Safety Benefits of the Safety Edge

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MTC

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Pavement Edge Drop-off

- Vertical elevation difference between adjacent roadway surfaces

Pavement Edge Drop-off

Image source: Quixote

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

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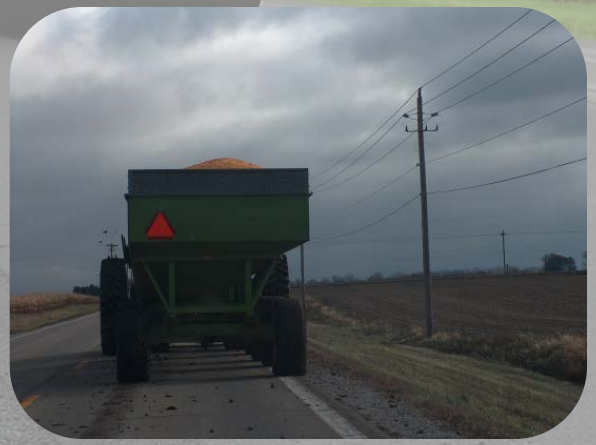
Causes

wear



resurfacing without maintenance

erosion

construction

image: Graham, MRI

Pavement Edge Drop-off

- Around 160 fatalities and 11,000 injuries annually
- Drop-off crashes 2 times more likely to result in fatal crash than other crashes on similar roadways
- **55% of 150 fatal crashes** on rural two-lane roads in Georgia (Dixon et al., 2004).
- Rural 2-lane roadways
  - more than ½ of all fatalities
  - 2/3 of roadway departure fatalities
- Liability for agencies

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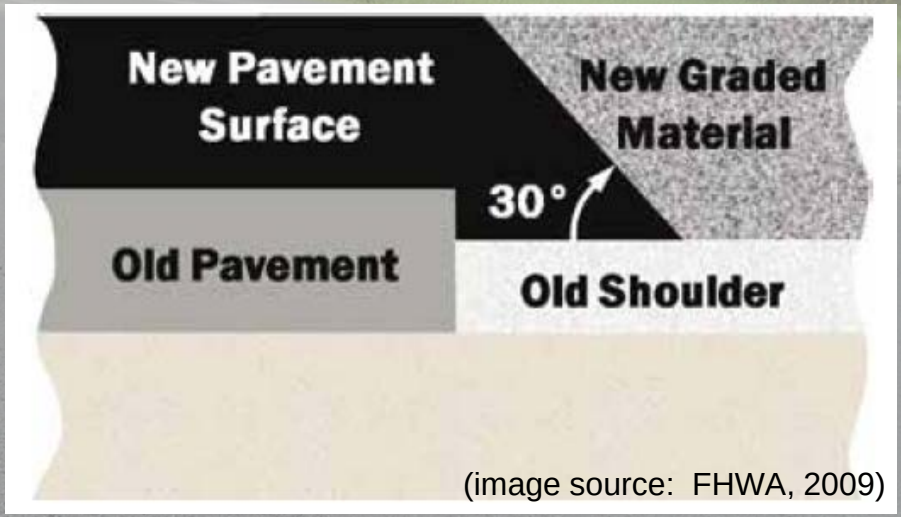
What is the Safety Edge?

- Creates a fillet along the outside edge of the paved section of a roadway
- Placed during Hot Mix Asphalt (HMA) paving
- Provides a sloped surface for errant vehicles to transition from an unpaved shoulder to paved surface



(image source: FHWA, 2009)

What is the Safety Edge?

- Device (shoe) shapes and consolidates asphalt material at the pavement edge into an approximate 30º slope

Iowa State University
Institute for Transportation

Iowa LTAP
Local Technical Assistance Program

Midwest Transportation Center
MTC

Safety Edge Construction Benefits

- Less likely to form extreme drop-off
- Some states do not require contractors to pull shoulders up immediately after construction
- Can reduce tort liability by showing “Due Care”

Other Benefits

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

resurfacing without Safety Edge (images: Roche)

resurfacing with Safety Edge

(images: Roche)

Additional Benefits

- Minimal hardware, labor or material costs are required
- Estimated additional material ~ 1 to 2% HMA

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%

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 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

Implementation of Safety Edge in Iowa

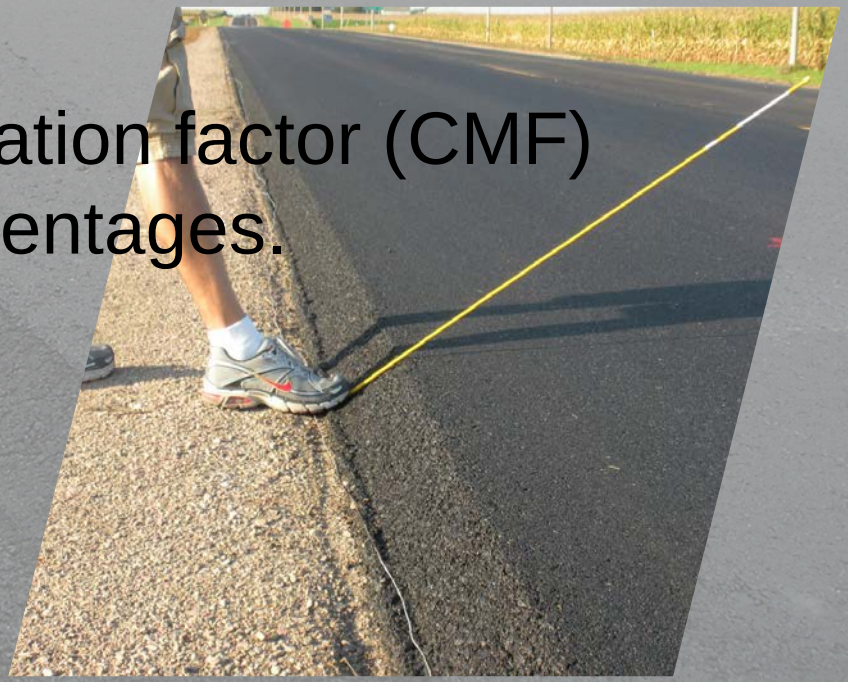
- Emphasis by FHWA (Every Day Counts)
- Iowa DOT adopted Safety Edge as a standard practice for construction and rehabilitation projects in 2010 based on recommendations from MTC and other researchers
- Slow to be adopted in Iowa
- Iowa DOT funded marketing and outreach of Safety Edge to local agencies

Implementation

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

Scope of Problem and Objectives

- Little research done
- Although low cost, agencies interested in understanding impacts to better program safety funds.
- Conducted before and after study to evaluate effectiveness.
- Calculated crash modification factor (CMF) and crash reduction percentages.



Identification of Treatment Sites

- Evaluated previous Iowa construction projects for 2010 and 2011.
- Construction locations and extents recorded for previous projects and from Iowa DOT.
- Installation dates recorded.
- Roadway characteristics available.

Data Collection

- Location mapped within the Iowa DOT geographic information management system (GIMS)
- Roadway information extracted for each of the corresponding 11 years (2004-2014) from the GIMS data
  - ✓ surface width
  - ✓ lane width
  - ✓ number of lanes
  - ✓ shoulder width
  - ✓ shoulder type
  - ✓ traffic volume
- Characteristics manually checked using site visits, aerial imagery, and Google forward roadway views.
- Contiguous GIMS segments with homogenous roadway characteristics were combined.

Control Segments

- Identified along similar roadways near treatment sites
- Curves removed. Rural two-lane asphalt roadways of speed limits of 45 or more mph.
- Contiguous GIMS segments with homogenous roadway characteristics were combined.
- 760 control sites (509 miles).
- Included control sections with repaving but without Safety Edge.
- Surface condition obtained.
- Selected control sites with only good and excellent surface conditions comparable to newly repaved surfaces

Total and Target Crashes

- 11 years (2004-2014)
- Total Crashes: All non-Intersection and non-animal related crashes.
- Target Crash: crash corresponding to any run-off-road (ROR) action listed in the sequence of events of a crash.
- Crashes with unknown sequence of events were excluded from the study.
- Crash Severity levels Grouped
  - ✓ total crashes: All severity levels
  - ✓ injury crashes: fatal, disabling and visible injury crashes.
  - ✓ Unknown/ PDO crashes: possible injury and property damage only

Simple Before and After Crash Counts

Group	Crash Type	Before	After	% Change
Treatment 516 sites (340 miles)	All total non-intersection crashes	878	366	-58.31%
	Total target crashes	283	119	-57.95%
Control Group 760 control sites (509 miles)	All total non-intersection crashes	1527	745	-51.21%
	Total target crashes	496	217	-56.25%

Descriptive Statistics

Variable	Description	Treatment segments data (N=5731)	Control segments data for SPF (N=8121)
AADT**	Annual Average Daily Traffic	Min: 25, Max: 5700 Mean: 1377.95 Std. dev: 1037.16	Min: 10 Max: 6200 Mean: 1686.588 Std. dev: 1190.217
Length**	length of aggregated segments in miles	Min: 0.2 Max: 1.76 Mean: 0.65 Std. dev: 0.33	Min: 0.3 Max: 2.07 Mean: 0.66 Std. dev: 0.31
Speed Limit**	speed limit in miles per hour of a segment	Min: 45 Max: 55 Mean: 54.39 Std. dev: 2.31	Min: 45 Max: 55 Mean: 54.78 Std. dev: 1.47
Rumble*	if any part or whole of the aggregated segment have rumble strips	Min: 0 Max: 1 Mean: 0.11 Std. dev: 0.32	Min: 0 Max: 1 Mean: 0.13 Std. dev: 0.33
ShdWDH>4*	1 denotes if total width of the shoulder is greater than 4 feet	Min: 0 Max: 1 Mean: 0.72 Std. dev: 0.45	Min: 0 Max: 1 Mean: 0.74 Std. dev: 0.44
LaneWDH<12*	1 denotes if total width of the lane is less than 12 feet	Min: 0 Max: 1 Mean: 0.38 Std. dev: 0.49	Min: 0 Max: 1 Mean: 0.21 Std. dev: 0.40

Methodology

- Used Empirical Bayes
- Step 1: Safety Performance Functions (SPFs) developed from control sites using negative binomial generalized linear models (GLM).
- Negative binomial model for expected number of crashes per segment per year:

$$\boldsymbol{\lambda_i = Length_i * \mathrm{EXP}(\beta X_i + \varepsilon_i)} \quad \text{.....(1)}$$

Where, $\mathrm{EXP}(\varepsilon_i)$ is the gamma-distributed error term with mean 1 and variance α.
The variance can be calculated using :

$$\mathbf{Var}(\boldsymbol{y_i}) = \mathbf{Var}(\boldsymbol{y_i}) = \boldsymbol{\lambda_i + \alpha\lambda_i^2} \quad \text{.....(2)}$$

Safety Performance Functions

Crash Type	Crash Severity	Safety Performance Functions	α
Non-intersection crashes	total crashes	*Length × EXP { -8.225 + (1.033 × **LNAADT**) + (0.361 × **LaneWDH<12**) + (-0.340 × **Rumble**) + (-0.153 × **ShdWDH>4**) }*	0.668
	injury crashes	*Length × EXP { -9.793 + (1.022 × **LNAADT**) + (0.381 × **LaneWDH<12**) + (-0.375 × **Rumble**) + (-0.398 × **ShdWDH>4**) }*	0.558
	Unknown/ PDO crashes	*Length × EXP { -8.356 + (1.009 × **LNAADT**) + (0.369 × **LaneWDH<12**) + (-0.330 × **Rumble**) }*	0.781
Target crashes	total ROR crashes	*Length × EXP { -6.870 + (0.711 × **LNAADT**) + (0.296 × **LaneWDH<12**) + (-0.274 × **Rumble**) + (-0.310 × **ShdWDH>4**) }*	1.422
	ROR injury crashes	*Length × EXP { -8.274 + (0.766 × **LNAADT**) + (-0.396 × **Rumble**) + (-0.475 × **ShdWDH>4**) }*	5.102
	ROR Unknown/ PDO crashes	*Length × EXP { -6.711 + (0.627 × **LNAADT**) + (0.294 × **LaneWDH<12**) + (-0.246 × **ShdWDH>4**) }*	1.452

Safety Performance Functions

- Crashes **decreased significantly with rumble strips** for total crashes
  - ✓ non-intersection crashes
  - ✓ total crash model for target crash type
- **Lane width < 12 ft** associated with **increase in crashes**
  - ✓ not significant target injury crashes
- **Shoulder width > 4 ft** associated with **decrease in crashes**
  - ✓ not significant in the unknown and PDO crash scenario for all non-intersection crashes

Crash Modification Factors

Crash Type	Crash Severity	Crashes in the after period		CMF	Percent Reduction (%)	S.E.	95% confidence interval	90% confidence interval
		Observed	Estimated					
non-intersection crashes	total crashes	366	425	**0.86**	13.83	0.045	**(0.77, 0.95)****	**(0.79,0.94)***
	injury crashes	63	75	**0.84**	16.45	0.106	(0.63, 1.04)	(0.66, 1.01)
	unknown and PDO crashes	303	349	**0.87**	13.17	0.050	**(0.77, 0.97)****	**(0.79, 0.95)***
ROR crashes	total crashes	119	145	**0.82**	17.78	0.076	**(0.67, 0.97)****	**(0.70, 0.95)***
	injury crashes	33	43	**0.78**	21.60	0.137	(0.51, 1.05)	(0.56, 1.01)
	unknown and PDO crashes	86	102	**0.85**	15.07	0.092	(0.67, 1.03)	(0.70, 1.10)

** Statistically significant at 95% confidence level
* Statistically significant at 90% confidence level

Discussion and conclusions

- Calculated CMFs for several injury combinations using observational before and after with EB method.
- Paper contains step by step EB Process.
- Found reduction of **13.2% to 21.6%** depending on the type of crash
  - ✓ Not all of the results statistically significant
- Reduced **total and PDO+unknown non-intersection crashes** by **13-14%.**
- **Total** and **PDO+unknown target/ROR crashes** showed greater reduction of **15-18%**
  - ✓ illustrates positive safety effectiveness of Safety Edge especially for ROR crashes.
- Could not determine statistical significance for total and target injury crashes

Limitations and Future Studies

- Accurate identification of ROR/target crash**es** depends on how officers code crashes
- Not sufficient number of crashes to develop CMFs for fatal/major injury
- Study based on only 1 state
- Sequence of events was not reported for roughly 22% of crashes which decreased the available sample.

Acknowledgements

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