Recommendations for Achieving Safety Edge Consistency during Paving

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Background

Pavement edge drop-offs can be a serious safety concern when a vehicle leaves the paved roadway surface and encounters a significant vertical elevation difference between the paved roadway and adjacent unpaved shoulder. Edge drop-offs are potential safety hazards because substantial vertical differences with adjacent surfaces can reduce vehicle stability and affect the driver's ability to control their vehicle when inadvertently leaving the paved driving area.

The Federal Highway Administration (FHWA) developed the Safety Edge based on results of research indicating that a sloped pavement edge surface could be traversed more easily by drivers of vehicles leaving their lanes and attempting to remount the pavement edge.

The Safety Edge is a design feature that creates a slope along the outermost edge of the paved section of the roadway. The Safety Edge is placed most commonly during hot-mix asphalt (HMA) paving using a device that shapes and consolidates the asphalt material at the pavement edge into an approximate 30 degree fillet as shown in Figure 1.

The shape created by the Safety Edge reduces the likelihood that tire scrubbing will occur and provides a gradual, rather than abrupt, transition back to the roadway as drivers of errant vehicles remount the pavement surface.

The Safety Edge provides this benefit before shoulders have been leveled after resurfacing, as well as when the unpaved shoulder material migrates away from the pavement edge over time due to wear or erosion.

Scope of the Problem

Safety Edge paver shoes are usually designed to place the fillet angle at about 30 degrees. It has been assumed that once the Safety Edge is placed with the paver, it will retain the proper shape. However, researchers from the Center for Research and Education (CTRE) monitored the slope on more than 35 HMA paving projects during the 2010-2012 construction seasons and found a significant amount of variation in final edge slope angle (from 18 to 52 degrees). The team also found most of this distortion of the slope was occurring during compaction and termed the problem "roll-over."

Figure 1. HMA Safety Edge in Kossuth County, Iowa

After discussions with other states where similar problems had been experienced, it was concluded that this difficulty is likely to be common. As a result, this tech brief summarizes solutions to address the issue of inconsistent slopes when the Safety Edge is applied.

Several other issues were also noted as the team monitored paving projects and possible solutions to address those problems are also presented.

Addressing Roll-Over

When distortion of the Safety Edge shape was first observed, the team speculated that roll-over could be impacted by roller pattern, magnitude of vibration, and/or design of the mix, resulting in HMA material being displaced toward the edge during compaction. The team discussed the problem with local agencies, contractors, the advisory team, and an HMA materials expert.

It was finally surmised that susceptibility to edge roll-over was not due entirely to the compaction process, but may have been related to several factors inherent with HMA projects, including mix design, support from underlying base, temperature of delivered mix, ambient temperature, roller patterns and magnitude of vibration, lift thickness and, possibly even latent aggregate moisture content in the mix prior to compaction.

The type of Safety Edge equipment used may also be a factor, although not as significant as crew and inspection dedication to producing the desired end product. The following recommendations summarize lessons learned to address roll-over.

Quality Assurance

For HMA pavements and overlays, it was concluded that no current Safety Edge shoe would produce a desirable Safety Edge all the time without attention paid to the final results. Although the newer design shoes did appear to perform more consistently than earlier models, a common practice of "Set it and forget it!" does NOT work.

Many factors, as listed above, plus the base width and shoulder conditions, all might have an influence on the final edge slope, no matter how satisfactory the slope appears immediately behind the paver. The contracting authority and the contractor both must agree before work begins, probably at the pre-construction conference, what final result is desired and comply by making adjustments as necessary throughout the project to achieve that level of success. Obviously, this goal must be made clear to the field inspector, paver operator, and crew, as they are the ones actually inspecting and performing the work.

The team feels that the single most important method to address roll-over and other issues with application of the Safety Edge is consistent monitoring so the issues can be addressed in the field.

Performance measures may need to be adopted to obtain desired results. These measures, with or without non-compliance penalties, should encourage both contractor crews and agency inspectors to exert more effort in monitoring the construction of a desired Safety Edge product. A minimum sampling frequency could be required with desired results of a 30 degree slope as a target with a 10 degree variance allowed.

Contractors and/or agency inspectors need to check and adjust (if necessary) crew procedures several times a day and demand the best work possible. Measurements should be accomplished with a common, inexpensive device to which both the owner and contractor have access. (Smart levels can be purchased in the $150 to $200 range.) Unacceptable results should be discussed as quickly as possible with the grade superintendent or foreperson so everyone is aware of both poor and acceptable results and needed adjustments are made.

Safety Edge Equipment

Several different types of equipment to form the Safety Edge are available. They are usually, but not always, termed Safety Edge "shoes."

In the first year that construction projects were monitored, it was felt that the shoe itself may not be providing a consistent slope. Two different contractors actually made modifications to the shoes for their HMA projects. Both modifications attempted to provide some additional consolidation to the sloped edge.

By the second year of evaluation, several vendors incorporated a design feature that offered an approximate extrusion process that seemed to add consistency to the Safety Edge slope and overall improved production of the desired slope. Although the newer design shoes did appear to perform more consistently than earlier models, problems with roll-over were still noted indicating how critical it is to provide adequate monitoring during construction.

Avoiding Outside Edge during Rolling

Because it was felt that much of the distortion was a result of roller pattern and compaction effort near the pavement edge, several contractors tried using only the final roller on the outside foot of pavement to avoid distorting the Safety Edge. However, concerns were raised about reduction in density of the outside foot of pavement, so other options should be explored first.

The research team requested that density core testing be conducted in the outside foot at two sites where the contractor used only the final roller for compaction. Normal cores from one location yielded a range of from 95.5 to 98.9 percent of laboratory density and cores from the outside foot at the other site ranged from 94.4 to 95.0 percent, so some reduction in density did indeed occur, although not major.

Mix Consistency

Throughout the conduct of the 2010-2011 and 2012 construction season evaluations, inconsistent Safety Edge results were viewed and documented even on the same projects from day to day or on near-by projects constructed with the same materials by the same contractor.

Several possible causes for this variation have been suggested and studied, including ambient and mix temperatures, variation in compaction activities, asphalt content, and aggregate type and gradation. Moisture content of the aggregate has been known to have an impact on stability during compaction, but the extraordinarily dry Iowa summer in 2012 made that unlikely.

In an effort to identify an item in the job mix factors that might impact stability, a list of gyratory mix design elements for 2012 HMA projects was examined for variations that could predict resultant stability of the mix in the field, but none could be identified.

Without a reliable means to predict when problems with HMA distortion under compaction to the degree that the integrity of the Safety Edge slope might be impacted, agencies and contractors therefore must rely on proven techniques and close monitoring to assure that the desired safety edge slope is attained.

The CTRE team also estimated that contractors who did not have problems with roll-over during the 2011 construction season were using mixes with total asphalt cement concrete (ACC) content from 5.7 to 6.5 percent with a higher percentage of coarse aggregates. It was also felt that temperature of the mix may have contributed, but this was not proven. As a result, quality assurance of the mix may help address some of the problems with roll-over.

Ensuring Stability of the Safety Edge

Especially on narrow roadways, existing shoulders need to be brought flush with the vertical edge of pavement before paving is started to provide a stable base for the Safety Edge.

For efficiency of operations and an acceptable final Safety Edge, a plan must be devised to establish a base width (Figures 2 and 3) necessary to accommodate the width of succeeding upper layers, while also following the pavement centerline as closely as possible.

Matching Safety Edge Between Lifts

Even when properly applied, the long-term stability of the Safety Edge can be compromised if the base width is insufficient to accommodate the design width of the surface layer. When this occurs, the upper layer width will extend beyond the base resulting in lack of proper support for the Safety Edge (with results as shown in Figure 2).

Another problematic issue noted during field reviews was that the Safety Edge did not always align horizontally between lifts (layers) consistently. To avoid this occurrence, the nominal base width to accommodate succeeding lifts of HMA resurfacing must be determined as accurately as possible before beginning work.

Figure 2. Insufficient base widths

Figure 3. Excess base widths

With multiple-lift HMA overlays, the lower lift width determination may require computation by the engineer or inspector, if multiple lifts are designed, to assure that all lifts will exhibit sufficient width to provide base for subsequent layers including the Safety Edge. In addition to adequate base width, maintaining the proper horizontal alignment of each course is also necessary to conform the Safety Edge slope from top to bottom of the entire overlaid section to assure maximum opportunity for errant vehicle recovery if several inches of pavement edge were to be exposed.

Where multiple lifts are designed, prior planning and proper paver operation are needed to avoid excess (and unused) base width with lower lifts and/or insufficient width to support the upper layer(s) completely. If the base width is too great, the results could be as shown in Figure 3 with wasted material.

Additional Consideration for Super-Elevated Locations

Attention must be given to the drop-off height created in super-elevated locations if the road is open to traffic during construction, even if the Safety Edge slope is acceptable.

Figure 4 shows a large elevation difference in a tangent section (which can also occur outside of curved areas), where the vertical alignment of a segment is being improved or corrected.

An interim level of shouldering should be required where excessive vertical differences in the shoulder and pavement elevations have occurred.

As illustrated in Figure 5, even with a perfect 30 degree Safety Edge slope, smaller errant vehicles could easily high center on the pavement edge and lose control with an excessive drop-off height.

Figure 4. Severe pavement edge drop-off near outside of curve

Figure 5. Severe pavement edge drop-off (10-12 inches)

Additional Resources

The Iowa DOT has produced several design and construction guidelines to address these issues and some of these are included in the following documents:

www.iowadot.gov/design/dmanual/03C-06.pdf
www.iowadot.gov/design/SRP/IndividualStandards/epv03.pdf

A slide from CTRE that includes background information and benefits for use of the Safety Edge is also available online:

onlinepubs.trb.org/onlinepubs/conferences/2011/UTC-Safety/Hallmark2.pdf

This Tech Brief and the Phase II report are also available online:

www.intrans.iastate.edu/research/projects/detail/?projectID=1421519206

Phase I research publications and outreach materials are also available online:

www.intrans.iastate.edu/research/projects/detail/?projectID=947242180