washington, D.C., 1993.
7. Christine M. Barsavage v. State of Louisiana, through the Department of Transportation and Development, Court of Appeal of Louisiana, First Circuit, December 20, 1996.
8. Gerald Holmquist v. State of Minnesota, Court of Appeals of Minnesota, July 6, 1987.
9. Tracy Lynn Penton v. J.F. Cleckley & Company and South Carolina Department of Transportation, Court of Appeal from Colleton County, June 23, 1997.
10. Special Report 214. *Designing for Safer Roads – Practices for Resurfacing, Restoration, and Rehabilitation*. TRB, National Research Council, Washington, D.C., 1987.
11. Roberts, Kandhal, Brown, Lee, and Kennedy. *Hot Mix Asphalt Materials, Mixture Design, and Construction. Second Edition*. NAPA Education Foundation. Lanham, Maryland, 1996.

## **LIST OF TABELS AND FIGURES**

FIGURE 1: Safety Edge Detail

FIGURE 2: GDOT Safety Wedge

FIGURE 3: Trans Tech Systems Inc. SEM

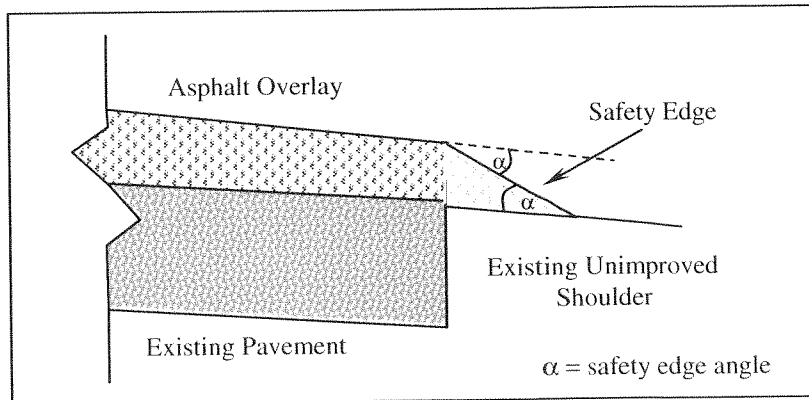
FIGURE 4: Core Density – 12.5 mm Superpave

FIGURE 5: Core Density – 9.5 mm Superpave

TABLE 1: Statistical Test Method of the Density Ratios

TABLE 2: Density Measurements

TABLE 3: Smoothness Data



**FIGURE 1: Safety Edge Detail**

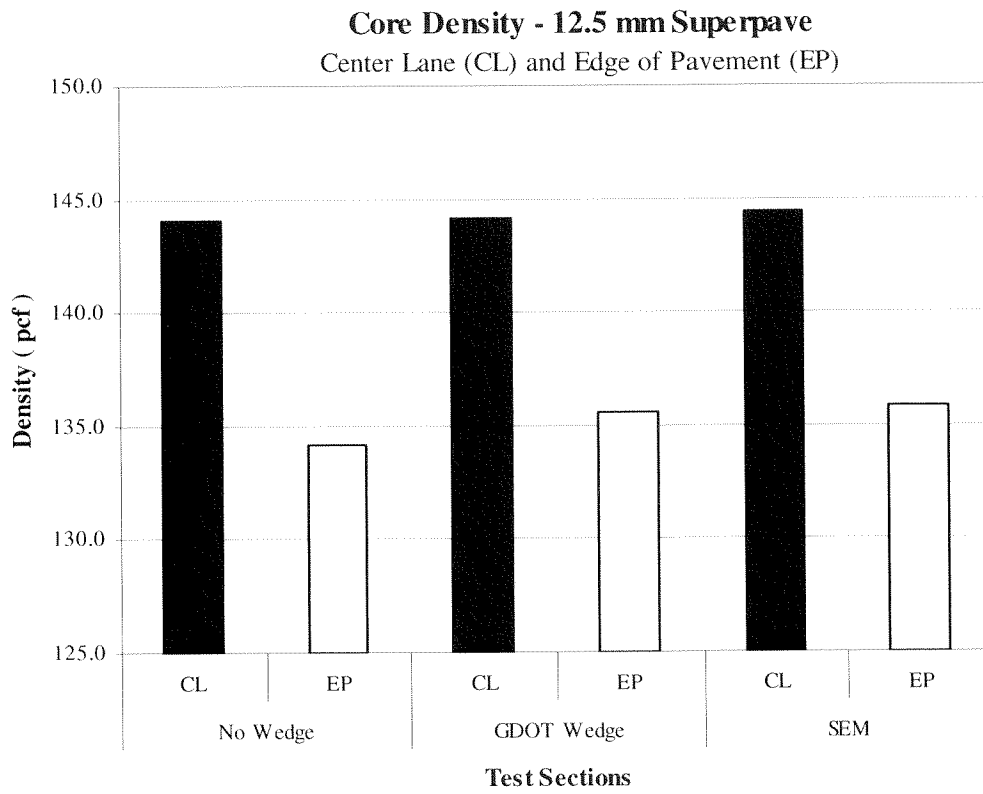
**TABLE 1: Statistical Test of the Means of the Density Ratios**

<b>Test Sections</b>	<b>t-statistics</b>	<b>Degree of Freedom</b>	<b>t-critical with 5% significance level</b>	<b>p-value</b>	<b>Significant Difference?</b>
[F mix – control] to [F mix – GDOT wedge]	0.676	10	2.228	0.514	No
[F mix – control] to [F mix – TT wedge]	0.051	5	2.571	0.961	No
[SP mix – control] to [F mix – GDOT wedge]	1.279	9	2.262	0.233	No
[SP mix – control] to [F mix – TT wedge]	0.856	9	2.262	0.414	No

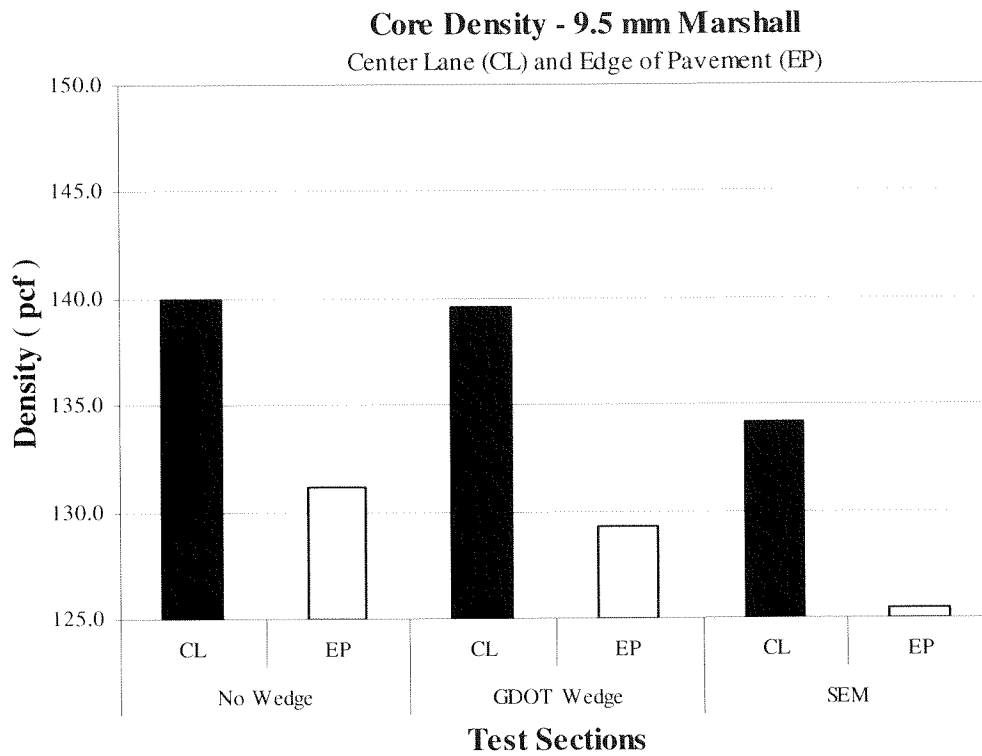
**TABLE 2: Density Measurements**

Test Lots	Mix Type	Wedge Maker	Location Number	Density at Center of Lane ( $\rho_{CL}$ , pcf)	Density at Edge of Pavement ( $\rho_{EP}$ , pcf)	Density Ratio ( $\rho_{EP} / \rho_{CL}$ )
1	9.5 mm Type F	No Wedge (Control Section)	1	139.5	126.5	0.907
			2	143.8	131.4	0.914
			3	140.2	132.3	0.943
			4	138.2	131.8	0.954
			5	138.7	133.9	0.965
			6	139.3	139.4*	1.001*
			<b>Average</b>	<b>140</b>	<b>131.2</b>	<b>0.9</b>
<b>Std. Dev.</b>	2.0	2.8	0.025			
2, 3, 4	9.5 mm Type F	GDOT Wedge	1	138.4	125.3	0.905
			2	138.5	129.8	0.937
			3	139.5	124.5	0.892
			4	135.9	131.5	0.967
			5	142.4	N. A.	N. A.
			6	139.6	128.9	0.923
			7	140.5	135.9	0.967
			8	142.4	128.9	0.905
			9	139.5	N. A.	N. A.
			<b>Average</b>	<b>139.6</b>	<b>129.3</b>	<b>0.926</b>
<b>Std. Dev.</b>	2	3.8	0.03			
8, 9, 10	9.5 mm Type F	TransTech Wedge	1	131.9	125.6	0.952
			2	135.8	N. A.	N. A.
			3	134.2	N. A.	N. A.
			4	138.0	127.2	0.922
			5	137.4	122.0	0.888
			6	130.8	N. A.	N. A.
			7	N. A.	129.0	N. A.
			8	N. A.	124.2	N. A.
			9	127.6	124.9	0.979
			<b>Average</b>	<b>134.15</b>	<b>125.5</b>	<b>0.935</b>
<b>Std. Dev.</b>	3.9	2.4	0.039			
6	12.5 mm Superpave	No Wedge (Control Section)	1	146.3	133.0	0.909
			2	144.1	132.3	0.918
			3	145.5	134.8	0.927
			4	141.1	132.5	0.939
			5	142.3	136.1	0.957
			6	145.4	136.3	0.938
			<b>Average</b>	<b>144.1</b>	<b>134.2</b>	<b>0.931</b>
<b>Std. Dev.</b>	2.1	1.8	0.017			
5	12.5 mm Superpave	GDOT Wedge	1	143.3	133.5	0.932
			2	141.5	134.6	0.952
			3	145.9	126.4*	0.866*
			4	142.3	135.1	0.949
			5	145.3	138.7	0.954
			6	147.1	136.2	0.926
			<b>Average</b>	<b>144.2</b>	<b>135.6</b>	<b>0.943</b>
<b>Std. Dev.</b>	2.2	2.0	0.013			
7	12.5 mm Superpave	TransTech Wedge	1	148.6	135.1	0.909
			2	144.2	135.5	0.94
			3	145.2	137.3	0.946
			4	144.3	138.6	0.96
			5	144	132.4	0.919
			6	140.4	136.7	0.974
			<b>Average</b>	<b>144.4</b>	<b>135.9</b>	<b>0.941</b>
<b>Std. Dev.</b>	2.6	2.2	0.024			

\*values were determined to be outliers and not included in the average and standard deviation



**FIGURE 4: Core Density – 12.5 mm Superpave**



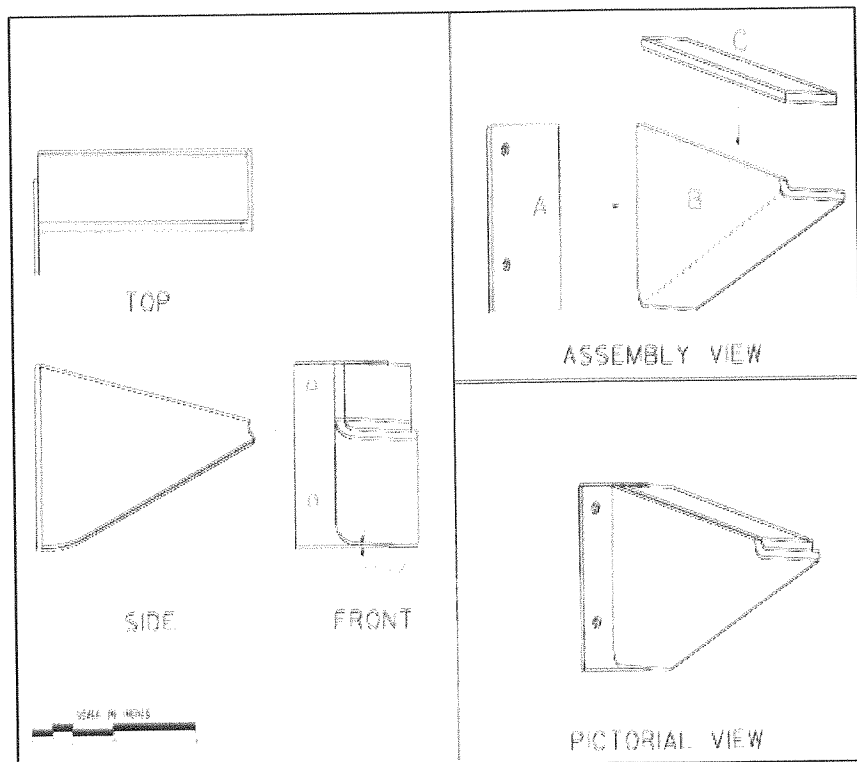
**FIGURE 5: Core Density – 9.5 mm Superpave**



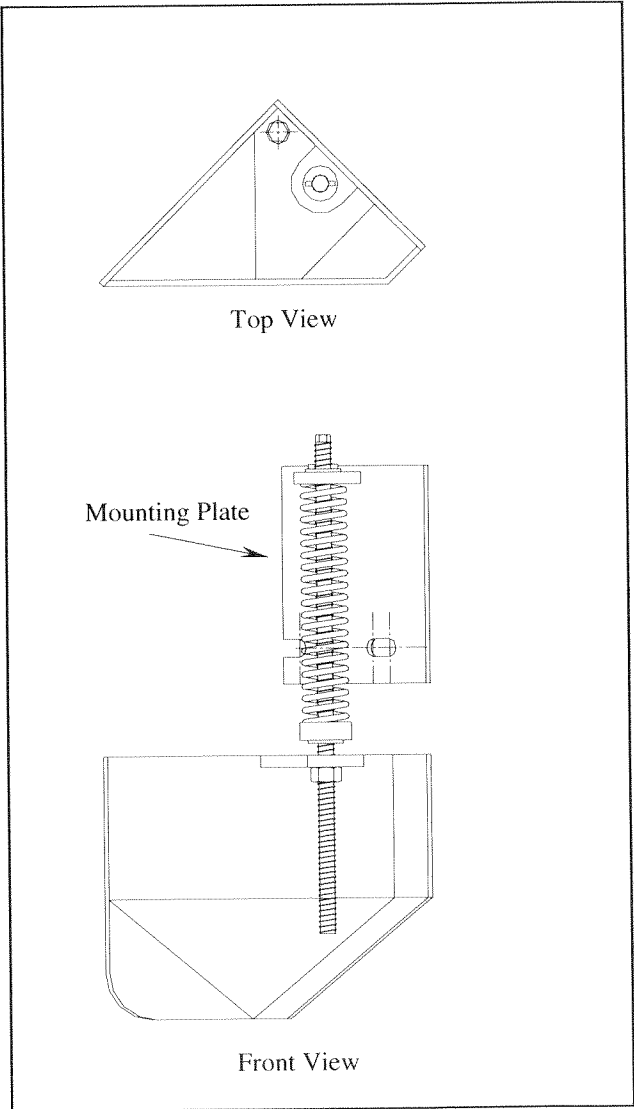
**TABLE 3: Smoothness Data**

From (mile)	To (mile)	Left Wheelpath IRI (in/mile)	Right Wheelpath IRI (in/mile)
0.437	1	71	73
1	2	73	73
<b>2*</b>	<b>3*</b>	<b>67</b>	<b>66</b>
3	4	80	73
4	5	70	66
5	6	67	63

\* *safety edge test section*



**FIGURE 2: GDOT Safety Wedge Technical Drawing**

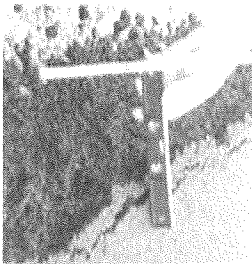


**FIGURE 3: Trans Tech Systems Inc. SEM**

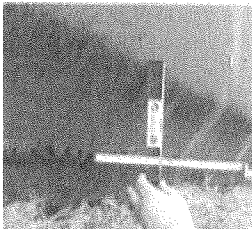
## Performance of the Safety Edge

After one year in service the Safety Edge retains its shape in "like new" condition, while sections without the safety edge have raveled to a near vertical face.

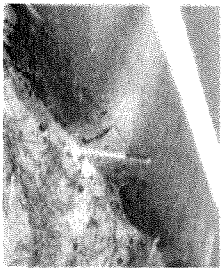
### Initial Construction



Without the Safety



With the Safety Edge



After One Year In-Service



Based on the findings from the pilot project, the Safety Edge Design does not affect the smoothness of the finished pavement nor does it increase erosion of the soil shoulders.

**Based on the successful construction and performance of the safety edge after one year in-service, GDOT will implement the design on a statewide basis beginning in January 2005.**

### For More Information Contact

**Harry W. Taylor**

Federal Highway Administration  
Office of Safety Design  
(202) 366-2175  
[Harry.Taylor@fhwa.dot.gov](mailto:Harry.Taylor@fhwa.dot.gov)

**Frank Julian**

Federal Highway Administration  
Resource Center - Atlanta  
(404) 562-3689  
[Frank.Julian@fhwa.dot.gov](mailto:Frank.Julian@fhwa.dot.gov)

**Chris Wagner**

Federal Highway Administration  
Resource Center - Atlanta  
(404) 562-3693  
[Christopher.Wagner@fhwa.dot.gov](mailto:Christopher.Wagner@fhwa.dot.gov)



# THE SAFETY EDGE

The Georgia Department of  
Transportation Experience

## Pavement Edge Treatment

- **Saves Lives**
- **Reduces Tort Liability**
- **Easily Constructable**
- **Cost Less than 1% Material Cost**



Benefits of the safety edge design include:

- Reduced Tort Liability
- Minimal Costs
- Increased Durability of the Pavement Edge
- Edge Dropoff Mitigation During Construction
- A Permanent Safety Feature if Drop-offs re-emerge

## Unsafe Pavement Edges are a Serious Safety Problem

One major concern for driver safety is a vertical dropoff between the paved surface and the unpaved shoulder. One solution to this problem is to form a thirty-degree tapered transition at the edge of the paved surface called the "safety edge". The Georgia Department of Transportation (GDOT) completed a pilot project in 2003 that incorporated the safety edge design.



30-Degree Safety Edge

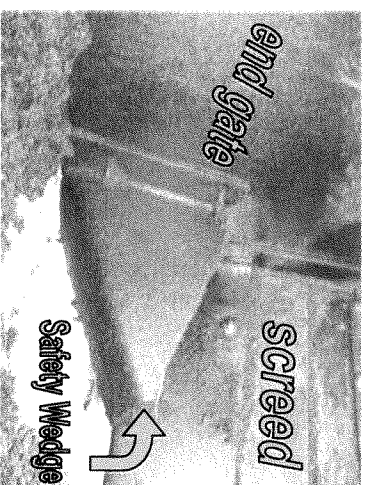
## How do Unsafe Edges Cause Crashes?

An errant vehicle that has departed the paved surface can experience difficulty reentering the travel way if the tires traverse a vertical edge of 3 inches or more. This tire to pavement interaction is known as "scrubbing". When a tire(s) scrubs the pavement edge, resulting forces of a vertical pavement edge act on that tire to prevent reentry. This may cause a sudden and steep-angled reentry onto the travel way. This resulting steep-angle

reentry can lead to over steering and head-on collisions.

## Safety Edge Hardware

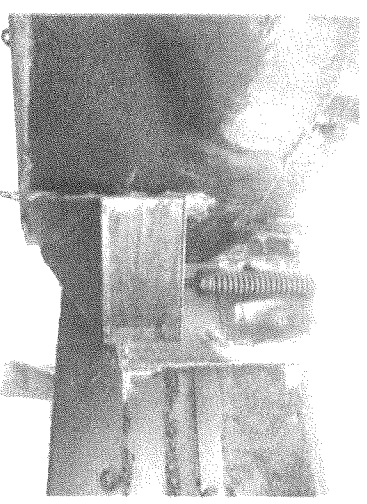
Two different devices used to construct the safety edge were evaluated in the pilot project. One device, the GDOT Safety Wedge, was fabricated "in house" by the GDOT maintenance department. The hardware is a steel wedge that is mounted with a simple two-bolt connection onto the screed end gate. This device has a rounded leading edge that is crucial to providing a smooth finished compaction to the safety edge. The device is also capable of adjusting vertically to varying dropoff heights.



GDOT Safety Wedge

A proprietary device developed by TransTech Systems, Inc was also evaluated. The Safety Edge Maker™ (SEM) hardware has a mounting plate that easily attaches to the screed with a self-adjusting spring that allows the device to follow the roadside surface. The unit provides a compound angled surface that pre-compacts the asphalt as it enters the

device. As the asphalt continues under the 30-degree edge it is then smoothed, as it would be under the screed bottom, to create a better surface finish on the angled mat.



Trans Tech Safety Edge Maker™

Both the GDOT Safety Edge Hardware and the Safety Edge Maker hardware successfully produced a durable safety edge.

## Construction of the Safety Edge

The safety edge can be implemented on any type of roadway facility as an integrated part of the asphalt paving process. Implementation of the Safety Edge cost less than 1% of the hot-mix asphalt material cost.

No additional construction operation is needed to place the safety edge. A typical installation includes clipping the earth shoulder back, constructing the asphalt overlay, and pulling the shoulders flush with the paved shoulder.