

# **Mitigating Pavement Edge Drop off**

**Nebraska Department of Roads  
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16. Abstract <p>The objective of this research was to investigate and document practices currently being used by the Nebraska Department of Roads (NDOR) districts and other State DOTs to mitigate pavement edge drop off. The NDOR has developed (or borrowed) and is currently incorporating into its standard practices several procedures that significantly decrease the incidence and magnitude of pavement edge-drop off. As these practices become more fully integrated into highway reconstruction projects, pavement edge drop off is expected to decrease dramatically. Localized areas of pavement edge drop off along paved lanes with bare or vegetated shoulders were noted as posing particular problems for NDOR maintenance personnel. Several commercial systems for artificially reinforcing soil beneath vegetated or aggregate shoulders were investigated. Suggestions for follow-on research and field studies involving various mitigation procedures are included in the recommendations.</p>			
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# Chapter 1

## Introduction

### 1.1 Pavement Edge Drop Off

The shoulders adjacent to traveled lanes are critical components of overall highway structure. Shoulders provide lateral support for the pavement, a place for vehicles to pull over during emergencies, a recovery area when a vehicle's wheel leaves the pavement and (in many states) increased width to accommodate oversized agricultural equipment.

Pavement edge drop off is the vertical elevation difference between the pavement's surface and the adjacent shoulder surface. Pavement edge drop off occurs on highways with both paved and unpaved shoulders. Edge drop off between a paved lane and an unpaved shoulder often results from lack of shoulder maintenance or from resurfacing a lane without a proper transition being created between the paved lane and its shoulder. Vehicle wheels leaving the edge of the pavement and erosion of unconsolidated and/or unstabilized shoulder material by wind and water also create significant pavement edge drop off.

The underlying cause of pavement edge drop off is displacement of shoulder material by one or more forces, creating a depression (drop off) adjacent to the pavement's edge. The extent to which shoulder material is displaced (by wheels, wind or water) is dependent upon its composition. Composition of shoulder material varies widely from one location to another. Some materials are more resistant to deformation and movement than others.

Unstabilized earth is the most common type of shoulder material displaying significant pavement edge drop off. Unstabilized earth shoulders exist where turf or vegetation has not been established due to inadequate time, precipitation, sunlight, or soil conditions/nutrients. When unstabilized earth shoulders become saturated by precipitation, the soil within often becomes incapable of supporting wheel loads. When a wheel strays off the pavement onto an unstabilized earth shoulder where the shoulder material is saturated by runoff or precipitation, the wheel creates a rut along the edge of the pavement.

Settlement of shoulder material along a pavement's edge can also create pavement edge drop off. Settlement is usually relatively uniform and occurs over a period of years. Settlement can be mitigated significantly by establishing and adhering to shoulder compaction standards during highway construction and resurfacing. Shoulders can be treated as embankments (or subgrades) and compacted to similar standards. Adequate shoulder compaction will eliminate much of the magnitude of uniform settlement along pavement edges.

Wind and water erosion is another problem along highways with unstabilized earth shoulders. Although pavements are somewhat porous, most are porous enough to pass only very small amounts of water to the soil beneath. Almost all precipitation events result in water flowing across the pavement's surface onto the shoulders. Significant rainfall is not required to generate significant quantities of runoff when water accumulates across one or two lanes of pavement. Runoff flows downhill across or along pavement until it reaches a low point, where it begins to move away from the road. Unstabilized earth shoulders, composed of lightly compacted or non-compacted in-situ material, lack a redundant source of stability such as vegetation or aggregate to hold soil particles in place. Runoff flowing parallel to pavement edges can transport considerable quantities of material, creating significant edge drop off.

Pavement edge drop off can be particularly annoying and is often more prevalent along narrow two-lane roads with unpaved shoulders that carry heavy truck traffic. Trucks displace shoulder material during dry weather by slipstream erosion. Trucks also disturb shoulder material by traveling with one (or more) wheel(s) overhanging the pavement's edge, particularly along the inside of curves. Shoulder material is highly susceptible to displacement by vehicles with a wheel off the road, especially during wet weather.

Common types of highway shoulders include concrete paved, bituminous paved, bituminous (or other) surface treated, stabilized aggregate (a compacted thickness of specified material), aggregate surfaced (a surface layer of gravel or crushed stone) and vegetated or unstabilized earth. Unstabilized earth, vegetated and aggregate surfaced shoulders are initially less expensive to construct than

paved shoulders, but are far more expensive to maintain. This study focused primarily on pavement edge drop off mitigation for unstabilized earth and vegetated shoulders.

## **1.2 Problems with Pavement Edge Drop Off**

Accidents on two-lane undivided highways accounted for almost 60% of total US traffic fatalities in 2006 (AASHTO, 2008). Conditions along the shoulder adjacent to the pavement edge have been identified as a primary cause of many of these accidents. Significant vertical drop off along the pavement edge becomes dangerous when a vehicle's wheel unexpectedly leaves the pavement. The surprised driver attempts to turn the wheel and steer his/her vehicle back onto the highway. The raised edge of pavement hinders the vehicle from easily reentering, forcing the driver to apply additional force on the steering wheel. This can result in the vehicle (1) moving abruptly across the travel lanes and colliding with a vehicle traveling in the opposite direction or colliding with roadside hazards on the opposite side of the roadway, (2) overturning on the roadway or roadside, or (3) colliding with roadside hazards on the side of the road along its original direction of travel (Glennon, 2005).

The ability of a driver to recover from an encounter with pavement edge drop off is a function of the vehicle's speed, the shape and height of the drop off, the width of the lane available for recovery and the driver's training and experience. Hallmark et al. (2006) reviewed driver's licensing manuals from 49 states and found that 32 contained advice to drivers about how to react when a vehicle's wheels leave the pavement edge. Advice can generally be summarized as follows: 1. Don't panic; 2. Grip the steering wheel tightly; 3. Slow down without braking hard; and 4. Return wheels to the pavement at slow speed. Only five states listed a recommended speed of travel when attempting to steer the vehicle's wheels back onto the pavement. This varied from 15 mph in Delaware to almost stopped in Colorado (Hallmark, et al., 2006).

Shoulder drop off is among the most cited accident-related highway conditions and is a common source for tort claims against state transportation agencies (Glennon, 2005). Substantial debate has occurred about what minimum

magnitude constitutes hazardous pavement edge drop and what responsibility state DOTs have for minimizing pavement edge drop off and/or warning drivers of its existence. This topic remains the subject of considerable discussion in courtrooms across the nation and research by institutions of higher learning.

### **1.3 Research Approach**

Multiple perspectives exist on pavement edge drop off and when or how it should be prevented or mitigated. Pavement edge drop off can be alleviated by using appropriate methods and procedures during design, construction and/or maintenance and repair. The Nebraska Department of Roads (NDOR) is actively committed to alleviating pavement edge drop off through development and use of appropriate and cost effective methods during all phases of design, construction and operation. This research study focused on documenting methods and procedures used successfully by the NDOR districts and other states with the goal of consolidating agency knowledge for dissemination to district personnel across the entire State.

## **Chapter 2**

### **Literature Search**

#### **2.1 Federal Guidelines**

This section summarizes federal guidelines addressing the problem of pavement edge drop off. While several agencies provide guidelines addressing this subject, there appears to be no agreed-upon national standard concerning the magnitude of pavement edge drop off which requires some form of remedial action. Considerable advice is offered, some of it conflicting, concerning appropriate thresholds where motorists should be warned about pavement edge drop off conditions.

##### **2.1.1 AASHTO Roadside Design Guidance**

Chapter 9 of the *Roadside Design Guide* (AASHTO, 2002) discusses control devices, barriers and safety features in construction work zones. The guide states “no vertical drop off greater than 50 mm (2 inches) should occur”. It further states that pavement edge drop off greater than 75 mm (3 inches) should not be allowed to remain overnight. Mitigation procedures discussed include placing a temporary wedge along the drop off, installing portable barriers to restrict traffic flow or using traffic channelizing devices to create a buffer along the edge of the drop off.

##### **2.1.2 Manual on Uniform Traffic Control Devices**

This manual contains national standards for installing and maintaining traffic control devices. Guidance specific to pavement edge drop off discusses signage requirements recommended when edge drop off occurs, both in temporary and permanent situations. Pavement edge drop off is discussed in Chapter 2C, *Warning Signs* and in Chapter 6F, *Temporary Traffic Control Devices*.

Chapter 2C recommends the use of warning signs to alert drivers to unexpected conditions at the pavement’s edge when the condition is permanent. When an elevation difference of three inches or less exists between the pavement surface and the shoulder, a sign warning of “Low Shoulder” is suggested. When an

elevation difference of greater than three inches exists, the same sign or a warning sign indicating “Shoulder Drop Off” is suggested. The above recommendations are intended as guidance only and can be overruled by engineering judgment (AASHTO, 2004).

Chapter 6F discusses temporary traffic control in construction work zones. Signage appropriate for drop off conditions in work zones is discussed Section 6F.42. Guidance is identical to that given in Chapter 2c where “Low Shoulder” signage is recommended when edge drop offs are less than three inches and “Shoulder Drop Off” signage is recommended when drop offs are in excess of three inches.

### **2.1.3 AASHTO Geometric Design of Highways and Streets**

This AASHTO design manual stresses that periodic maintenance is necessary to maintain shoulder elevation that is near the pavement’s surface. It provides no guidance on what level of edge drop off is acceptable or what level of edge drop off begins to warrant shoulder maintenance. It states that unstabilized shoulders will undergo consolidation over time, so the elevation of the shoulder will gradually become lower than the elevation of the traveled way (AASHTO, 2001).

### **2.1.4 Federal Highway Administration (FHWA)**

The FHWA publication, *Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects*, offers guidance concerning pavement edge drop off in construction work zones only. It states that “Low Shoulder” warning signs should be used where the edge drop off exceeds two inches. Where the edge drop off exceeds four inches, warning signs should be used and a 1:3 safety (beveled) edge should be constructed along the pavement edge (FHWA, 2012a).

When bituminous pavement is being resurfaced, the FHWA recommends installing a fillet (safety wedge) along the pavement edge adjacent to each shoulder. The surface angle of the wedge should be inclined 30-35° from vertical to allow a vehicle to reenter the driving lane without the driver having to overcompensate (FHWA, 2012b). Placing new aggregate against the wedge flush with the pavement

surface eliminates the potential for edge drop off. The fillet adds minimal cost to the paving project but has the potential to significantly reduce the number and severity of accidents caused by edge drop off. Although the fillet reduces the hazards associated with edge drop off, it does not eliminate the need for regular shoulder maintenance on unpaved shoulders.

### **2.1.5 Transportation Research Board (TRB)**

TRB publications basically summarize the results of various studies concerning how levels of pavement edge drop off affect highway safety and influence the severity and probability of vehicular crashes. Some contain information about the effects of pavement edge drop off on safety in construction work zones (Ivey et al., 1988) while others focus on the effects of pavement edge drop off during post-construction highway operations (Glennon, 1985).

Studies have shown that a statistically significant relationship exists between the frequency of pavement edge drop off related vehicle crashes and the magnitude of pavement edge drop off when drop off is equal to or exceeds 2.5 inches (Hallmark et al., 2006). Numerous states have established their threshold to begin repair or maintenance work when pavement edge drop off exceeds 2 inches (White et al., 2007), which seems prudent and provides a small margin of safety.

## **2.2 Iowa Research**

Other states have conducted significant research on mitigating and repairing pavement edge drop off, with the States of Iowa and Texas among the leaders in published material. Iowa has tested a wide array of materials and methods in an attempt to alleviate both pavement edge drop off and shoulder rutting on a variety of shoulder types. Research on stabilization of granular shoulders in Iowa was investigated specifically to determine if procedures had been developed that could be adapted to stabilize highway shoulders in the Nebraska Sandhills.

A study completed in 2008 attempted to develop strategies for mitigating pavement edge rutting problems using various combinations and gradations of granular materials and soil stabilizing agents (Jahren et al., 2011). Calcium chloride,

magnesium chloride, Base One® and DUSTLOCK® were employed as soil stabilization agents. Calcium chloride, magnesium chloride and Base One® did not provide noticeable improvement (Jahren et al., 2011). DUSTLOCK appeared to work well in locations where the underlying subgrade provided a stable base.

Iowa State University (ISU) conducted research which examined six methods of stabilizing aggregate shoulders to mitigate edge drop off (White, et al., 2007). Six locations along Iowa highways were selected to test chemical and mechanical stabilization products designed to hold granular shoulder material in place. The stabilization products tested included:

1. Liquid Polymer topically applied to a silty-gravel shoulder material.
2. Foamed asphalt over 12" full-depth shoulder reclamation with 3-4% class C fly ash added (wet subgrade problem).
3. Soybean Oil emulsion applied to silty sand shoulder material by spray bar.
4. Portland cement mixed and compacted into silty sand shoulder material.
5. Fly Ash subgrade (6") with 50% asphalt/ 50% concrete top layer.
6. Geogrid on sandy clay granular material placed at the interface between the subgrade and granular aggregate layer above.

### **2.2.1 Liquid Polymer**

Liquid polymer was tested on a section of pavement that had experienced 1.5-3" of rutting adjacent to the pavement edge before application. The liquid polymer was applied as a 6-12" wide strip to a thickness of ½" adjacent to the pavement edge. The polymer strip became detached from the pavement edge under the impact of traffic and showed signs of delamination after only 30 days. Shoulder material stabilized with liquid polymer began to disintegrate after soaking in water for four hours, indicating poor stability under wet conditions. The liquid polymer was characterized as performing inadequately as a soil stabilization agent on highway shoulders by this study.



### **2.2.2 Foamed Asphalt**

Soil mixing equipment was used to mix fly ash and fine aggregate into the shoulder material to a depth of twelve inches. The mixture was then compacted using a vibratory pad-foot roller followed by a smooth-wheel roller. Foamed asphalt was subsequently placed over the compacted subgrade material.

The foamed asphalt improved the compressive strength of the shoulder adjacent to the pavement edge by only 20%. However, significant edge drop off and rutting were observed on the test section after eight months. Foamed asphalt was judged to be useful only as a short-term solution, as this material showed no permanence with regard to mitigating edge drop off or rutting.

### **2.2.3 Soybean Oil**

Commercial emulsions were used to simplify application of soybean oil to pavement shoulders. Problems were encountered with the oil separating from water in the emulsion during application, which plugged the distributor. A two-foot wide by six-inch deep section of shoulder 340 feet in length was stabilized using various soybean emulsions.

After soybean oil had been applied to the shoulder subgrade using a spray bar, an additional six inches of crushed rock was placed on top, bladed and then compacted. Soybean oil proved unsuccessful in mitigating the formation of ruts along the pavement edge. Ruts three inches deep were observed along the pavement edge after only eight months. Performance of soybean oil as a soil stabilization agent varied significantly depending on which commercial product was being tested, but overall soybean oil was not considered to be successful as a mitigating agent for pavement edge drop off.

### **2.2.4 Portland Cement**

Well-graded sand with silt shoulder material was mixed and then compacted with 10% Portland cement and water to a depth of six inches. The resulting mixture was subsequently sealed using a pad foot roller.

Four months after placement, significant wash-boarding and lateral erosion were observed along this shoulder section. At that time, pavement edge drop off averaged about one inch. Eight months after placement of the Portland cement-shoulder material mix, edge drop off had increased to an average of three inches. Cement stabilization was not considered successful in mitigating pavement edge drop off.

### **2.2.5 Fly Ash, Recycled Concrete and Asphalt**

The first step in this shoulder reconstruction was to mix 15-20% fly ash into the upper twelve inches of clay subgrade. The subgrade was then compacted using a pad foot roller. On top of the compacted subgrade, a six-inch layer of 50% concrete/50% recycled asphalt millings was placed and compacted using a smooth wheel roller.

The fly ash subgrade stabilization with a compacted aggregate surface layer was considered successful in mitigating both short and long term pavement edge drop off as well as rutting. Little to no pavement edge drop off or rutting was noted after one year. A comparison section with an identical subgrade where six inches of crushed limestone was used as the surface layer achieved similar results.

### **2.2.6 Geo-grid**

Geo-grid was installed between a compacted subgrade and six inches of compacted, granular surface material. Three different types of Tensar geo-grids were tested, with their cost varying from \$1.50-\$3.50/yd<sup>2</sup>.

The control section, which contained no geo-grid, began developing rutting adjacent to the pavement edge within 30 days. Little to no pavement edge drop off in sections where geo-grid was installed had occurred after one year. All three types of geo-grid provided significant improvement to the soft foundation soil and were effective in preventing both rutting and pavement edge drop off. Areas where the geo-grid had been exposed to weathering (uncovered

by a snow plow) showed more rutting and pavement edge drop off than areas where the geo-grid remained entirely covered by aggregate.

### **2.2.7 Conclusions from the Iowa Study**

Of the six strategies tested, only two were considered to be successful. These two, fly ash stabilization and geo-grid stabilization of the subgrade, both require removal of existing shoulder material, emplacement of select replacement material(s) in layers and compaction. While these strategies work well as permanent solutions to the problem of pavement edge drop off, they are currently too expensive to be used for stabilizing shoulders on most roads in the Nebraska Sandhills.

Fly ash stabilization of shoulder material could most economically be employed in conjunction with either major highway reconstruction or resurfacing operations. The high cost of geo-grid stabilization makes it useful for shoulder stabilization mostly on high traffic volume roads. However, geo-grid stabilization, applied on a much smaller scale, may be appropriate for making repairs to small sections of shoulder plagued by locally induced problems.

## **2.3 Texas Initiatives**

The Texas Department of Transportation (TxDOT) embraces a wide range of maintenance and repair activities designed to decrease the rate of pavement edge deterioration and to mitigate pavement edge drop off. A brief description of activities thought by researchers to be most applicable to adoption for use in Nebraska follows.

### **2.3.1 Raw Edging**

Sealing transverse cracks that begin at the edge of the pavement and progress inward is known as “raw edging”. This procedure is normally performed by TxDOT in-house maintenance personnel and is charged against the maintenance function code for fog sealing. Raw edging involves spraying a liquid asphalt material along the pavement edge, generally covering somewhere

between one and two feet of pavement. The most common types of spray solution include asphalt emulsions or cutbacks. The spray width is often centered on the pavement edge, so the spray pattern includes 50% of the pavement surface and 50% of the unpaved soil along the pavement edge. When done in this manner, raw edging confers a degree of resistance to shoulder erosion from wind and light rain. Some districts distribute a thin layer of fine sand over the initial spray pattern to prevent stickiness. Raw edging is often done after other forms of edge repair as preventative maintenance.

This process extends the lifespan of asphalt pavement and retards raveling of aggregate along the pavement's edge. It also helps to seal the pavement edge to prevent damage from water infiltration (Lawson and Hossain, 2004).

### **2.3.2 Edge Seal/Strip Seal**

Edge seal or strip seal is another common preventative maintenance procedure used on asphalt pavement edges in Texas. This practice involves spray application of a single layer of binder (emulsion or cutback) followed by immediate application of a thin layer of aggregate which is then rolled. The process is commonly done on a one to two foot wide strip along the outer edge of the pavement.

This process is similar to raw edging but it generally extends over a larger area and includes the addition (and rolling) of aggregate. The main concern with repeatedly using this procedure is a buildup of aggregate along the pavement's outer edge, which can inhibit water from draining freely off the pavement's surface (Lawson and Hossain, 2004).

### **2.3.3 Promoting the Growth of Desirable Vegetation**

Vegetation along a roadway's shoulders is beneficial, as it controls both wind and water erosion of shoulder material. A well-developed root system along a roadway also helps to support and stabilize the pavement's edge. Roadside vegetation must ultimately be maintained by natural precipitation. In

the eastern one-third of Texas (as in the eastern one-third of Nebraska), rich soil and adequate rainfall is usually sufficient to establish and maintain successful roadside vegetation. In the western two-thirds of Texas (as in the western two-thirds of the Nebraska), the sparse rainfall and sandy soil make establishment of good vegetative cover challenging and sometimes impossible.

In the eastern one-third of Texas, maintenance personnel try to promote vegetation growth during scheduled repair and maintenance processes (Lawson and Hossain, 2004). Many districts rely upon native processes to reseed the disturbed soil, while others sow native or Buffalo grass along highway shoulders as the last step of rehabilitation or repair.

Establishment of vegetation is often included in TxDOT's construction contracts for road repair and maintenance projects. EPA regulations for storm water pollution prevention plans (SWPPP) require that 70% of the original roadside vegetation be re-established before the contractor can be relieved of responsibility for maintaining the roadside. This requirement can present a major challenge for a contractor repairing roads in West Texas.

#### **2.3.4 Edge Striping**

The most common form of delineation used to address the pavement edge drop off problem in Texas is white edge striping. A high contrast (white) edge stripe helps move traffic away from the edge and reduces edge drop off problems. All roads in Texas are centerline striped, regardless of their width. TxDOT policy requires that all roads with a minimum traveled way of twenty feet receive edge striping as well. In practice, minimum pavement width for edge striping is around 22 feet, as this width allows sufficient room for the centerline stripe, two minimum width lanes of traffic, and two edge stripes (Lawson and Hossain, 2004).

#### **2.3.5 Reshaping Shoulders with On-Site Material**

The *TxDOT Maintenance Manual* (2001) identifies reshaping material already in-place along the shoulder as a procedure for mitigating pavement edge

drop off. This method consists of using equipment (most commonly a motor grader) to pull materials from down the shoulder slope back up to the pavement's edge. Material is then compacted by equipment tires or by a pneumatic tire roller as part of the reshaping process.

Reshaping shoulders has become quite common in Texas as minimum personnel and equipment required consist of one man and a grader. Reshaping is a very quick and inexpensive method of mitigating pavement edge drop off. However, reshaping may be effective for only a few weeks up to a year under optimal conditions. Adjusting the moisture content of the soil and applying a minimum level of compaction can extend the life of this repair procedure by up to three years (Lawson and Hossain, 2004).

### **2.3.6 Replenishing Pavement Edge with Select Borrow Material**

Replenishing the pavement edge with select borrow material is similar to reshaping shoulders except new material must be added to the shoulder. New material can consist of reclaimed asphalt pavement (RAP), concrete or asphalt millings, or other select borrow materials. Typical steps when replenishing pavement edge material includes surface preparation, delivering and spreading borrow material(s), compaction and surface sealing (Lawson and Hossain, 2004). Compaction specifications for this type of repair vary. In many instances compaction is applied using only wheels of equipment already on-site.

Replenishing a pavement's edge requires traffic control personnel plus a crew of equipment operators (grader, borrow trucks, water trucks and roller) and at least one person controlling deposition of the borrow material along the pavement edge. The effectiveness and durability of this procedure is a function of the effort expended and quality of borrow materials used.

### **2.3.7 Edge (Lane) Widening**

Lawson and Hossain (2004) make the claim that lane widening is the ultimate solution for pavement edge repair problems. This strategy is based upon the observation that narrow lanes lacking shoulders, in combination with

moderate traffic loads and local environmental factors, create an environment where pavement edge drop off occurs more frequently. An example cited is the Houston district, where most of the edge maintenance procedures during the past seven years consisted of installing narrow (two feet wide), paved shoulders. Most accidents attributed to pavement edge drop off problems in the Houston District now result from deliberate or illegal activities (Lawson and Hossain, 2004). Examples of where narrow paved shoulders have reduced pavement edge drop off problems in Georgia and Pennsylvania are also cited.

Edge widening can be completed as part of a larger rebuild, rehabilitation or construction effort. Upgrading the traveled way width to a minimum of twenty-six feet has become the customary TxDOT standard for pavement reconstruction projects (Lawson and Hossain, 2004). TxDOT also regularly lets both construction and maintenance contracts to add two feet of width on both sides of narrow but otherwise serviceable highways.

### **2.3.8 Buffalo Grass**

Researchers at Texas Transportation Institute found that Buffalo grass, which is extremely hardy, requires no water (other than natural precipitation) and little maintenance, can be very effective when used to stabilize highway shoulders. Buffalo grass is naturally adapted to dryland conditions on prairies and plains and new varieties have been developed that extend its natural area of adaption. It is less invasive of asphalt pavement structure and requires less water than to hold soil together than many other grasses (TTI, 1996). Buffalo grass matures at a rate competitive with fast growing weeds, but because of its low density, stands of Buffalo grass often become weedy.

## **2.4 Other Initiatives**

Many other states are experimenting with various methods and procedures to mitigate pavement edge drop off. Most currently employed methods and procedures are similar to those already discussed. Two additional

examples are included here to illustrate that pavement edge drop off is being addressed using a wide variety of techniques.

#### **2.4.1 Minnesota**

MNDOT routinely lets contracts for paving an additional two feet beyond the point where edge striping will be placed on its major highways (Shoulder Safety and Maintenance, 2009). The additional two feet of pavement allows drivers of straying vehicles to recover while their wheels remain on pavement, rather than having a wheel move onto an aggregate or earth shoulder. Rumble strips are being experimentally incorporated into paved shoulders along the outside edge of the white edge stripe to provide drivers with an acoustic warning that a wheel is leaving the normal driving lane.

#### **2.4.2 Washington State**

Shoulder rumble strips are meant to warn drivers that they are entering a portion of the roadway that is not intended for routine traffic use. Washington State has experimented with installing shoulder rumble strips on several sections of its interstates and US highways with paved shoulders. Shoulder rumble strips installed on a 44-mile test section of I-82 in 1992 resulted in a 40% reduction in off-road vehicle crashes. A before-and-after comparison evaluating 56 miles of pavement conducted on I-5, I-90 and US 395 showed a 35% reduction in off-road crashes after installation of shoulder rumble strips (Washington State DOT, 2014).



## Chapter 3

### The NDOR's Current Strategies

#### 3.1 Published NDOR Guidance

The NDOR provides guidance for shoulder construction and maintenance in both its Roadway Design Manual and in Specifications for Highway Construction. Guidance in the Roadway Design Manual (NDOR, 2014) is included in Chapters 8 and 17. Chapter 8, Surfacing, contains the following information:

*Shoulder Construction. The subgrade on all projects that have new surfacing shall be designed an additional 0.2 ft (50 mm) high for trimming. The excess material should be incorporated into the earth shoulder as shown in Exhibits 8.3a and 8.3b. Soil material used for shoulder construction must have the capability to support vegetation.*

*Sources of shoulder material include:*

- *Undercutting, leaving the grade high for use in shoulders after the trimming operation.*
- *Excess excavation.*
- *Located sites within state right-of-way (station-to-station).*
- *Locations outside the state right-of-way (contractor's responsibility).*

Exhibits 8.3a and 8.3b from the Roadway Design Manual are shown below as Figure 1 and 2. Both figures show subgrade preparation extending a minimum of three feet (0.9 m) outward from where the edges of the subgrade have been prepared for paving. Thirty feet is thus the minimum subgrade preparation required to accommodate two twelve-foot lanes of traffic. The extra three feet of subgrade preparation on each side of the traffic lanes provides a stable platform on which a stabilized aggregate, aggregate surfaced or paved shoulder can be constructed.

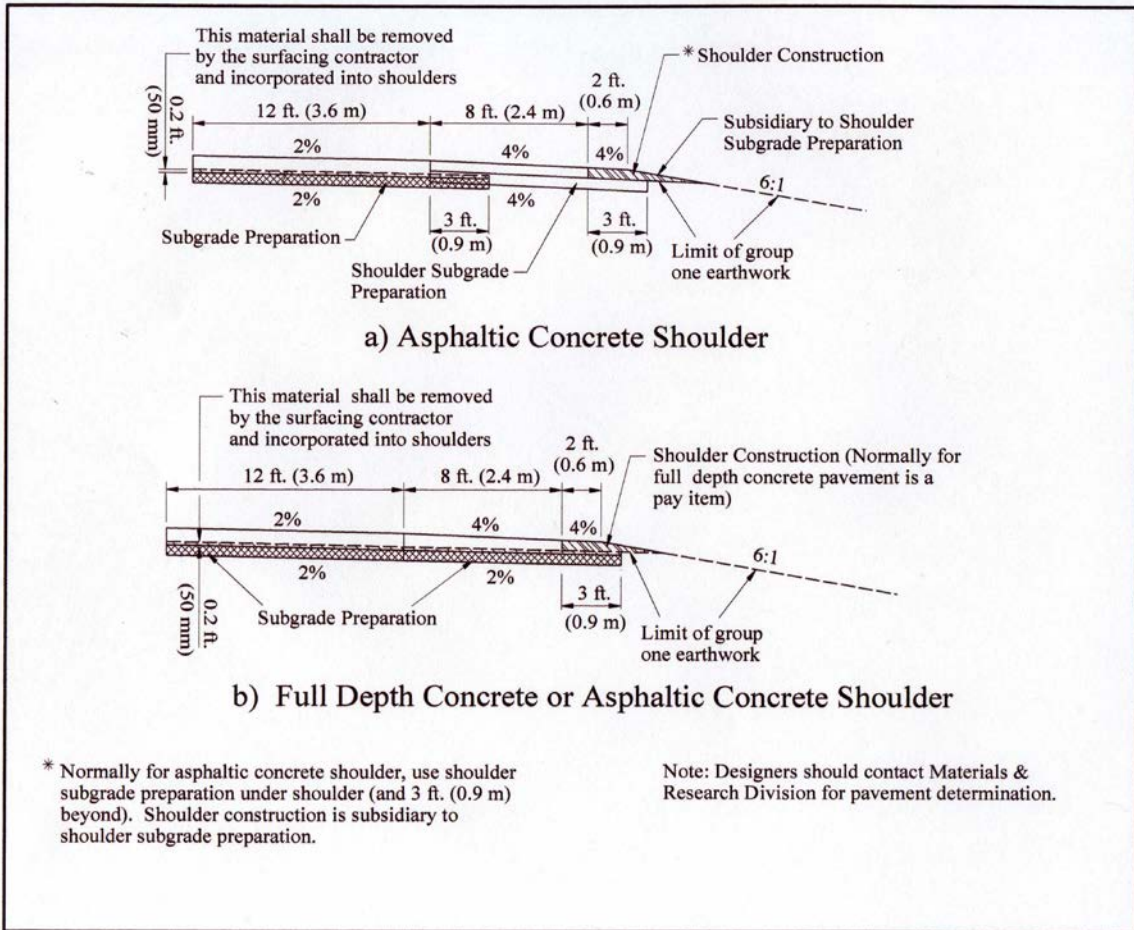


Figure 1 – Exhibit 8.3a Typical Shoulder Construction (Uncurbed Section)

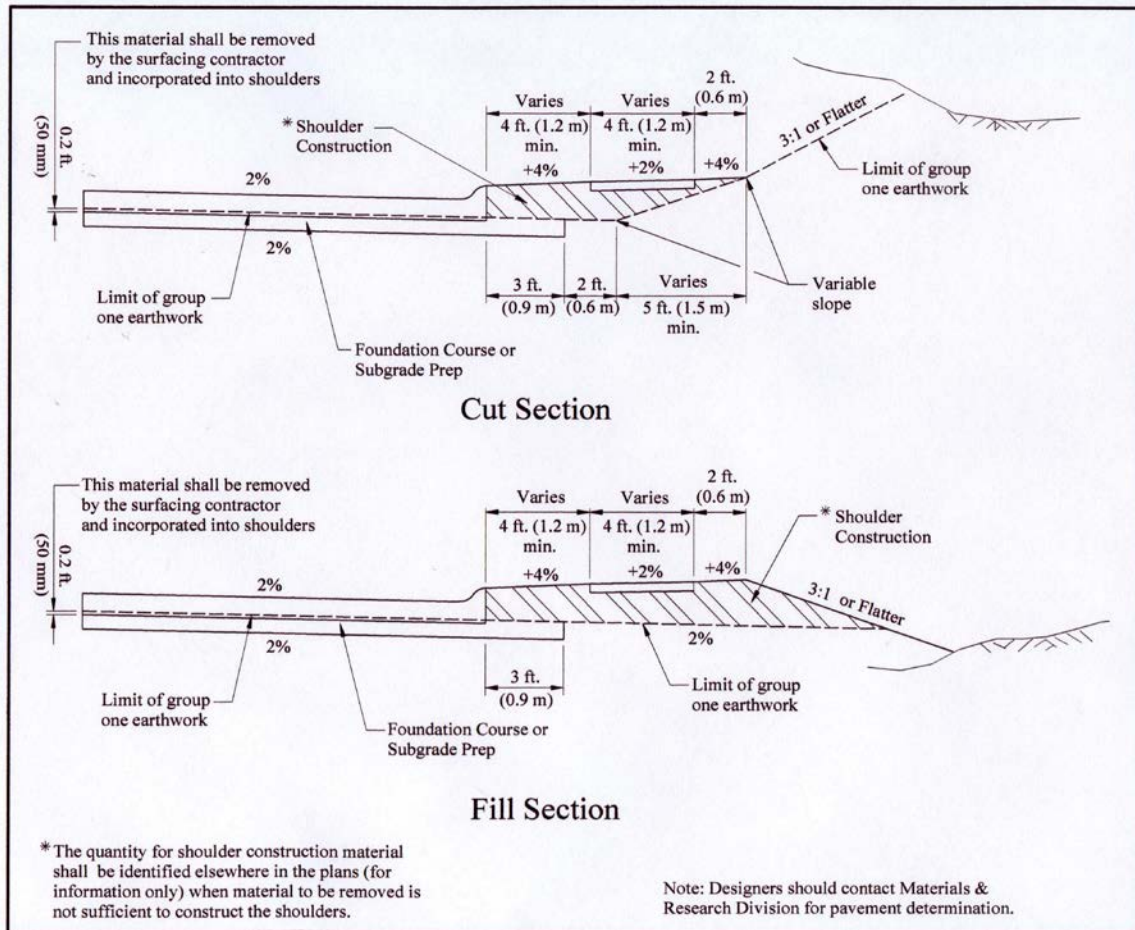


Figure 2 – Exhibit 8.3b Typical Shoulder Construction (Curbed Section)

The Roadway Design Manual also contains information on pavement shoulders in Chapter 17 – Resurfacing, Restoration and Rehabilitation (3R) Projects. Page 17-4, Safety Improvements, contains information in the ninth bullet from the top, which reads:

*A beveled edge is a sloped finish to the edge of pavement (both asphaltic concrete and Portland Cement Concrete). The beveled edge will be installed on rural high-speed ( $V \geq 50$  mph) highways when:*

1. *The project includes 3 inches or greater of surfacing placement.*
2. *Surfaced shoulders are less than 6 feet in width, not including segments of erosion control curbed shoulder.*
3. *The highway is not curbed.*

4. *At other project locations identified by Traffic as a mitigation measure for crash history.*

No specifications or details concerning composition or methods of construction for the beveled edge are included.

Section 304, Earth Shoulder Construction, from Specifications for Highway Construction (NDOR, 2007), contains additional information on shoulder construction. Section 304.03, Construction Methods, includes:

*4. a. (1) The contractor shall construct shoulders to the typical cross sections shown in the plans.*

*(2) The shoulder shall be tight bladed using a motor grader to remove any vegetation. The underlying subgrade shall be scarified to a depth of 6 inches (150 mm) and then compacted with at least two complete coverages over the area with an approved roller.*

*(3) Shoulder construction shall match the existing width and fill slope or plan sections widths, whichever is widest.*

This section contains no compaction specifications. No compaction of shoulder material is appropriate for locations where rainfall is sufficient to establish vegetated shoulders. Compaction generally inhibits but does not prevent eventual establishment of vegetation on road shoulders.

Page 43 of the Pavement Design Manual (NDOR, 2013) contains a letter by Robert Rae, an NDOR pavement engineer, discussing a widened in-place recycling strategy for asphalt pavement. This strategy consists of placing milled asphalt in a trench along the outer edges of each lane during mill-and-fill operations to minimize grade rise when an asphalt overlay is applied over the milled surface. The total overlaid width becomes twenty-eight feet, creating two fourteen foot lanes.

Advantages cited for this practice include:

- 1) Reduces duration of pavement edge drop off during paving operations.
- 2) Eliminates the need to borrow material for shoulder construction.
- 3) Pavement elevation increase is minimized.
- 4) Incidence of pavement edge drop off accidents should be reduced post-construction because of wider lanes.

- 5) Wider lanes are better able to accommodate agricultural equipment.
- 6) Snow plowing is safer due to the increased surface area.

This strategy has been widely adopted by the NDOR districts and is currently being used extensively for asphalt overlay operations.

### **3.2 NDOR Pavement Edge Drop Off Mitigation Procedures**

The NDOR districts have developed several procedures for shoulder maintenance and/or repair which significantly alleviate pavement edge drop off. Some procedures work better than others under specific climatic conditions and with particular types of soil. Some procedures are used only within a few NDOR districts, while others are used across the entire state. These procedures include:

- Reclaim or redistribute aggregate or soil that has moved away from the pavement edge.
- Add material (usually soil) to raise the shoulder elevation.
- Add aggregate or other materials to stabilize the shoulder.
- Widen the lane.
- Pave the shoulder.

#### **3.2.1 Reclaim Material That Has Moved Away From The Pavement Edge**

Wind, water and vehicle tires all move shoulder material away from pavement edges. Material remains nearby, but it is not performing its intended function. The NDOR has traditionally recovered this material by using a grader to reshape the highway shoulder, moving material closer to the pavement edge.

A type of specialized equipment (referred to as a shoulder retriever) created especially for this task is being used by District 3 in lieu of a grader. Figure 3 shows a shoulder retriever being used to increase the elevation of the shoulder material adjacent to the pavement. A shoulder retriever can be mounted on a tractor, grader, or loader.



Figure 3 – Shoulder Retriever Behind Tractor.

This procedure involves minimal investment in equipment and personnel. The task is usually performed by one maintenance worker operating a single piece of equipment. Compaction is seldom applied unless some type of shoulder surfacing procedure is scheduled to follow recovery of material.

### **3.2.2 Add Soil to Raise the Shoulder Elevation**

Soil is commonly added to shoulders where settlement over time has resulted in a fairly uniform edge drop off over an extended distance. Soil is commonly transported to the site by truck and emplaced by mechanical equipment before being smoothed with a blade (Figure 4). The graded soil will usually be compacted if the shoulder is scheduled to be surfaced. Since obtaining and transporting borrow material to the site is required, this procedure is more complicated and more expensive than reclaiming material already on-site.



Figure 4 - NDOR District Maintenance Crews Adding Soil to Shoulder.

### 3.2.3 Add Material to Stabilize the Shoulder

Various types of materials other than soil can be incorporated into highway shoulders to help stabilize against both lateral and vertical movement of shoulder material. Crushed or milled concrete and asphalt millings from highway reconstruction projects are now routinely used for this purpose by many of the NDOR districts. This process is similar to adding soil to raise the shoulder's elevation but the material must be transported to the site. Crushed concrete or asphalt millings could present a disposal problem if they were not incorporated into a highway shoulder. Figure 5 shows the results of incorporating milled concrete into a highway shoulder on NE 66. The resulting shoulder has increased bearing capacity and exhibits significantly less settlement than shoulders where recycled material has not been incorporated.



Figure 5 – Concrete Millings Incorporated into Shoulder on NE 66.

### 3.2.4 Widen the Lane

One of the most effective methods of reducing pavement edge drop off is to widen the lanes. The enhanced safety afforded by paved shoulders can often be achieved by paving only an extra two to three feet (Souleyrette et al., 2001). Figure 6 shows NE 41 west of Wilber where pavement width was increased to fourteen feet through the NDOR's recycling in-place strategy for bituminous pavement. Distance from the center of roadway to the inner edge of the outside lane marking is twelve feet. Nebraska may be partially realizing the benefits of paved shoulders from the 14-foot-wide lanes, where effectively a 2-foot-wide paved shoulder abuts each 12-foot-wide lane. For highways with significant bicycle traffic, a minimum paved shoulder width of four feet is desirable (Souleyrette et al., 2001).

Delineating a traffic lane's outer edge with a white line mitigates pavement edge drop off by providing a visual clue to the driver as the vehicle's wheels begin nearing the edge of the lane. The NDOR requires marking the outside edge of all pavements ten or more feet in width with solid white lines five inches in width.





Figure 6 – 12-Foot-Wide Lanes on 14-Foot-Wide Pavement (NE 41 west of Wilber).

### **3.2.5 Pave the Shoulder**

Paved shoulders are more expensive to construct than bare earth, vegetated or aggregate shoulders. However, paved shoulders experience significantly less repair problems over their lifetime and require less maintenance. Paved shoulders exhibit higher bearing capacity when a vehicle leaves the traveled way and are less susceptible to rutting. Asphalt paved shoulders on NE 61 south of Ogallala are shown in Figure 7.

Rumble strips installed on paved shoulders provide the driver with an acoustic warning of when a vehicle's wheels begin to leave the traffic lane. The NDOR's current policy states that rumble strips will be installed on all paved shoulders of state and federal highways. Shoulder rumble strips south of Beatrice on US 77 are shown in Figure 8. Numerous studies have found that adding rumble strips to paved shoulders significantly reduces the number and severity of off-road accidents (Souleyrette et al., 2001).

Paved shoulders offer significant benefits for bicyclists as well. AASHTO's Guide for the Development of Bicycle Facilities (1999) and the FHWA's Selecting Roadway Design Treatments to Accommodate Bicycles (1992) provide further

guidance relating to paving shoulders where significant bicycle travel on rural highways is expected.



Figure 7 – Paved shoulders on NE 61 South of Ogallala.



Figure 8 – Rumble Strips on Shoulder (US 77 South of Beatrice).

As the methods described earlier become more fully integrated into the NDOR's highway reconstruction and overlay procedures, the occurrence of pavement edge drop off will decrease dramatically. The NDOR is already making significant strides toward alleviating or eliminating this problem.

# Chapter 4

## Earth or Vegetated Shoulders

### 4.1 Earth Shoulders

A well-maintained shoulder has a sloped surface only slightly lower than the adjacent highway's driving surface. The shoulder elevation should be flush with the pavement surface where the two meet and slope gently away from the paved lane. Ideally the shoulder should not exhibit any abrupt changes in elevation (have erosion problems) either longitudinally or transversely.

Shoulder surfaces can be as simple as bare earth. Composition of earth shoulders varies from stabilized, compacted, select fill material to unmodified, in-situ soil. Earth shoulders are the least expensive type of shoulders to construct, but generally require more maintenance and repair than any other type due to erosion of material by wind, water and the passage of vehicles.

The size of particles within and composition of earth shoulders varies with geology and the landscape position (Figure 9). Unique problems with pavement edge erosion are encountered where road shoulders are composed of relatively uniform, unconsolidated material, such as soil found in the Sandhills.

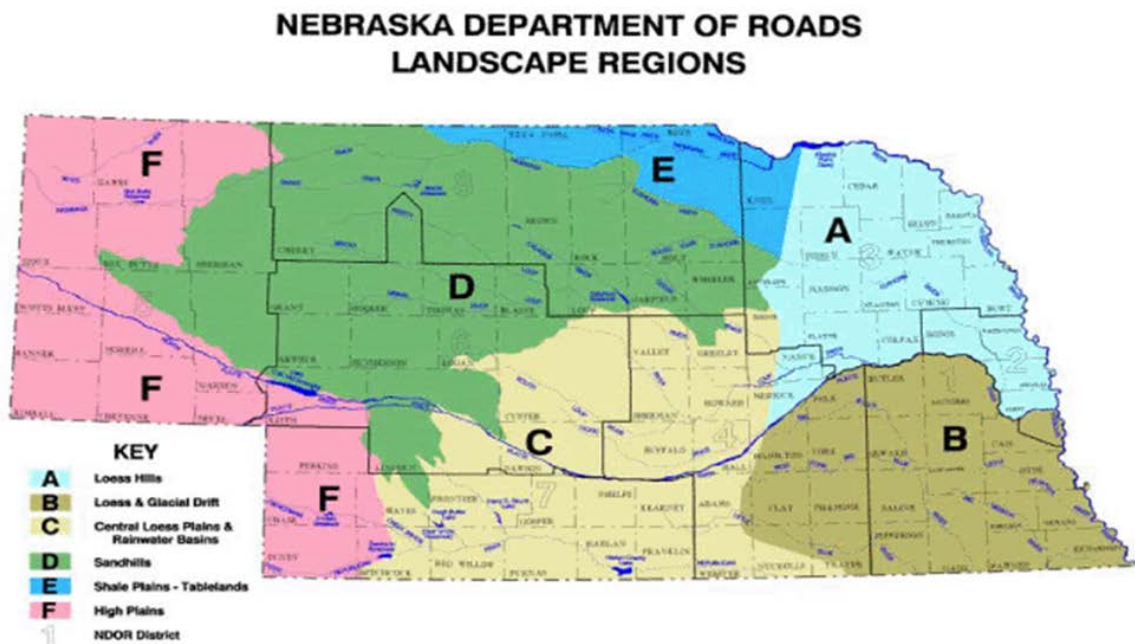


Figure 9 - Landscape Regions of Nebraska.

The Sandhills (Region D in Figure 9) is a region of mixed-grass prairie covering a large field of sand dunes in north-central Nebraska. This region was formed by wind action across glacial outwash during the late Tertiary and Early Pleistocene. Shoulders along highways in the Sandhills have proven to be highly erodible. The relatively uniform particle size and absence of smaller particles produce considerable void space within the soil and enable the shoulder to drain extremely well. The absence of smaller particles, however, robs the soil of sufficient internal cohesion to remain stable when buffeted by wind or water. When emplacing material to support vehicular loads and to resist wind and water erosion, not less than ten percent should pass the #200 sieve. The most economical solution for prevention of erosion on this type of shoulders is to encourage the growth of vegetation, which stabilizes shoulder material through root penetration.

#### **4.2 Vegetated Shoulders**

Vegetation is temporarily removed from road shoulders by construction activities. Road shoulders sometimes remain without vegetation for long periods of time because of the inability of vegetation to re-establish itself in a particular climate or under adverse nutrient or light conditions.

Vegetation along a highway is beneficial to stabilization of the pavement edges. It represents the most edge drop off resistant non-paved shoulder option where precipitation is adequate to maintain it. Vegetation increases shoulder stability in all climates and under all soil conditions due to its roots penetrating soil layers and holding larger soil particles in place. The principle factor influencing vegetation growth is rainfall. Rainfall is remarkably different across Nebraska, varying from almost thirty-four inches annually in the southeastern corner of the State to less than twelve inches annually along its far western border (Figure 10).

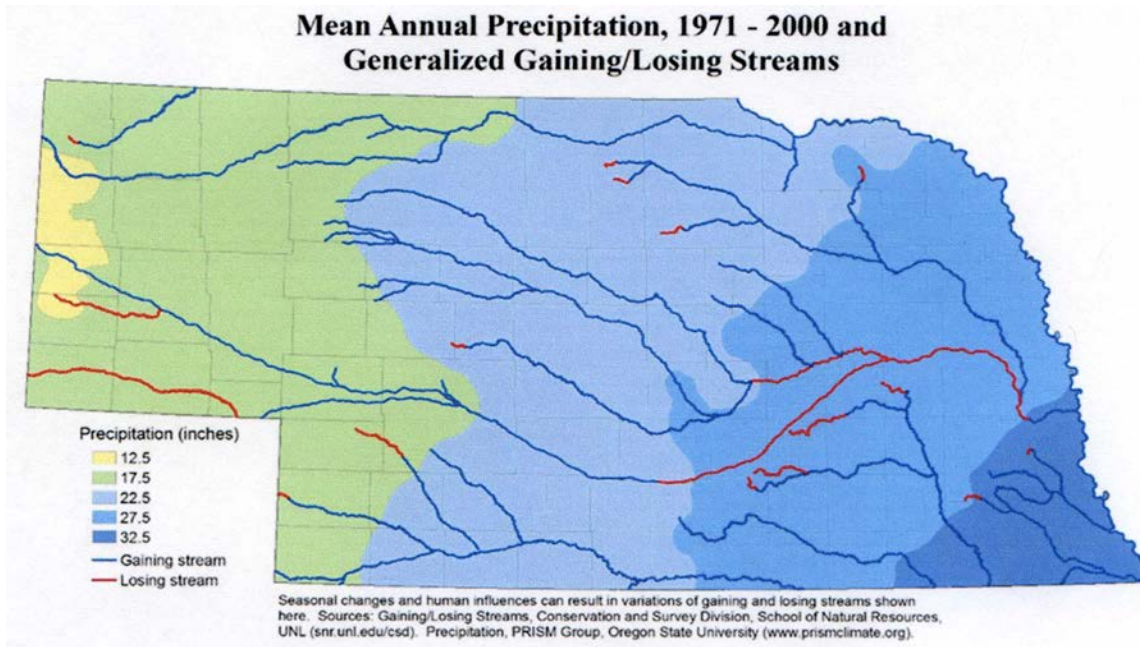


Figure 10 - Mean Annual Precipitation in Nebraska.

Based primarily upon quantity of rainfall, road shoulders in the southeastern one-third of Nebraska are mostly vegetated. Rainfall is sufficient for vegetation to re-establish itself after clearing and grubbing, either with or without deliberate reseeding. Minimal pavement edge erosion occurs once vegetation has been established. Shoulder repair/maintenance strategies that are successful for vegetated shoulders include placing soil, aggregate or recycled materials along the pavement edge to increase shoulder elevation and stabilize the soil or recovering material that has moved away from the pavement edge with a retriever or blade.

Establishing vegetation on highway shoulders is the most practical and economical method available for reducing soil erosion. Last year the NDOR published the first version of its Roadside Vegetation Establishment and Management guide. This guide lists seed mix specifications for establishing roadside vegetation under different soil and climate conditions across the State of Nebraska. Species selection is based upon many factors, including time required for vegetation to establish and permanence (NDOR Roadside Vegetation Establishment and Management, 2014, p. 11). Suggested seed mixes tailored to soil types and climatic conditions within specific areas of Nebraska can be found within the guide.

The seed mix specified for the Sandhills region of Nebraska (Region D in Figure 9) is shown in Figure 11.

Species	Minimum Purity (percent)	Lbs. of PLS/acre
Perennial ryegrass – Linn	85	7
Slender wheatgrass	85	5
Western wheatgrass – Rodan, Rosana, Barton, Flintlock	85	5
Kentucky fescue	85	3
Blue grama – NE, KS, CO, MN	30	2.5
Sideoats grama – Pierre, Butte	75	4
Sand dropseed ( <i>Sporobolus cryptandrus</i> )	90	0.2
Sand lovegrass – NE-27, Nebraska native	90	1
Purple prairie clover – inoculated	90	0.2
Rye	90	16

Figure 11 - Suggested Highway Shoulder Seed Mixture for the Sandhills.

Vegetation root systems are an inexpensive, natural method of reinforcing highway shoulder material to minimize erosion. Chapter 5 explores other methods that, while more expensive, are capable of retaining soil under a wider array of adverse climate and traffic conditions.

## Chapter 5

### Repair of Localized Problem Areas

#### 5.1 Localized Problem Areas

Pavement edge drop off is seldom uniform along a highway unless it was created by shoulder settlement or by resurfacing where no attempt was made to provide a suitable transition from pavement to shoulder. Wagner (2004) identifies the six locations where pavement edge drop off is most frequently encountered which include: horizontal curves, near mailboxes, in shaded areas, near turnarounds, along eroded areas, and adjacent to asphalt pavement overlays. The authors have identified their own set of locations specific to Nebraska where pavement edge drop off occurs more commonly. These locations are shown in Table 1.

**Table 1 – Problematic Locations for Pavement Edge Drop Off**

Location/Situation	Cause(s)
Inside of horizontal curves, especially superelevated curves	Water flows toward the inside of the curve, transporting away shoulder material. Wheels stray off the pavement more frequently along the inside of curves, actively pushing surface material away from the pavement’s edge.
Areas shaded by trees/structures	Shaded areas dry more slowly after precipitation. Water acts as a lubricant, reducing bearing capacity and making soil more susceptible to rutting.
Steep or extended longitudinal grades	Water flowing along the pavement edge erodes shoulder material.
Cohesive soils with high plasticity index, especially when shaded.	Soils stay softer over a wider range of moisture contents, making the soil more susceptible to rutting.
Granular soils on steep longitudinal or transverse slopes	Water flowing off the roadway carries away shoulder material.
Mailboxes, turnarounds, T-intersections	Wheels tracking off the pavement’s edge form ruts in the adjacent soil.

Methods of alleviating edge drop off in small areas can be very different from methods used to mitigate edge drop off along extended sections of highway. One of the most practical methods of treating edge drop off in localized areas is the addition of some type of artificial soil reinforcement to the problem shoulder.

## **5.2 Artificial Soil Reinforcement**

Artificial soil reinforcement is basically of two types, mesh and grid. Mesh has a very limited vertical cross-section. Its thickness is often measured in millimeters. Mesh was originally conceived and created as a membrane to separate different layers of soil. It is typically used for reinforcement of soil in retaining walls, steepened slopes, embankments, and waste containment facilities.

Mesh is composed of high molecular weight multifilament yarns coated with PVC and woven into a stable network. It is very resistant to biological degradation and to attack from naturally occurring chemicals and soil conditions. Mesh limits downward movement of aggregate larger than the size of the mesh openings, which creates a layer of soil more resistant to penetration (i.e. rutting). Mesh is sometimes used without an aggregate layer but this practice does not confer the same resistance to rutting as use of mesh with an aggregate layer provides.

Grid is three-dimensional soil reinforcement which creates a composite layer of material having increased strength. Vertical depth of the grid can vary from a minimum of about one inch to a maximum of eight inches or more. Greater depth makes placement of infill material more difficult. Infill material is typically select aggregate, although gravel, sand and many different types of soil have all been used successfully under varying conditions. Grids reinforce soil by confining infill material within a three-dimensional framework. Spreading of the infill material under load is prevented by the grid's honeycomb structure. The composite layer created by the grid distributes concentrated wheel loads across a larger area of subgrade beneath, which prevents rutting.

Many different types and sizes of meshes and grids are available from a wide variety of manufacturers. Most meshes and grids are patented; many are trademarked. Meshes and grids are commonly employed to control soil erosion on



slopes, stabilize vegetation or aggregate for overflow and temporary parking lots, to stabilize soil beneath fire and utility lanes as well as to improve the bearing capacity of cart paths and driveways. Some commercially available meshes and grids specifically used to mitigate rutting caused by automobile and emergency vehicle wheel loads are discussed in the remainder of this chapter.

### **5.3 Meshes for Vegetated Surfaces**

Mesh is used almost exclusively to reinforce vegetated surfaces, since mesh has minimal vertical cross-section and thus has limited ability to laterally contain material within its openings. Mesh only partially decreases penetration by wheel loads due to its tensile strength, so it is used to mitigate rutting only where rutting does not constitute a serious problem .

#### **5.3.1 Terratame2**

Terratame2 is a woven polyethylene mesh that was originally developed for control of scour in highly erosive locations. It is widely used for scour protection below culvert outlets and for erosion control on slopes and in ditches. Terratame2 has been used in traffic applications primarily to reinforce unstable soils in temporary and permanent grass parking lots. Terratame2 is placed over a seeded or sodded soil surface. Vegetation grows up and through the mesh structure. Figure 12 shows Terratame2 being unrolled to create a parking lot.



Figure 12 – Terratame2.

### 5.3.2 Grass Protecta

Grass Protecta is a polyethylene mesh that is also available in 2 m x 20 m rolls (Figure 13). It was originally developed for reinforcing soft soils beneath fire and utility lanes, but its uses have evolved to include reinforcement of soil beneath temporary and recreational vehicle parking lots, aircraft taxiways, helicopter landing pads and recreational trails. Grass Protecta can be installed directly over existing grass by cutting the grass short, unrolling the mesh and securing the mesh to the existing surface with metal or plastic pins. Grass Protecta protects, reinforces and stabilizes grass against damage caused by traffic (both pedestrian and vehicular). It has been found to be especially effective in minimizing rutting on muddy surfaces. Grass Protecta is actively marketed for use as grass shoulder reinforcement along highways.



Figure 13 – Grass Protecta.

### 5.4 Grids for Vegetated Surfaces

Grids are more versatile than meshes because a grid can be used to reinforce either vegetated or aggregate surfaces. Common thicknesses of grids used to reinforce vegetated surfaces vary from one to two and one-half inches. The three-dimensional structure of a grid retains soil or aggregate particles and creates a stable layer of composite material within the overall soil structure. This stable layer increases the bearing capacity of the soil and decreases rutting.

### 5.4.1 Airpave

Airpave is a three-dimensional copolymer grid that is manufactured as 32" x 32" x 1" interlocking pieces. It has been used successfully to reinforce soil beneath fire and utility lanes, to provide overflow vehicular parking and for golf cart and walking paths. Airpave is normally placed over a prepared subgrade of sandy gravel and filled with clean sand (Figure 14). Cut sod or hydro-seeding is suggested as the means of establishing the final vegetated surface.

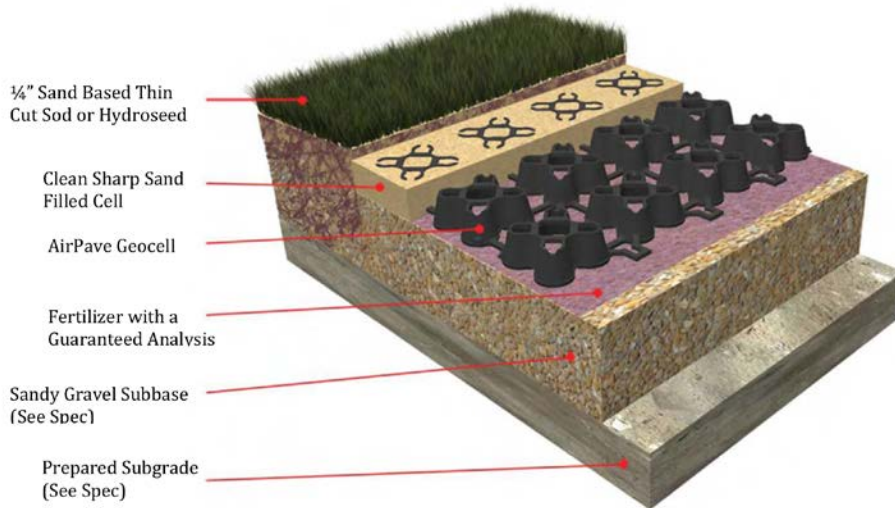


Figure 14 – Airpave Cross Section.

### 5.4.2 Grasspave2

Grasspave2 is a three-dimensional HDPE grid that is manufactured in 3.3 feet x 3.3 feet or 1.65 feet x 1.65 feet squares (Figure 15) packaged into rolls 3.3-8.2 feet wide x 33-66 feet in length. It has been used successfully beneath fire and utility access lanes, for parking lots, pedestrian walkways, golf cart paths and in erosion control structures. A permeable base course up to twelve inches thick (depending upon the subgrade) is recommended. Thin-cut sod, washed sod or hydro-seeding are the recommended methods of establishing permanent vegetation cover.



Figure 15 – Grasspave2 Showing Infill Material.

### 5.4.3 Geoblock

Geoblock is a recycled polyethylene grid that is marketed as porous pavement. It is manufactured as 20 inch x 40 inch mats (Figure 16), of one or two inch thickness. It has been successfully used for grass driveways, walkways, plus fire and emergency vehicle access lanes. The polyethylene grid should be placed upon well-drained aggregate or topsoil engineered fill. Material placed as infill should be conducive to vegetation growth. Sod or hydro-seeding are the recommended methods of establishing vegetation cover.



Figure 16 – Geoblock Porous Pavement with Sod.

## 5.5 Grids for Aggregate Surfaces

Grids designed for aggregate surfaces are characterized by a greater vertical dimension than grids used for vegetated surfaces, with thicknesses between two and eight inches being the most common. Specifications for infill material (aggregate) differ slightly depending upon the product.

### 5.5.1 Stabilization Grid

Stabilization grid consists of non-woven geotextile strips thermo-welded into a cellular matrix (Figure 17). Unfolded area is 25 feet by 4 feet with thickness being either 2 or 4 inches. Stabilization grid has been used successfully to create parking lots, driveways, golf cart pathways, and sports fields.



Figure 17 – Stabilization Grid Partially Filled.

### 5.5.2 Envirogrid

EnviroGrid is a three dimensional grid composed of sheets of three, four, six or eight inch high interlocking HDPE cells with mesh thermos-welded across the bottom. It has been used successfully as a road base (Figure 18), as driveways, for streets and for beach stabilization projects. Envirogrid is shipped as a 12" x 5" x cell height bundle which expands to 27.4' and 8.4' x cell height grid when expanded. Expanded grids are connected to one another using clips and pins.



Figure 18 – Envirogrid Used as a Road Base.

### 5.5.3 Gravelpave2

Gravelpave2 is a three-dimensional HDPE or HIPP grid that is manufactured in 3.3 feet x 3.3 feet x 1 inch or 1.65 feet x 1.65 feet x 1 inch squares packaged into rolls 3.3-8.2 feet wide x 33-66 feet in length. Edges of squares lock together to prevent slippage. Gravelpave2 is flexible enough to allow rapid installation around obstacles (signs, posts, etc.,). It can be cut and trimmed using a saw. Gravelpave2 has been used successfully for parking lots, access roads, vehicle bays, storage yards, service, utility and fire access drives, loading docks and boat ramps.



Figure 19 – Driveway Constructed With Gravelpave2.

#### 5.5.4 Geopave

Geopave is a recycled polyethylene grid that is manufactured in 20 inch x 40 inch mats, two inches in thickness. It has been successfully used to reinforce soil beneath trails, fire and emergency vehicle access lanes plus temporary and permanent parking lots. The grid can be installed on top of an engineered drainage layer varying from two to six inches in depth depending upon the traffic loading conditions. Geopave is recommended for use on highway (aggregate) shoulders and is advertised as a “natural storm water retention system”.



Figure 20 – Constructing Parking with Geopave.

#### 5.6 Selecting Soil Reinforcing Systems

The various types of artificial soil reinforcement systems mentioned earlier are shown in Table 2 with their websites listed. Further information about each product is available from the websites.

A soil reinforcement system should ideally have reinforcing material available in large rolls for repair of extended areas when necessary. Sections of reinforcing material should be detachable as smaller units for repair of localized edge drop off. A similar system could be used for repair of both vegetated and granular shoulders with only the infill material being different between the two applications. Infill material would consist of soil/seed where a vegetated shoulder is desired and some type of aggregate where the shoulder is expected to remain unvegetated.

Table 2 – Artificial Soil Reinforcement Systems.

	Surface	Product	Website
Meshes	Vegetation	Terratame2	<a href="http://www.invisiblestructures.com/terratame2.html">http://www.invisiblestructures.com/terratame2.html</a>
	Vegetation	Grass Protecta	<a href="http://www.typargeosynthetics.com/">http://www.typargeosynthetics.com/</a>
Grids	Vegetation	Airpave	<a href="http://www.airfieldsystems.com/grass-pave/">http://www.airfieldsystems.com/grass-pave/</a>
	Vegetation	Grasspave2	<a href="http://www.invisiblestructures.com/grasspave2.html">http://www.invisiblestructures.com/grasspave2.html</a>
	Vegetation	Geoblock	<a href="http://www.prestogeo.com/geoblock_porous_pavement">http://www.prestogeo.com/geoblock_porous_pavement</a>
	Aggregate	Stabilization Grid	<a href="http://www.landscapediscount.com/Ground-Grid-DuPont-p/dpgg-5055.htm">http://www.landscapediscount.com/Ground-Grid-DuPont-p/dpgg-5055.htm</a>
	Aggregate	Envirogrid	<a href="http://iwtcargoguard.com/products/envirogrid-cellular-confinement-system">http://iwtcargoguard.com/products/envirogrid-cellular-confinement-system</a>
	Aggregate	Gravelpave2	<a href="http://www.invisiblestructures.com/gravelpave2.html">http://www.invisiblestructures.com/gravelpave2.html</a>
	Aggregate	Geopave	<a href="http://www.prestogeo.com/geopave_porous_pavement">http://www.prestogeo.com/geopave_porous_pavement</a>

The presence or absence of vegetation along the highway shoulder is the best indicator of what that shoulder’s surface will ultimately resemble. If vegetation is growing near a highway’s edge, a system that stabilizes soil while supporting vegetation growth would be ideal. Two systems considered appropriate which promote vegetation growth are Grasspave2 and Geoblock (Figure 21).

**Grasspave2** - 3.3' x 3.3' or 1.65' x 1.65' squares



**Geoblock** – 20" x 40" x 1" or 2" rectangles

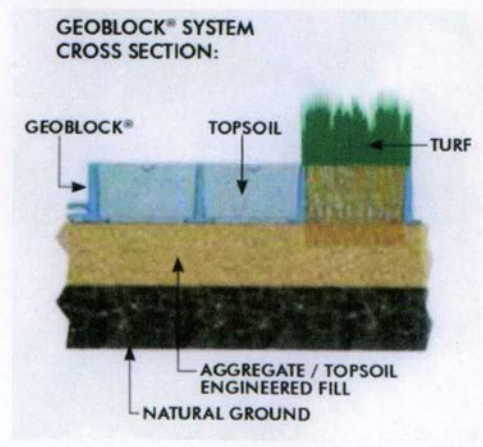


Figure 21 - Grids for Vegetated Shoulders.



Grasspave2 and Geoblock can be purchased in large rolls for placement over extended areas. Rolls of each can be disassembled into smaller pieces. Smaller pieces can be hand-placed for more localized repair work at specific locations.

Similar systems produced by the same manufacturers for aggregate shoulders are Gravelpave2 and Geopave (Figure 22). These systems perform better when installed over an aggregate base course which functions as a drainage layer. Manufacturer's suggestions for base course include material ranging in size from 0.1875 – 0.5 inches (Figure 23).

Because the primary function of the base course is to act as a drainage layer, any material with good hydraulic conductivity should be acceptable. Acceptable base course materials include Nebraska's 47B aggregate. Theoretically, any material with less than ten percent passing the #200 sieve could be used to construct a base course.

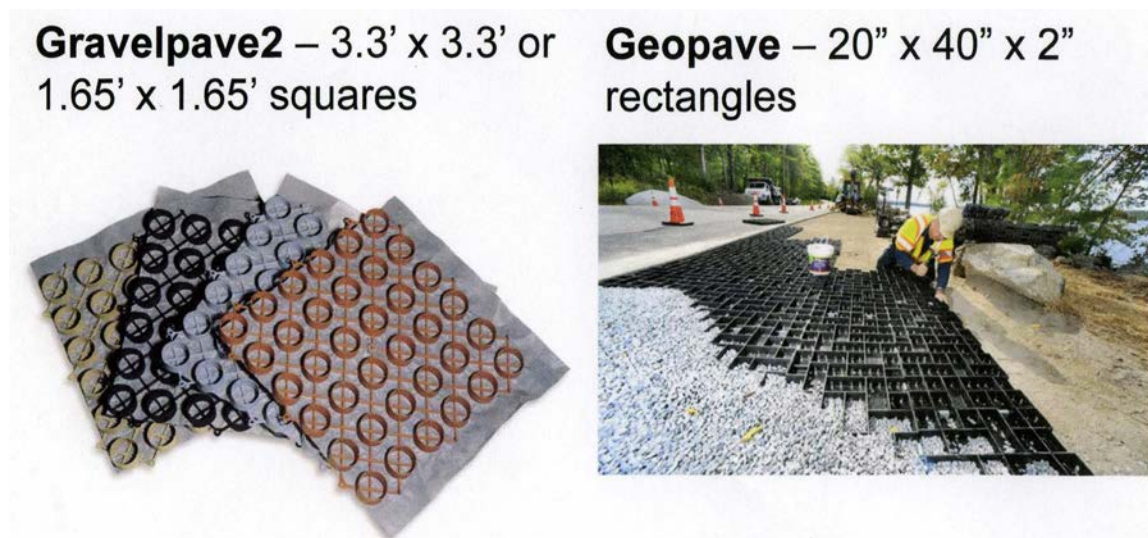


Figure 22 - Grids for Aggregate Shoulders.

Infill material must resist vertical forces imposed by wheel loads, so angular aggregate will perform better than smooth. The top surface of infill material must resist movement by air and water, so larger particles will perform better than

smaller. However, aggregate particles should be no larger than one-third of the reinforcement cell's least dimension so that proper compaction can be achieved.

### GravelPave

- Aggregate infill crushed angular stone uniformly graded 3/16" - 3/8" .
- Recommended base course material .

Size	% pass
1"	100
3/4"	90-100
3/8"	70-80
#4	55-70
#10	45-55
#40	25-35
#200	3-8

### GeoPave

- Aggregate infill crushed angular stone well-graded 3/8" – 1/2" .
- Minimum 2" of aggregate base should be placed below GeoPave as a drainage layer.
- Recommended base course material.

Size	% pass
1/2"	95-100
3/8"	15-20
1/4"	0-5%

Figure 23 - Recommended Base Course and Infill Materials.

# Chapter 6

## Recommendations

### 6.1 Research Focus and Limitations

This study focused on documenting methods and procedures used successfully by the NDOR districts and by other state DOTs to mitigate pavement edge drop off. The goal of this research was consolidation of institutional knowledge, making it available for dissemination to district design and maintenance personnel across Nebraska. No funding for field trials or for testing of recommended pavement edge drop off mitigation procedures was included in this study's submission.

### 6.2 Suggestions for Additions to NDOR Publications

Suggested changes that would assist with dissemination of pavement edge drop off mitigation information via currently published NDOR documents include adding specifications for construction of a safety edge (Figure 24) to the Roadway Design Manual (NDOR, 2014).

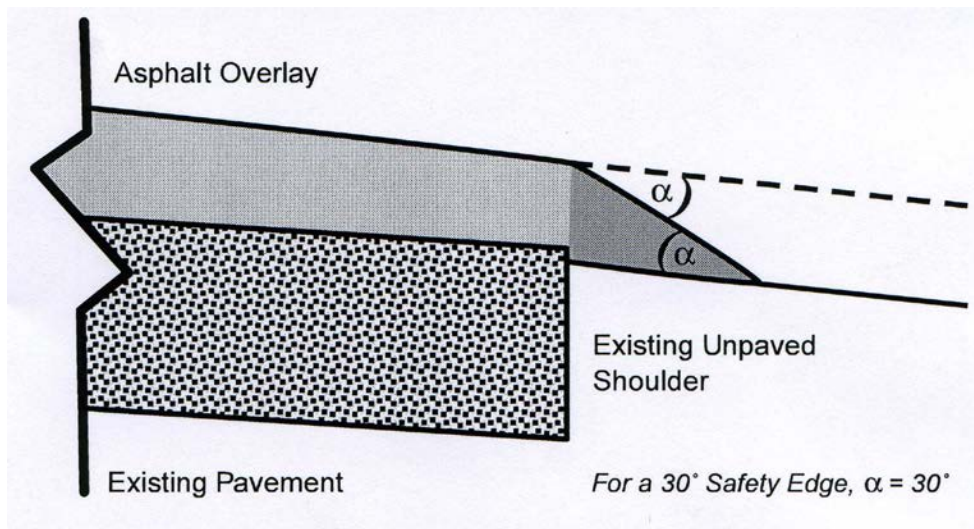


Figure 24 – The FHWA's Safety Edge (Hallmark, et al., 2006).

Initial studies by Humphreys and Parham (1994) recommended a 45° safety edge sloping downward from the top edge of the overlay toward the top edge of the existing unpaved shoulder. A 30° safety edge was found to have a higher degree of safety regardless of the degree of longitudinal elevation change (Ivey, 2008) and was much easier to construct. Crossing a 30° slope has roughly 60% of the detrimental effects of crossing a 45° slope of the same vertical height (Ivey, 2008), so the safety edge ultimately adopted (and promoted) by the FHWA incorporated the 30° (versus 45°) angle. A safety edge can be added to bituminous overlays with almost zero impact on productivity while adding less than one percent to material costs (Wagner, 2004).

The Roadway Design Manual could be modified to include information added about stabilizing highway shoulder material characterized by a high plasticity index. This practice is already being required by the NDOR for highway subgrades. Provisions for subgrade preparation could simply be extended to cover shoulder material as well. Reducing the plasticity index of materials used for shoulder construction will limit the range of water contents over which the shoulder is most subject to rutting.

Specifications for soil that has the ability to support vegetation growth (on highway shoulders) could be added to the Roadside Vegetation Establishment and Management (NDOR, 2014) guide. Specifications might include the requirement that only topsoil can be used as the shoulder's surface layer where vegetation is the desired surface cover. Compaction could be limited or prohibited, as compaction minimizes void space needed for successful root development as vegetation matures.

### **6.3 Suggestions for Future Research**

District maintenance personnel may wish to experiment with raw edging and/or strip sealing/edge sealing (mentioned under Texas Initiatives) as methods to extend the lifespan of asphalt overlays. Cost of these strategies is significantly less than for fog sealing or chip sealing applied across the entire width of pavement.

These procedures are considered to be both effective and economical and are used extensively by the State of Texas.

During TAC meetings, several research initiatives were suggested that have the potential to provide valuable data which could improve highway shoulder drop off mitigation procedures in Nebraska. Some of these include:

- Field testing to determine whether broadcast seeding or drilling produces thicker and more uniform shoulder vegetation.
- Field testing to determine whether the current practice of placing cattle manure on unvegetated highway shoulders encourages satisfactory establishment of local vegetation.
- Field testing of soil reinforcement meshes and grids using agricultural machinery and/or cattle as loads.

#### **6.4 Conclusions**

Current NDOR practices will mitigate many of the problems associated with pavement edge drop off as they become more commonly employed on Nebraska highways in future years. The most economical way for the NDOR to mitigate present and future hazards associated with pavement edge drop off is to issue resurfacing/reconstruction contracts that require providing a stabilized shoulder flush with the pavement surface as an integral part of each contract. All resurfacing contracts for lanes with unpaved shoulders should require that the pavement be constructed with a 30° safety edge per FHWA guidance.

Effective shoulder maintenance requires many different strategies depending upon climate, soil composition and type of shoulder material. Most NDOR districts have multiple variations of climate, soil composition and type of shoulder material to consider, which necessitates that maintenance personnel apply the most appropriate strategy for many differing sets of conditions. NDOR district maintenance personnel seem to have adapted well to this challenge and are either using or experimenting with strategies that effectively mitigate pavement edge drop off in a wide variety of situations.

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