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Local Technical Assistance Program

Marketing and Outreach for the Safety Edge

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March 11, 2011

IOWA STATE UNIVERSITY
Institute for Transportation

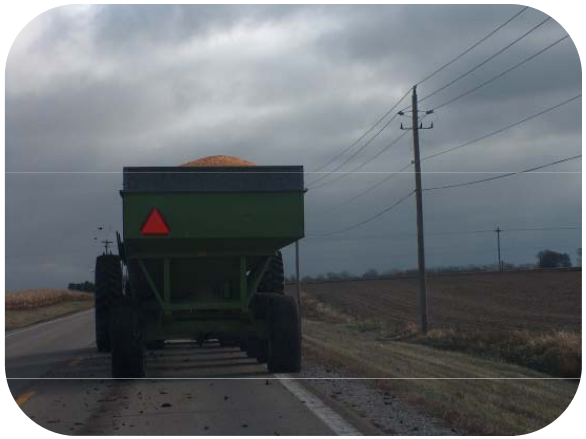
Pavement Edge Drop-off

- Vertical elevation difference between adjacent roadway surfaces

Pavement Edge Drop-off

- Causes

wear



resurfacing without maintenance

construction

erosion

image: Graham, MRI

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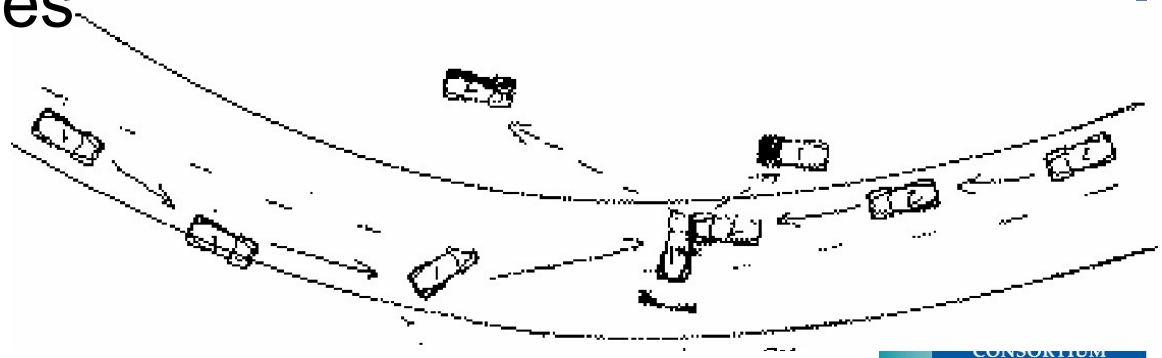
Safety Hazard

- Vehicle leaves roadway and encounters drop-off
  - Affects driver handling and stability
  - Overcompensation (loss of control)
  - Scrubbing as driver attempt to return to roadway
    - driver steers to overcome friction between tire sidewall and pavement edge, loss of resistance on return to roadway causes yawing

Image source: Quixote

Pavement Edge Drop-off

- Around 160 fatalities and 11,000 injuries annually[1]
- Contributing factor in 55% of rural fatal crashes on 2-lane roadway in Georgia[2]
- Drop-off crashes were 2 times more likely to result in fatal crash than other crashes on similar roadways[3]
- Rural 2-lane roadways[4]
  - more than ½ of all fatalities
  - 2/3 of roadway departure fatalities
- Liability for agencies



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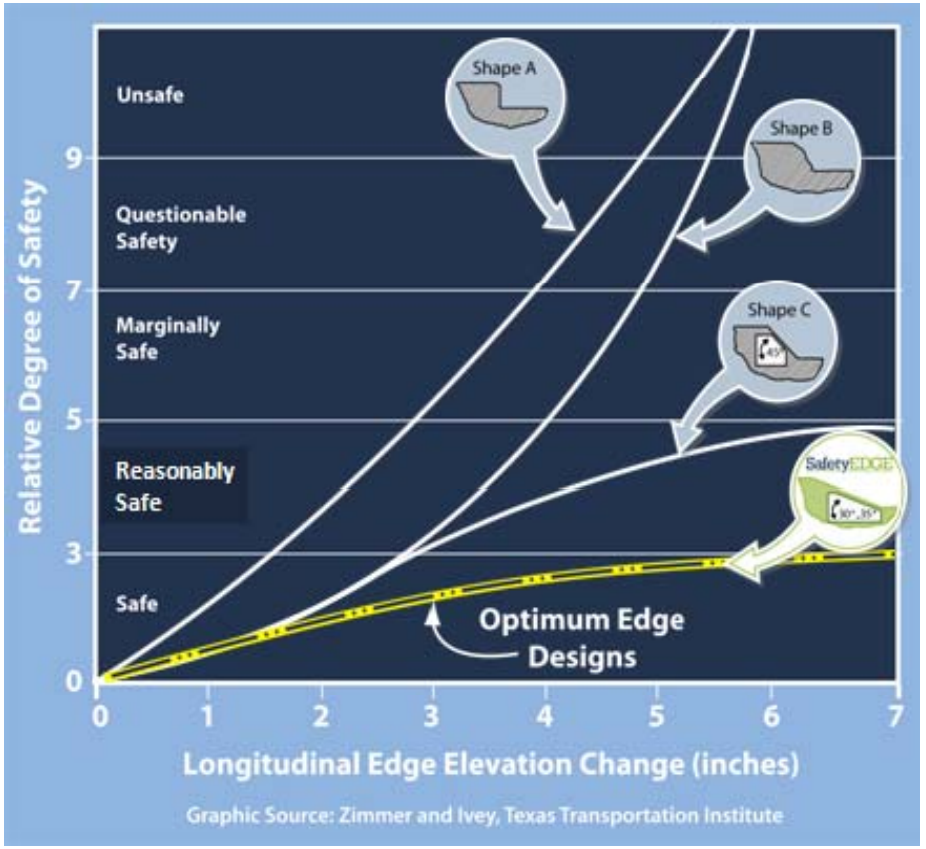
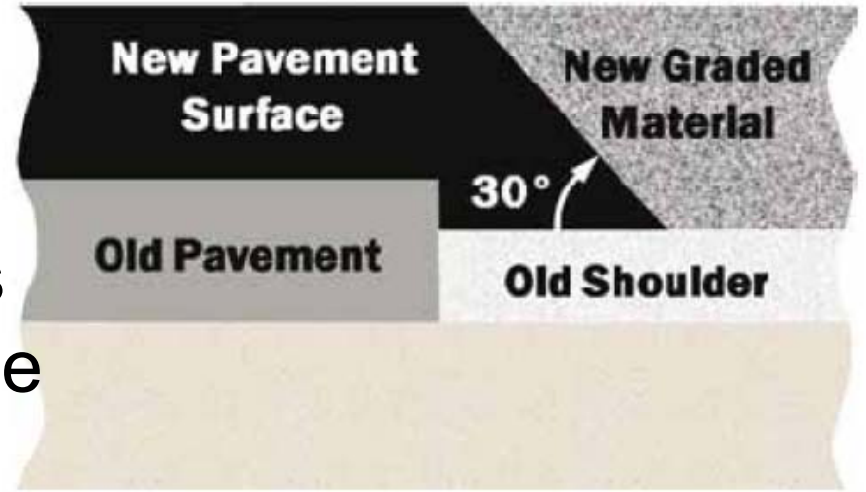
Solutions to Pavement Edge Drop-off

- Paved shoulders
- Regular shoulder maintenance
- Sloped pavement surface can be more easily traversed when vehicles leave the roadway and paved edge is exposed

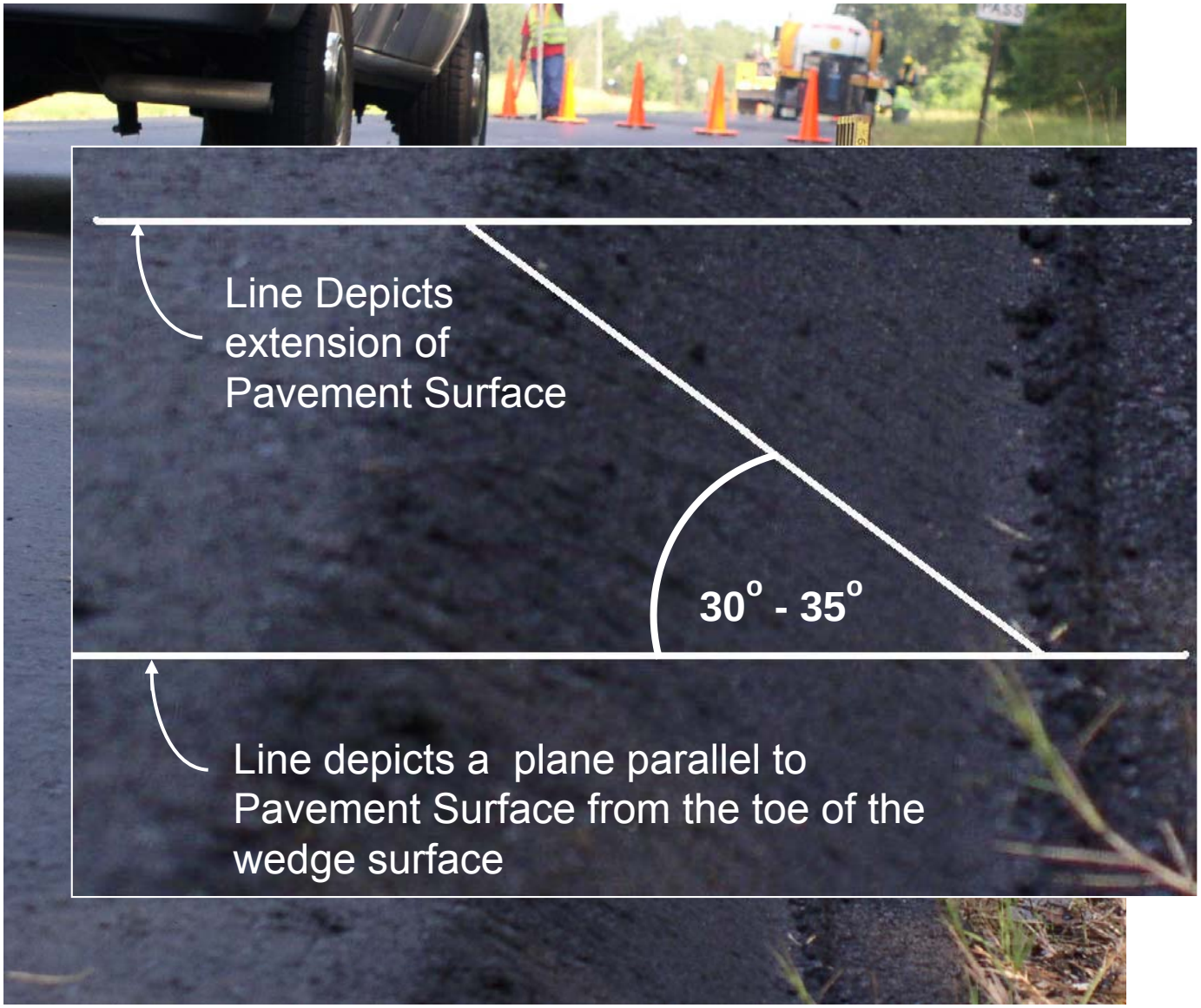


Safety Edge

- Design feature which creates a fillet along the outside edge of the paved section of a roadway
- Placed during Hot Mix Asphalt (HMA) paving using a device that shapes and consolidates the asphalt material at the pavement edge into an approximate 30º fillet



(image source: FHWA, 2009)



(images: Roche)

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Model of Safety Edge

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Safety Edge Benefits

- Pooled fund study (MRI)
  - Sites with Safety Edge slightly less likely to form extreme drop-off

- Crash reduction factor of 5.7%
- Benefit-cost ratio for rural 2-lane
  - 4 to 44 for paved shoulder
  - 4 to 63 for unpaved shoulders

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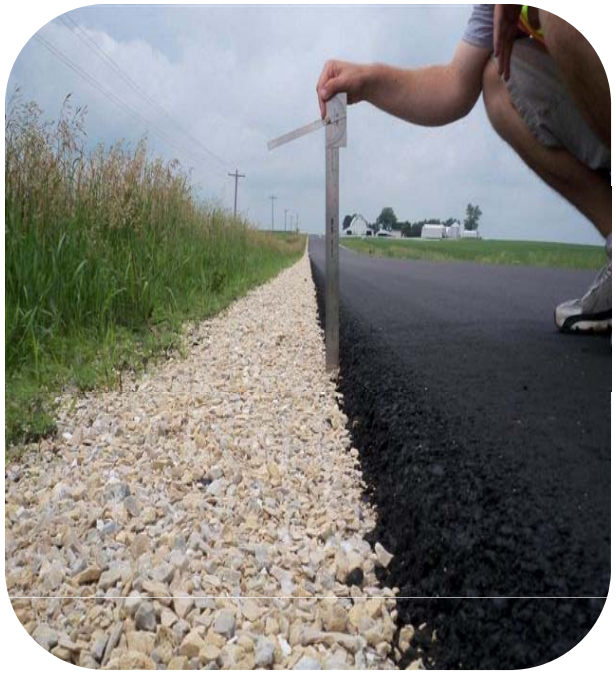
Safety Edge Benefits

- Potential increased pavement edge durability
- Provides temporary safety during construction while pavement edge face is exposed



resurfacing without Safety Edge (images: Roche)

resurfacing with Safety Edge

(images: Roche)

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Safety Edge Benefits

- Some states do not require contractors to pull shoulders up immediately after construction which results in increased production for contractors since shoulder work can be done after overlay is completed
- Provides a permanent solution for drop-off
- Can reduce tort liability by showing “Due Care”
- Minimal hardware, labor or material costs are required

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Marketing/Outreach of Safety Edge in Iowa

- Use of Safety Edge relatively new in Iowa
- Team conducted marketing/outreach activities to encourage use:
  - Attended pre-con to answer questions about equipment
  - Loaned Safety Edge “shoes:
  - Conducted open houses to provide information and demonstrate application
  - Sites visits
  - Provided technical assistance
  - Measured slope

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Safety Edge in Iowa

- First use in 2008: HMA resurfacing project on County Road Z-36 in Clinton County
- 2010: Iowa DOT adopted Safety Edge as Standard Practice for construction and rehabilitation projects
- Iowa DOT Design Manual (2010) requires use of the Safety Edge on all primary highways unless one of the following is met:
  - Roadway is an interchange ramp or loop
  - Roadway or shoulder has curbs
  - Paved shoulder width ≥ 4 ft

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Acceptance

- Benefits easily described
- Most agencies using Safety Edge in the 2010 construction season “bought in” once advantages were explained
  - Maintenance benefits easily sold
- Early outreach critical
  - Pre-letting assistance
  - Pre-construction assistance
  - Open houses

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GUIDANCE FOR USE OF SAFETY EDGE -- HMA

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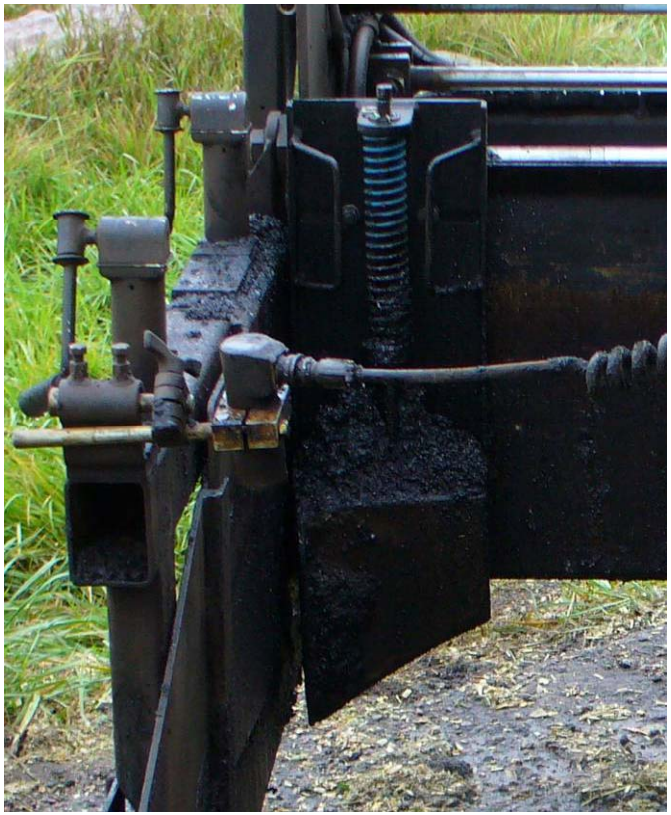
Safety Edge Equipment

- Several types of equipment available for HMA

(image source: FHWA, 2009a)

(http://www.transtechsys.com/products/pro_products_main.htm)



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Safety Edge Equipment

- Commercially available
- Can be removed for use on different pavers
- Most agencies in 2010 season did not have problems with install or use in general
  - One suggested mounting Safety Edge to end gate rather than paver to minimize mix accumulation behind the shoe when changing the width laid for fillets

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Durability of Safety Edge

- Density from compaction necessary for Safety Edge durability
- Some concern about long term durability
- Only compaction is from paver and Safety Edge Shoe

No Safety Edge

Images: Roche, 2009

Condition After six years in-service (Georgia Site)

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Density

- 80% of desired compaction occurs from laydown machine, Safety Edge should be >= 80%
- Tested cores within regular pavement and Safety Edge for one project over 2 days
- Safety Edge compaction tested by contractor 80.6 to 86.3%
- Normal cores: 96.1 to 98.3%

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Quality Assurance of 30° Slope

- Equipment places slope appropriately but actual application varies in the field
- Team evaluated in field
- Slope varied significantly (18 to 52°)

Table 6-1: Final Slope Measurements

Site	Average Slope (degrees)
Blackhawk County D46	26
Cedar County Y26	40
Clinton County Z30	39
Delaware County D34	52
Jasper County F62	37
Jones County E34	30
Keokuk County V63	31
Kossuth County A21	36
Kossuth County P20	35
Sac County M50	36
Union County H24	18
Union County Green Valley Road	18
Webster County D46	30
Webster County P59	31
Ida-Sac County U.S. 20	31

SLH1

Rollover

- 30° slope distorted during compaction
- Usually results in slope > 30°
- Also noted by MN and other states

- Possible causes:
  - Compaction
    - material pushed towards edge during compaction
    - Roller pattern
    - Magnitude of vibration
  - Mix
    - design
    - support of underlying base
    - temperature of mix
    - ambient temperature
    - lift thickness

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Slide 22

SLH1 Are these good examples of "rollover"?
Shauna Hallmark -- CTRE, 3/9/2011

Solutions to Rollover

- Underscores need for quality assurance during paving
  - Check slope
- Use final roller only on outside foot of pavement (measured from pavement edge)
  - Some reduction in density may occur
  - Concern about durability
  - Consider other options first

Density Comparison for Outside Foot

- concerns were raised leaving outside foot of pavement except for final pass
- Conducted density test of normal cores and outside foot with only final pass compaction
- Tested at 2 sites (contractor results)
  - Jasper normal cores: 96.8 to 98.3%
  - Jasper outside foot: 94.8%
  - Webster normal cores (2 days): 95.5 to 98.9%
  - Webster outside foot (2 days): 94.4 to 95.0%
- Differences of 1.1 to 3.9%

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Other Solutions to Rollover

- most consistently performing mixes in terms of stability appeared to be those with total ACC contents from 5.7 - 6.5% with a higher percentage of coarse aggregates
- Contractor modifications to Safety Edge shoe
  - 2 contractors modified shoe
  - Slope the entrance and exit of material to approximate an extrusion process resulting in higher consolidation of sloped edge

- Discussion with equipment vendors

Matching Safety Edge Between Lifts

- Problem noted during field reviews and noted by contractors
- Determine nominal base width to accommodate succeeding lifts of HMA before beginning work
- Compute lift width to ensure sufficient width
- Maintain proper horizontal alignment of each course
- May only need to include Safety Edge in top lift or two (3 to 5”)

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Drop-off Performance With Safety Edge

- Safety Edge provides benefit when drop-off occurs
- Some concern that sloped surface would have slightly greater tendency for formation of drop-off due to tire wear or turbulence from passing vehicles

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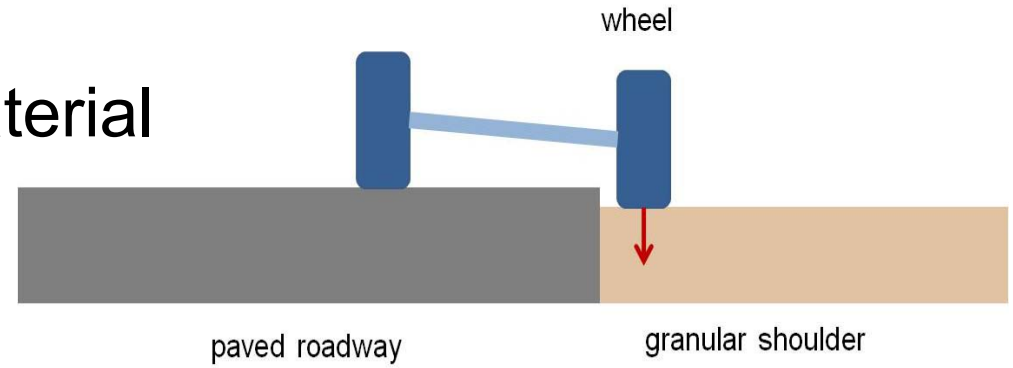
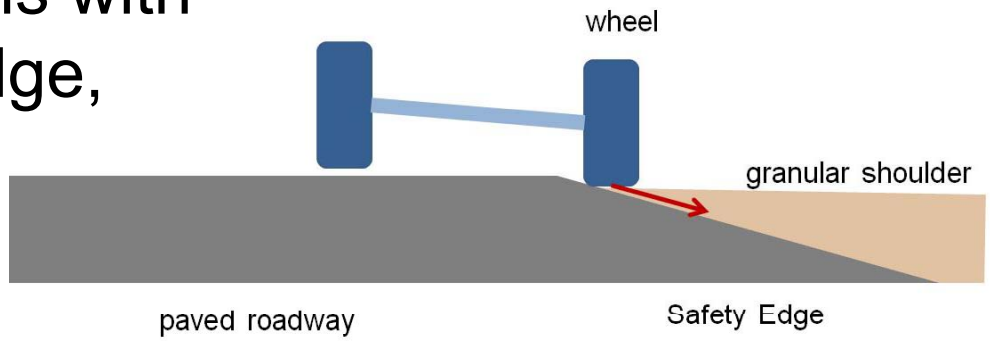
Drop-off Performance With Safety Edge

- With normal pavement face, tire on shoulder would push down and compact shoulder material



- With Safety Edge, may push material down slope
- Pooled fund study evaluated drop-off 1 year after resurfacing for sections with and without Safety Edge, found slightly fewer instances of extreme drop-offs



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Assessment of Drop-off

- Sites in Iowa were recently resurfaced (no drop-off currently)
- Freeborn county, MN using Safety Edge since 2005
  - 2 sites with Safety Edge on one side and no Safety Edge on other
  - Have been monitoring drop-off since 2007
  - Used paired t-test to compare
  - No statistically significant difference in drop-off between side with/without Safety Edge for either site

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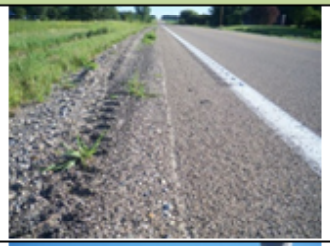
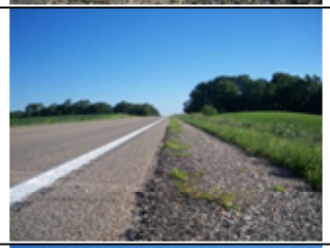
Drop-off Measurements Along CSAH #18 (ADT 280 to 395 vpd)

Westside	Eastside		Aug 2007	May 2008	Sept 2009	July 2010
		**North of State Line ½ mile - Pipeline post on west side**				
		West	1.25	1.25	0.75	0.0
		East	1.50	1.50	0.75	0.0
		difference	-0.25	0.25	0.0	0.0
		**North of State Line 1 mile - No Pass on east side**				
		West	1.25	1.50	1.0	0.125
		East	1.50	1.375	1.0	0.0
		difference	0.25	0.13	0.0	0.125
		**North of State Line 1 ½ mile Intake on west side**				
		West	1.0	1.0	1.0	0.0
		East	1.75	1.75	0.75	0.0
		difference	-0.75	-0.75	0.25	0.0
		**North of State Line 2 miles - Pipeline post on west side**				
		West	1.25	1.5	1.0	1.175
		East	1.5	2.0	1.0	1.0
		difference	-0.25	-0.5	0.0	0.175
		**North of State Line 2.4 miles – Power box on east side**				
		West	1.25	1.5	1.0	0.875
		East	2.0	2.0	1.175	0.0
		difference	-0.75	-0.5	-0.175	0.875

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Drop-off Measurements Along CSAH #5 (ADT 350vpd)

Westside	Eastside		Aug 2007	May 2008	Sept 2009	July 2010
		**0.3 miles West of # 18 South – Intake on both sides of road**				
		West	2.00	2.25	1.50	0.875
		East	1.50	2.00	1.25	0.625
		difference	0.50	0.25	0.25	0.25
		**½ mile north of # 5 – No Pass on east side of road**				
		West	1.50	1.75	1.0	0.0
		East	1.875	2.0	1.25	0.0
		difference	-0.375	-0.25	-0.25	0.0
		**1 mile north of #5 – 82 route marker on east side of road**				
		West	1.375	1.50	0.675	0.0
		East	1.75	1.75	0.75	0.0
		difference	-0.275	-0.25	-0.075	0.0
		**1.3 miles north of #5 – 85 route marker on east side of road**				
		West	1.00	1.25	0.50	0.0
		East	1.75	1.75	0.75	0.0
		difference	-0.75	-0.5	-0.25	0.0

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Other concerns

- Responses to an informal survey indicated most had no problems with shouldering
  - one indicated, “hard to get rock to stick to the wedge”
- Some concerns were expressed with interpretation of 30° slope
  - Some equipment intentionally creates slope < 30°
  - No likely safety concerns, but flatter slope may be more prone to deterioration under loading
  - Slope not likely to be uniform
  - Strict interpretation could require precise 30° slope requiring contractors to repair or replace edge
  - Team recommended range or “approximate”

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Costs

- Using Iowa DOT specifications, assumes additional material is the difference between an 80 degree (non-Safety Edge) slope and a 30 degree (Safety Edge) slope

Additional Material Needed for HMA Safety Edge

Total Depth All Lifts (in)	Additional Area for 30 vs. 80° (in^2)	Material in slope (ton/mile)	% of Additional material per mile For 22' wide pvmt	% of Additional material per mile for 24 foot pvmt
1.0	1.56	4.1	0.6%	0.5%
1.5	3.50	9.3	0.9%	0.8%
2.0	6.22	16.5	1.2%	1.1%
2.5	9.72	25.8	1.5%	1.4%
3.0	14.00	37.2	1.8%	1.6%
4.0	24.89	66.2	2.4%	2.2%
5.0	38.89	103.4	2.9%	2.7%

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GUIDANCE FOR USE OF SAFETY EDGE -- PCC

Typical face of PCC without Safety Edge

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Safety Edge in Iowa

- Prior to marketing/outreach effort in Iowa, no know instances of the Safety Edge applied to PCC existed
- Iowa DOT developed design standards and specifications for PCC applications
- CTRE worked with Keokuk County to develop design standards and specifications for county projects
- Jones/Linn counties applied along E-34 (unbonded 6-inch PCC overlay over existing 6-inch pavement with 1-min HMA bond breaker), 2.5 miles

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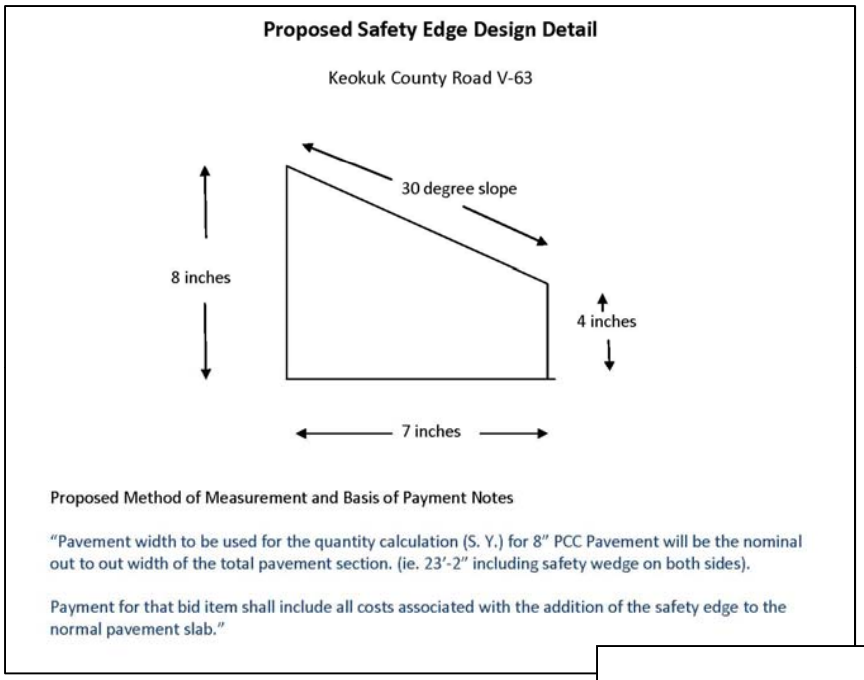
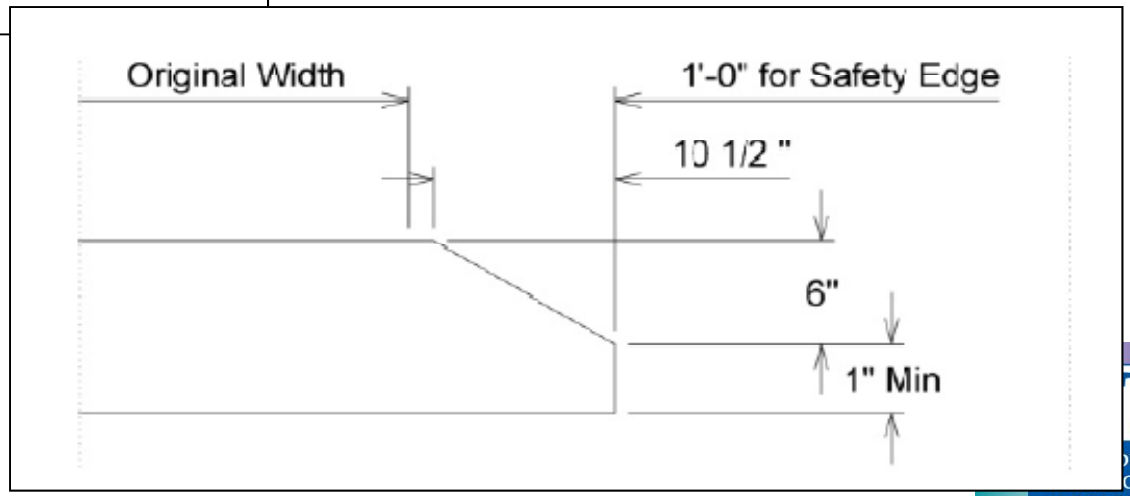
Design Standards



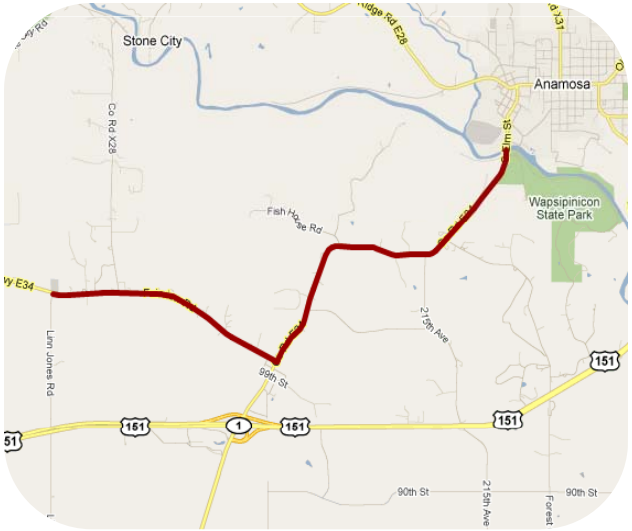
CTRE PCC Safety Edge Design Used in Keokuk County

PCC Safety Edge Dimensions from Iowa DOT Design Guide



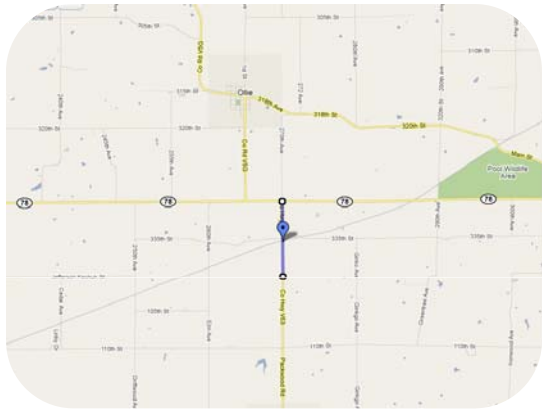
Iowa PCC Applications of Safety Edge

- Jones/Linn county
  - First PCC application in US
  - E-34
  - Paved width: 26 feet
  - Unbonded 6-inch PCC overlay over an existing 6-inch PCC pavement with a 1-inch HMA bond breaker
  - 2.5 miles
  - Construction dates: May 1, 2010 – July 20, 2010



Iowa PCC Applications of Safety Edge

- Keokuk county
  - V-634
  - Paved width: 26 feet
  - 1 miles in a 2.7 miles project
- Construction dates: May 17, 2010 – November, 2010
- Omitted section of Safety Edge due to RR crossing
- Project inspector felt process went smoothly
- Hope Safety Edge helps with future rutting problems



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Equipment

- No commercially available equipment
- Contractors fabricated Safety Slope Pan

PCC Paver modification for Linn/Jones by Horsfield Construction

PCC Paver modification for Wicks Construction

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Edge Shape

- Unlike HMA height of Safety Edge for PCC is constant (4 to 6”) ,
  - shape of the pavement edge will vary depending on slab thickness
  - Toe depth (vertical face at edge of Safety Edge slope) will vary

Pavement with 3 inches of vertical toe

Pavement with significantly more vertical toe

Quality Assurance of 30° Slope

- Assessment of E-34 by FHWA
  - Slope ranged from 28.5 to 34.0° (mean 31.5°)
  - Slope face was slightly concave or convex in some locations which may have resulted from flex in paving pan or during finishing

Edge of PCC Safety Edge Showing Ridge and Bow (image source: FHWA, 2011)

Modifications for Intersections

- In Iowa, a reinforced joint is constructed to adequately tie the intersecting pavements together and this is accomplished with a vertical pavement edge
- Sloped edge needs to be removed for intersection tie-in

- ► Saw cut
- ► Construct formed box-out to prevent placement of Safety Edge

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Accounting for Transverse Joints

- Full width saw cutting is used in newly placed PCC to control random cracking
- Discussion with contractors about how to handle sawing through Safety Edge section
  - Challenges in operating saw on slope
  - Anticipated that crack would eventually extend through Safety Edge

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Accounting for Transverse Joints

- Saw-cut only to edge of pavement
- Cracking through Safety Edge did occur as expected

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Additional Costs for PCC

- Depends on design standards (DOT or county)
- Calculated additional cost for both
- Iowa DOT standards require use of out to out width of paved area in square yards or meters

Additional Square Yards Needed for PCC Safety Edge

Total Depth of Pvmt (in)	Additional material/Station Both sides (SY)	Additional material/Mile Both sides (SY)	% of Additional SY per mile 22' wide pvmt	% of Additional SY per mile 24 foot pvmt
CTRE Design	12.963	684.444	5.30%	4.86%
DOT Design	22.222	1173.333	9.09%	8.33%

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CONCLUSIONS

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Conclusions from Study

- Expectations for Safety Edge on a particular project should be thoroughly reviewed at a preconstruction conference and procedures verified (and/or adjusted) as necessary at the beginning of construction to assure satisfactory results are achieved
- Monitoring alignment and setting base (and subsequent lift) widths
  - contractor's responsibility
  - But needs periodic review by the engineer and inspection team

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Conclusions from Study

- Slope for PCC was fairly consistent
- Maintaining constant slope for HMA can be difficult due to a number of factors
  - Recommend quality control
  - Recommend use of range of acceptable values for slope
- Allowing HMA contractors to omit placement of a temporary granular fillet along the shoulders adjacent to new paving each day (providing the Safety Edge is constructed to design requirements) provides incentive for adoption of Safety Edge and quality construction

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